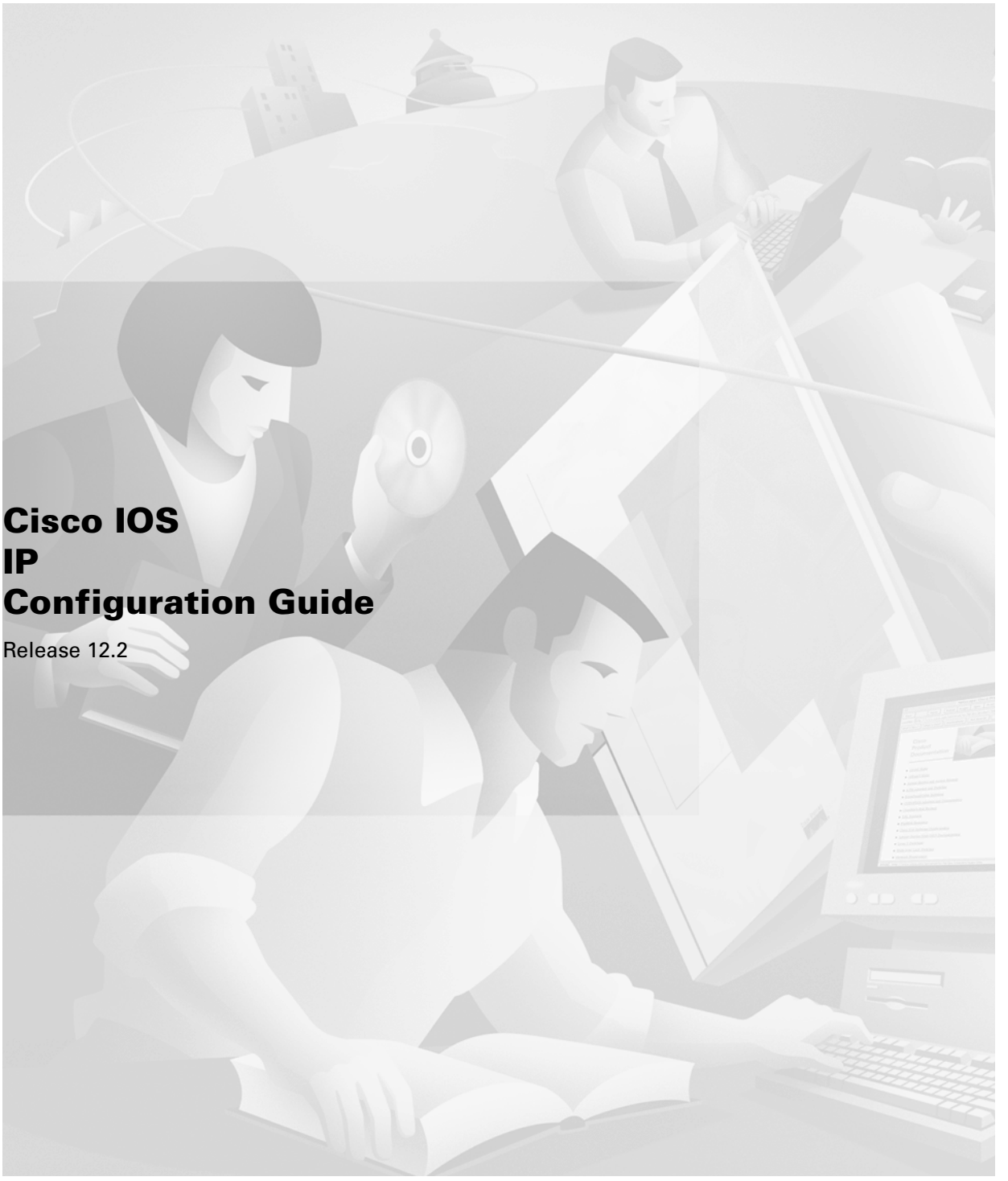

Cisco IOS IP Configuration Guide

Release 12.2

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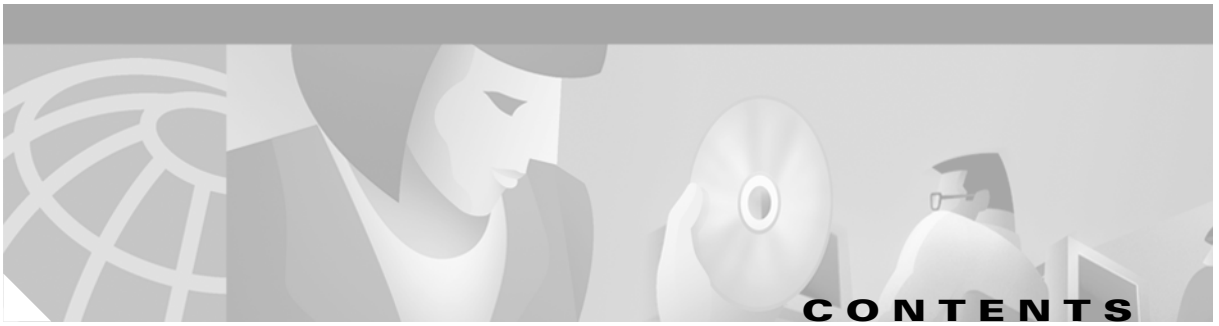


CONTENTS

IP MULTICAST

INDEX

About Cisco IOS Software Documentation

This chapter discusses the objectives, audience, organization, and conventions of Cisco IOS software documentation. It also provides sources for obtaining documentation from Cisco Systems.

Documentation Objectives

Cisco IOS software documentation describes the tasks and commands necessary to configure and maintain Cisco networking devices.

Audience

The Cisco IOS software documentation set is intended primarily for users who configure and maintain Cisco networking devices (such as routers and switches) but who may not be familiar with the tasks, the relationship between tasks, or the Cisco IOS software commands necessary to perform particular tasks. The Cisco IOS software documentation set is also intended for those users experienced with Cisco IOS software who need to know about new features, new configuration options, and new software characteristics in the current Cisco IOS software release.

Documentation Organization

The Cisco IOS software documentation set consists of documentation modules and master indexes. In addition to the main documentation set, there are supporting documents and resources.

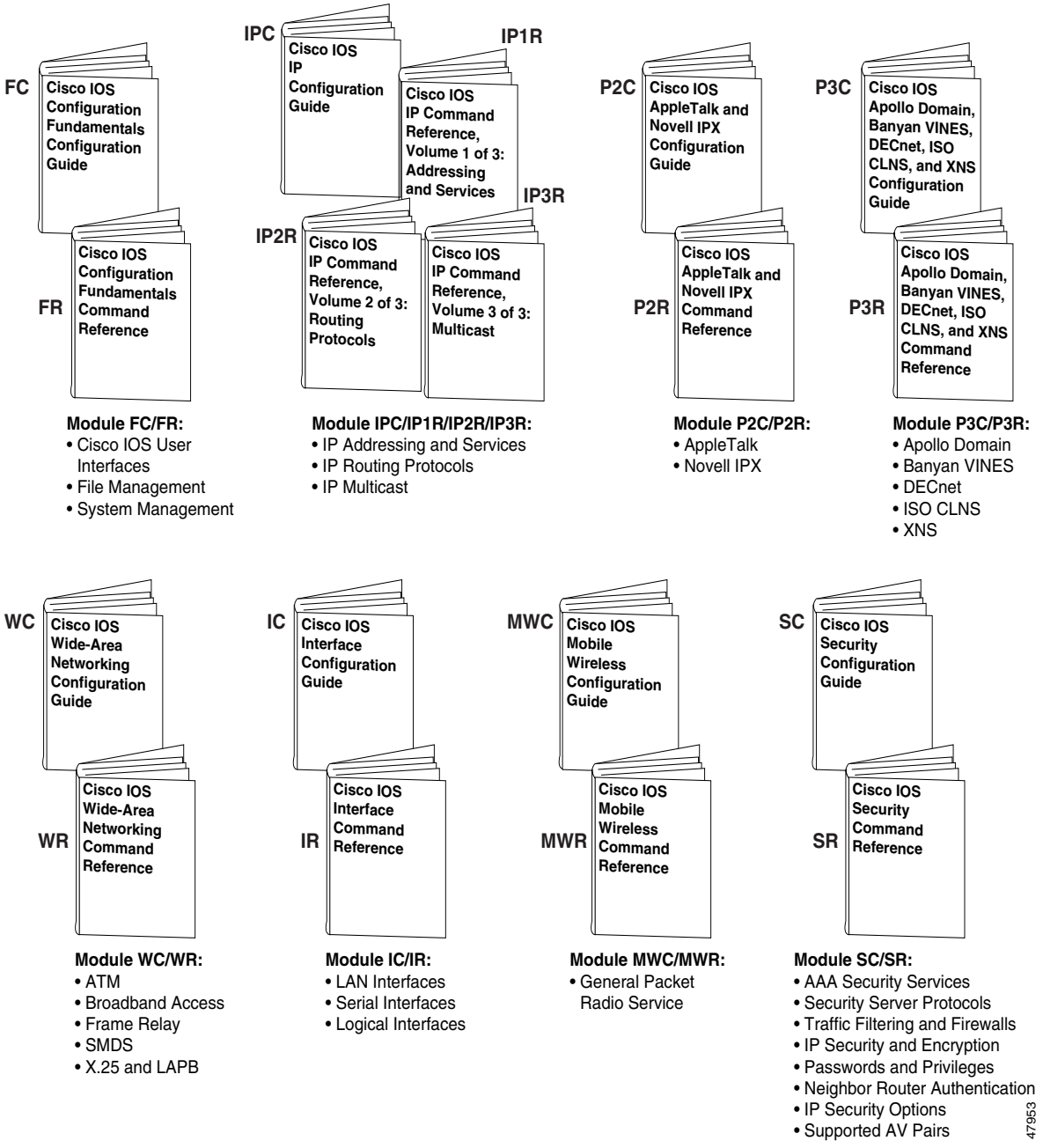
Documentation Modules

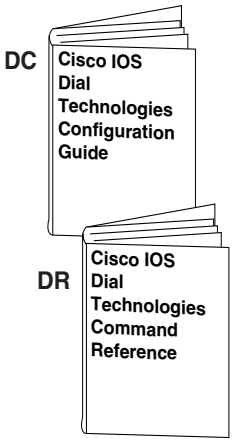
The Cisco IOS documentation modules consist of configuration guides and corresponding command reference publications. Chapters in a configuration guide describe protocols, configuration tasks, and Cisco IOS software functionality and contain comprehensive configuration examples. Chapters in a command reference publication provide complete Cisco IOS command syntax information. Use each configuration guide in conjunction with its corresponding command reference publication.

Figure 1 shows the Cisco IOS software documentation modules.

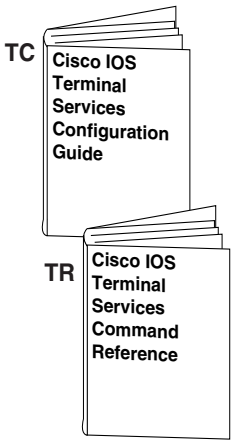
Note The abbreviations (for example, FC and FR) next to the book icons are page designators, which are defined in a key in the index of each document to help you with navigation. The bullets under each module list the major technology areas discussed in the corresponding books.

Figure 1 Cisco IOS Software Documentation Modules

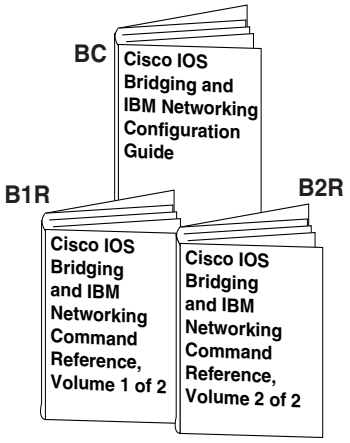




Module DC/DR:
- Preparing for Dial Access
- Modem and Dial Shelf Configuration and Management
- ISDN Configuration
- Signalling Configuration
- Dial-on-Demand Routing Configuration
- Dial-Backup Configuration
- Dial-Related Addressing Services
- Virtual Templates, Profiles, and Networks
- PPP Configuration
- Callback and Bandwidth Allocation Configuration
- Dial Access Specialized Features
- Dial Access Scenarios

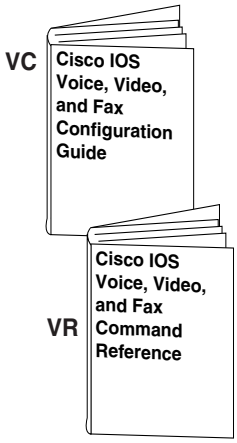


Module TC/TR:
- ARA
- LAT
- NASI
- Telnet
- TN3270
- XRemote
- X.28 PAD
- Protocol Translation

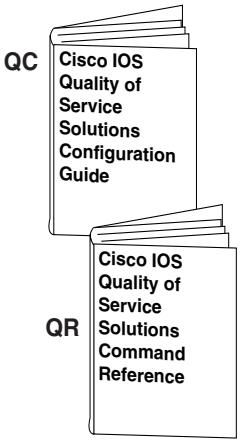


Module BC/B1R:
- Transparent Bridging
- SRB
- Token Ring Inter-Switch Link
- Token Ring Route Switch Module
- RSRB
- DLSw+
- Serial Tunnel and Block Serial Tunnel
- LLC2 and SDLC
- IBM Network Media Translation
- SNA Frame Relay Access
- NCIA Client/Server
- Airline Product Set

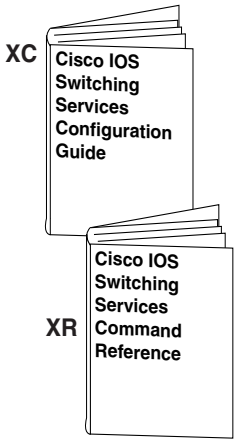
Module BC/B2R:
- DSPU and SNA Service Point
- SNA Switching Services
- Cisco Transaction Connection
- Cisco Mainframe Channel Connection
- CLAW and TCP/IP Offload
- CSNA, CMPC, and CMPC+
- TN3270 Server



Module VC/VR:
- Voice over IP
- Call Control Signalling
- Voice over Frame Relay
- Voice over ATM
- Telephony Applications
- Trunk Management
- Fax, Video, and Modem Support



Module QC/QR:
- Packet Classification
- Congestion Management
- Congestion Avoidance
- Policing and Shaping
- Signalling
- Link Efficiency Mechanisms



Module XC/XR:
- Cisco IOS Switching Paths
- NetFlow Switching
- Multiprotocol Label Switching
- Multilayer Switching
- Multicast Distributed Switching
- Virtual LANs
- LAN Emulation

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Master Indexes

Two master indexes provide indexing information for the Cisco IOS software documentation set: an index for the configuration guides and an index for the command references. Individual books also contain a book-specific index.

The master indexes provide a quick way for you to find a command when you know the command name but not which module contains the command. When you use the online master indexes, you can click the page number for an index entry and go to that page in the online document.

Supporting Documents and Resources

The following documents and resources support the Cisco IOS software documentation set:

- *Cisco IOS Command Summary* (two volumes)—This publication explains the function and syntax of the Cisco IOS software commands. For more information about defaults and usage guidelines, refer to the Cisco IOS command reference publications.
- *Cisco IOS System Error Messages*—This publication lists and describes Cisco IOS system error messages. Not all system error messages indicate problems with your system. Some are purely informational, and others may help diagnose problems with communications lines, internal hardware, or the system software.
- *Cisco IOS Debug Command Reference*—This publication contains an alphabetical listing of the **debug** commands and their descriptions. Documentation for each command includes a brief description of its use, command syntax, usage guidelines, and sample output.
- *Dictionary of Internetworking Terms and Acronyms*—This Cisco publication compiles and defines the terms and acronyms used in the internetworking industry.
- New feature documentation—The Cisco IOS software documentation set documents the mainline release of Cisco IOS software (for example, Cisco IOS Release 12.2). New software features are introduced in early deployment releases (for example, the Cisco IOS "T" release train for 12.2, 12.2(x)T). Documentation for these new features can be found in standalone documents called "feature modules." Feature module documentation describes new Cisco IOS software and hardware networking functionality and is available on Cisco.com and the Documentation CD-ROM.
- Release notes—This documentation describes system requirements, provides information about new and changed features, and includes other useful information about specific software releases. See the section "Using Software Release Notes" in the chapter "Using Cisco IOS Software" for more information.
- Caveats documentation—This documentation provides information about Cisco IOS software defects in specific software releases.
- RFCs—RFCs are standards documents maintained by the Internet Engineering Task Force (IETF). Cisco IOS software documentation references supported RFCs when applicable. The full text of referenced RFCs may be obtained on the World Wide Web at http://www.rfc-editor.org/.
- MIBs—MIBs are used for network monitoring. For lists of supported MIBs by platform and release, and to download MIB files, see the Cisco MIB website on Cisco.com at http://www.cisco.com/public/sw-center/netmgmt/cmtk/mibs.shtml.

New and Changed Information

The following is new or changed information since the last release of the Cisco IOS IP and IP routing publications:

- The title of the *Cisco IOS IP and IP Routing Configuration Guide* has been changed to *Cisco IOS IP Configuration Guide*.
- The *Cisco IOS IP and IP Routing Command Reference* has been divided into three separate publications with the following titles:
  - *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services*
  - *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols*
  - *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*
- The following new chapters were added to the *Cisco IOS IP Configuration Guide*:
  - "Configuring Server Load Balancing"
  - "Configuring Source Specific Multicast"
  - "Configuring Bidirectional PIM"
  - "Configuring Router-Port Group Management Protocol"
- The following new chapter was added to the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services*:
  - "Server Load Balancing Commands"

Document Conventions

Within Cisco IOS software documentation, the term *router* is generally used to refer to a variety of Cisco products (for example, routers, access servers, and switches). Routers, access servers, and other networking devices that support Cisco IOS software are shown interchangeably within examples. These products are used only for illustrative purposes; that is, an example that shows one product does not necessarily indicate that other products are not supported.

The Cisco IOS documentation set uses the following conventions:

Convention	Description
^ or Ctrl	The ^ and Ctrl symbols represent the Control key. For example, the key combination ^D or Ctrl-D means hold down the Control key while you press the D key. Keys are indicated in capital letters but are not case sensitive.
string	A string is a nonquoted set of characters shown in italics. For example, when setting an SNMP community string to public, do not use quotation marks around the string or the string will include the quotation marks.

Command syntax descriptions use the following conventions:

Convention	Description
boldface	Boldface text indicates commands and keywords that you enter literally as shown.
italics	Italic text indicates arguments for which you supply values.
[x]	Square brackets enclose an optional element (keyword or argument).
|	A vertical line indicates a choice within an optional or required set of keywords or arguments.
[x | y]	Square brackets enclosing keywords or arguments separated by a vertical line indicate an optional choice.
{x | y}	Braces enclosing keywords or arguments separated by a vertical line indicate a required choice.

Nested sets of square brackets or braces indicate optional or required choices within optional or required elements. For example:

Convention	Description
[x {y | z}]	Braces and a vertical line within square brackets indicate a required choice within an optional element.

Examples use the following conventions:

Convention	Description
`screen`	Examples of information displayed on the screen are set in Courier font.
`boldface screen`	Examples of text that you must enter are set in Courier bold font.
< >	Angle brackets enclose text that is not printed to the screen, such as passwords.
!	An exclamation point at the beginning of a line indicates a comment line. (Exclamation points are also displayed by the Cisco IOS software for certain processes.)
[ ]	Square brackets enclose default responses to system prompts.

The following conventions are used to attract the attention of the reader:

Caution Means *reader be careful*. In this situation, you might do something that could result in equipment damage or loss of data.

Note Means *reader take note*. Notes contain helpful suggestions or references to materials not contained in this manual.

Timesaver Means the *described action saves time*. You can save time by performing the action described in the paragraph.

Obtaining Documentation

The following sections provide sources for obtaining documentation from Cisco Systems.

World Wide Web

The most current Cisco documentation is available on the World Wide Web at the following website:

http://www.cisco.com

Translated documentation is available at the following website:

http://www.cisco.com/public/countries_languages.html

Documentation CD-ROM

Cisco documentation and additional literature are available in a CD-ROM package, which ships with your product. The Documentation CD-ROM is updated monthly and may be more current than printed documentation. The CD-ROM package is available as a single unit or through an annual subscription.

Ordering Documentation

Cisco documentation can be ordered in the following ways:

- Registered Cisco Direct Customers can order Cisco product documentation from the Networking Products MarketPlace:

  http://www.cisco.com/cgi-bin/order/order_root.pl

- Registered Cisco.com users can order the Documentation CD-ROM through the online Subscription Store:

  http://www.cisco.com/go/subscription

- Nonregistered Cisco.com users can order documentation through a local account representative by calling Cisco corporate headquarters (California, USA) at 408 526-7208 or, in North America, by calling 800 553-NETS(6387).

Documentation Feedback

If you are reading Cisco product documentation on the World Wide Web, you can submit technical comments electronically. Click **Feedback** in the toolbar and select **Documentation**. After you complete the form, click **Submit** to send it to Cisco.

You can e-mail your comments to bug-doc@cisco.com.

To submit your comments by mail, use the response card behind the front cover of your document, or write to the following address:

Cisco Systems, Inc.
Document Resource Connection
170 West Tasman Drive
San Jose, CA 95134-9883

We appreciate your comments.

Obtaining Technical Assistance

Cisco provides Cisco.com as a starting point for all technical assistance. Customers and partners can obtain documentation, troubleshooting tips, and sample configurations from online tools. For Cisco.com registered users, additional troubleshooting tools are available from the TAC website.

Cisco.com

Cisco.com is the foundation of a suite of interactive, networked services that provides immediate, open access to Cisco information and resources at anytime, from anywhere in the world. This highly integrated Internet application is a powerful, easy-to-use tool for doing business with Cisco.

Cisco.com provides a broad range of features and services to help customers and partners streamline business processes and improve productivity. Through Cisco.com, you can find information about Cisco and our networking solutions, services, and programs. In addition, you can resolve technical issues with online technical support, download and test software packages, and order Cisco learning materials and merchandise. Valuable online skill assessment, training, and certification programs are also available.

Customers and partners can self-register on Cisco.com to obtain additional personalized information and services. Registered users can order products, check on the status of an order, access technical support, and view benefits specific to their relationships with Cisco.

To access Cisco.com, go to the following website:

http://www.cisco.com

Technical Assistance Center

The Cisco TAC website is available to all customers who need technical assistance with a Cisco product or technology that is under warranty or covered by a maintenance contract.

Contacting TAC by Using the Cisco TAC Website

If you have a priority level 3 (P3) or priority level 4 (P4) problem, contact TAC by going to the TAC website:

http://www.cisco.com/tac

P3 and P4 level problems are defined as follows:

- P3—Your network performance is degraded. Network functionality is noticeably impaired, but most business operations continue.
- P4—You need information or assistance on Cisco product capabilities, product installation, or basic product configuration.

In each of the above cases, use the Cisco TAC website to quickly find answers to your questions.

To register for Cisco.com, go to the following website:

http://www.cisco.com/register/

If you cannot resolve your technical issue by using the TAC online resources, Cisco.com registered users can open a case online by using the TAC Case Open tool at the following website:

http://www.cisco.com/tac/caseopen

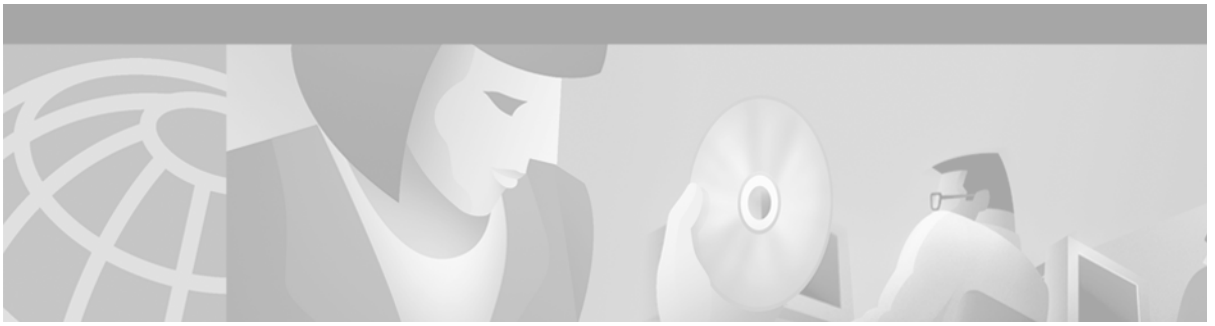
Contacting TAC by Telephone

If you have a priority level 1 (P1) or priority level 2 (P2) problem, contact TAC by telephone and immediately open a case. To obtain a directory of toll-free numbers for your country, go to the following website:

http://www.cisco.com/warp/public/687/Directory/DirTAC.shtml

P1 and P2 level problems are defined as follows:

- P1—Your production network is down, causing a critical impact to business operations if service is not restored quickly. No workaround is available.
- P2—Your production network is severely degraded, affecting significant aspects of your business operations. No workaround is available.



Using Cisco IOS Software

This chapter provides helpful tips for understanding and configuring Cisco IOS software using the command-line interface (CLI). It contains the following sections:

- Understanding Command Modes
- Getting Help
- Using the no and default Forms of Commands
- Saving Configuration Changes
- Filtering Output from the show and more Commands
- Identifying Supported Platforms

For an overview of Cisco IOS software configuration, refer to the *Cisco IOS Configuration Fundamentals Configuration Guide*.

For information on the conventions used in the Cisco IOS software documentation set, see the chapter "About Cisco IOS Software Documentation" located at the beginning of this book.

Understanding Command Modes

You use the CLI to access Cisco IOS software. Because the CLI is divided into many different modes, the commands available to you at any given time depend on the mode you are currently in. Entering a question mark (**?**) at the CLI prompt allows you to obtain a list of commands available for each command mode.

When you log in to the CLI, you are in user EXEC mode. User EXEC mode contains only a limited subset of commands. To have access to all commands, you must enter privileged EXEC mode, normally by using a password. From privileged EXEC mode you can issue any EXEC command—user or privileged mode—or you can enter global configuration mode. Most EXEC commands are one-time commands. For example, **show** commands show important status information, and **clear** commands clear counters or interfaces. The EXEC commands are not saved when the software reboots.

Configuration modes allow you to make changes to the running configuration. If you later save the running configuration to the startup configuration, these changed commands are stored when the software is rebooted. To enter specific configuration modes, you must start at global configuration mode. From global configuration mode, you can enter interface configuration mode and a variety of other modes, such as protocol-specific modes.

ROM monitor mode is a separate mode used when the Cisco IOS software cannot load properly. If a valid software image is not found when the software boots or if the configuration file is corrupted at startup, the software might enter ROM monitor mode.

Table 1 describes how to access and exit various common command modes of the Cisco IOS software. It also shows examples of the prompts displayed for each mode.

Table 1 Accessing and Exiting Command Modes

Command Mode	Access Method	Prompt	Exit Method
User EXEC	Log in.	`Router>`	Use the **logout** command.
Privileged EXEC	From user EXEC mode, use the **enable** EXEC command.	`Router#`	To return to user EXEC mode, use the **disable** command.
Global configuration	From privileged EXEC mode, use the **configure terminal** privileged EXEC command.	`Router(config)#`	To return to privileged EXEC mode from global configuration mode, use the **exit** or **end** command, or press **Ctrl-Z**.
Interface configuration	From global configuration mode, specify an interface using an **interface** command.	`Router(config-if)#`	To return to global configuration mode, use the **exit** command. To return to privileged EXEC mode, use the **end** command, or press **Ctrl-Z**.
ROM monitor	From privileged EXEC mode, use the **reload** EXEC command. Press the **Break** key during the first 60 seconds while the system is booting.	`>`	To exit ROM monitor mode, use the **continue** command.

For more information on command modes, refer to the "Using the Command-Line Interface" chapter in the *Cisco IOS Configuration Fundamentals Configuration Guide*.

Getting Help

Entering a question mark (**?**) at the CLI prompt displays a list of commands available for each command mode. You can also get a list of keywords and arguments associated with any command by using the context-sensitive help feature.

To get help specific to a command mode, a command, a keyword, or an argument, use one of the following commands:

Command	Purpose
help	Provides a brief description of the help system in any command mode.
abbreviated-command-entry`?`	Provides a list of commands that begin with a particular character string. (No space between command and question mark.)
abbreviated-command-entry<**Tab**>	Completes a partial command name.
?	Lists all commands available for a particular command mode.
command **?**	Lists the keywords or arguments that you must enter next on the command line. (Space between command and question mark.)

Example: How to Find Command Options

This section provides an example of how to display syntax for a command. The syntax can consist of optional or required keywords and arguments. To display keywords and arguments for a command, enter a question mark (**?**) at the configuration prompt or after entering part of a command followed by a space. The Cisco IOS software displays a list and brief description of available keywords and arguments. For example, if you were in global configuration mode and wanted to see all the keywords or arguments for the **arap** command, you would type **arap ?**.

The <cr> symbol in command help output stands for "carriage return." On older keyboards, the carriage return key is the Return key. On most modern keyboards, the carriage return key is the Enter key. The <cr> symbol at the end of command help output indicates that you have the option to press **Enter** to complete the command and that the arguments and keywords in the list preceding the <cr> symbol are optional. The <cr> symbol by itself indicates that no more arguments or keywords are available and that you must press **Enter** to complete the command.

Table 2 shows examples of how you can use the question mark (**?**) to assist you in entering commands. The table steps you through configuring an IP address on a serial interface on a Cisco 7206 router that is running Cisco IOS Release 12.0(3).

Table 2 How to Find Command Options

Command	Comment

`Router> enable`
`Password: <password>`
`Router#`
	Enter the **enable** command and password to access privileged EXEC commands. You are in privileged EXEC mode when the prompt changes to `Router#`.

`Router# configure terminal`
`Enter configuration commands, one per line. End with CNTL/Z.`
`Router(config)#`
	Enter the **configure terminal** privileged EXEC command to enter global configuration mode. You are in global configuration mode when the prompt changes to `Router(config)#`.

`Router(config)# interface serial ?`
`  <0-6>  Serial interface number`
`Router(config)# interface serial 4 ?`
`  /`
`Router(config)# interface serial 4/ ?`
`  <0-3>  Serial interface number`
`Router(config)# interface serial 4/0`
`Router(config-if)#`
	Enter interface configuration mode by specifying the serial interface that you want to configure using the **interface serial** global configuration command.
	Enter **?** to display what you must enter next on the command line. In this example, you must enter the serial interface slot number and port number, separated by a forward slash.
	You are in interface configuration mode when the prompt changes to `Router(config-if)#`.

Table 2 How to Find Command Options (continued)

Command	Comment
Router(config-if)# **?** Interface configuration commands: . . . ip Interface Internet Protocol config commands keepalive Enable keepalive lan-name LAN Name command llc2 LLC2 Interface Subcommands load-interval Specify interval for load calculation for an interface locaddr-priority Assign a priority group logging Configure logging for interface loopback Configure internal loopback on an interface mac-address Manually set interface MAC address mls mls router sub/interface commands mpoa MPOA interface configuration commands mtu Set the interface Maximum Transmission Unit (MTU) netbios Use a defined NETBIOS access list or enable name-caching no Negate a command or set its defaults nrzi-encoding Enable use of NRZI encoding ntp Configure NTP . . . Router(config-if)#	Enter **?** to display a list of all the interface configuration commands available for the serial interface. This example shows only some of the available interface configuration commands.
Router(config-if)# **ip ?** Interface IP configuration subcommands: access-group Specify access control for packets accounting Enable IP accounting on this interface address Set the IP address of an interface authentication authentication subcommands bandwidth-percent Set EIGRP bandwidth limit broadcast-address Set the broadcast address of an interface cgmp Enable/disable CGMP directed-broadcast Enable forwarding of directed broadcasts dvmrp DVMRP interface commands hello-interval Configures IP-EIGRP hello interval helper-address Specify a destination address for UDP broadcasts hold-time Configures IP-EIGRP hold time . . . Router(config-if)# **ip**	Enter the command that you want to configure for the interface. This example uses the **ip** command. Enter **?** to display what you must enter next on the command line. This example shows only some of the available interface IP configuration commands.

Table 2 How to Find Command Options (continued)

Command	Comment

`Router(config-if)# ip address ?`
`  A.B.C.D  IP address`
`  negotiated  IP Address negotiated over PPP`
`Router(config-if)# ip address`
	Enter the command that you want to configure for the interface. This example uses the **ip address** command.
	Enter **?** to display what you must enter next on the command line. In this example, you must enter an IP address or the **negotiated** keyword.
	A carriage return (<cr>) is not displayed; therefore, you must enter additional keywords or arguments to complete the command.

`Router(config-if)# ip address 172.16.0.1 ?`
`  A.B.C.D  IP subnet mask`
`Router(config-if)# ip address 172.16.0.1`
	Enter the keyword or argument you want to use. This example uses the 172.16.0.1 IP address.
	Enter **?** to display what you must enter next on the command line. In this example, you must enter an IP subnet mask.
	A <cr> is not displayed; therefore, you must enter additional keywords or arguments to complete the command.

`Router(config-if)# ip address 172.16.0.1 255.255.255.0 ?`
`  secondary  Make this IP address a secondary address`
`  <cr>`
`Router(config-if)# ip address 172.16.0.1 255.255.255.0`
	Enter the IP subnet mask. This example uses the 255.255.255.0 IP subnet mask.
	Enter **?** to display what you must enter next on the command line. In this example, you can enter the **secondary** keyword, or you can press **Enter**.
	A <cr> is displayed; you can press **Enter** to complete the command, or you can enter another keyword.

`Router(config-if)# ip address 172.16.0.1 255.255.255.0` `Router(config-if)#`	In this example, Enter is pressed to complete the command.

Using the no and default Forms of Commands

Almost every configuration command has a **no** form. In general, use the **no** form to disable a function. Use the command without the **no** keyword to reenable a disabled function or to enable a function that is disabled by default. For example, IP routing is enabled by default. To disable IP routing, use the **no ip routing** command; to reenable IP routing, use the **ip routing** command. The Cisco IOS software command reference publications provide the complete syntax for the configuration commands and describe what the **no** form of a command does.

Configuration commands also can have a **default** form, which returns the command settings to the default values. Most commands are disabled by default, so in such cases using the **default** form has the same result as using the **no** form of the command. However, some commands are enabled by default and

have variables set to certain default values. In these cases, the **default** form of the command enables the command and sets the variables to their default values. The Cisco IOS software command reference publications describe the effect of the **default** form of a command if the command functions differently than the **no** form.

Saving Configuration Changes

Use the **copy system:running-config nvram:startup-config** command to save your configuration changes to the startup configuration so that the changes will not be lost if the software reloads or a power outage occurs. For example:

```
Router# copy system:running-config nvram:startup-config
Building configuration...
```

It might take a minute or two to save the configuration. After the configuration has been saved, the following output appears:

```
[OK]
Router#
```

On most platforms, this task saves the configuration to NVRAM. On the Class A Flash file system platforms, this task saves the configuration to the location specified by the CONFIG_FILE environment variable. The CONFIG_FILE variable defaults to NVRAM.

Filtering Output from the show and more Commands

In Cisco IOS Release 12.0(1)T and later releases, you can search and filter the output of **show** and **more** commands. This functionality is useful if you need to sort through large amounts of output or if you want to exclude output that you need not see.

To use this functionality, enter a **show** or **more** command followed by the "pipe" character (|); one of the keywords **begin**, **include**, or **exclude**; and a regular expression on which you want to search or filter (the expression is case-sensitive):

command | {**begin** | **include** | **exclude**} *regular-expression*

The output matches certain lines of information in the configuration file. The following example illustrates how to use output modifiers with the **show interface** command when you want the output to include only lines in which the expression "protocol" appears:

```
Router# show interface | include protocol

FastEthernet0/0 is up, line protocol is up
Serial4/0 is up, line protocol is up
Serial4/1 is up, line protocol is up
Serial4/2 is administratively down, line protocol is down
Serial4/3 is administratively down, line protocol is down
```

For more information on the search and filter functionality, refer to the "Using the Command-Line Interface" chapter in the *Cisco IOS Configuration Fundamentals Configuration Guide*.

Identifying Supported Platforms

Cisco IOS software is packaged in feature sets consisting of software images that support specific platforms. The feature sets available for a specific platform depend on which Cisco IOS software images are included in a release. To identify the set of software images available in a specific release or to find out if a feature is available in a given Cisco IOS software image, see the following sections:

- Using Feature Navigator
- Using Software Release Notes

Using Feature Navigator

Feature Navigator is a web-based tool that enables you to quickly determine which Cisco IOS software images support a particular set of features and which features are supported in a particular Cisco IOS image.

Feature Navigator is available 24 hours a day, 7 days a week. To access Feature Navigator, you must have an account on Cisco.com. If you have forgotten or lost your account information, e-mail the Contact Database Administration group at cdbadmin@cisco.com. If you do not have an account on Cisco.com, go to http://www.cisco.com/register and follow the directions to establish an account.

To use Feature Navigator, you must have a JavaScript-enabled web browser such as Netscape 3.0 or later, or Internet Explorer 4.0 or later. Internet Explorer 4.0 always has JavaScript enabled. To enable JavaScript for Netscape 3.x or Netscape 4.x, follow the instructions provided with the web browser. For JavaScript support and enabling instructions for other browsers, check with the browser vendor.

Feature Navigator is updated when major Cisco IOS software releases and technology releases occur. You can access Feature Navigator at the following URL:

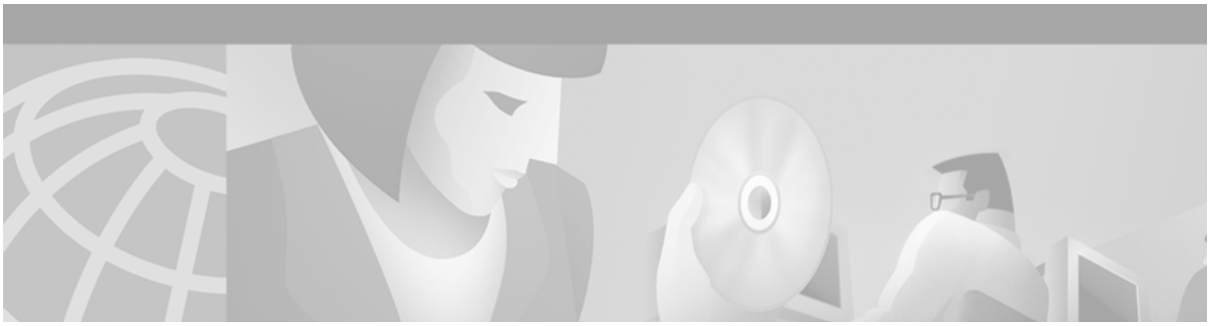
http://www.cisco.com/go/fn

Using Software Release Notes

Cisco IOS software releases include release notes that provide the following information:

- Platform support information
- Memory recommendations
- Microcode support information
- Feature set tables
- Feature descriptions
- Open and resolved severity 1 and 2 caveats for all platforms

Release notes are intended to be release-specific for the most current release, and the information provided in these documents may not be cumulative in providing information about features that first appeared in previous releases.



IP Overview

The Internet Protocol (IP) is a packet-based protocol used to exchange data over computer networks. IP handles addressing, fragmentation, reassembly, and protocol demultiplexing. It is the foundation on which all other IP protocols (collectively referred to as the IP Protocol suite) are built. A network-layer protocol, IP contains addressing and control information that allows data packets to be routed.

The Transmission Control Protocol (TCP) is built upon the IP layer. TCP is a connection-oriented protocol that specifies the format of data and acknowledgments used in the transfer of data. TCP also specifies the procedures that the networking devices use to ensure that the data arrives correctly. TCP allows multiple applications on a system to communicate concurrently because it handles all demultiplexing of the incoming traffic among the application programs.

The Cisco implementation of IP provides most of the major services contained in the various protocol specifications. Cisco IOS software also provides the TCP and User Datagram Protocol (UDP) services called Echo and Discard, which are described in RFCs 862 and 863, respectively.

Cisco supports both TCP and UDP at the transport layer, for maximum flexibility in services. Cisco also supports all standards for IP broadcasts.

This overview chapter provides a high-level description of IP. For configuration information, see the appropriate chapter in this publication.

The *Cisco IOS IP Configuration Guide* has the following three parts:

- IP Addressing and Services
- IP Routing Protocols
- IP Multicast

For information on other network protocols, refer to the *Cisco IOS AppleTalk and Novell IPX Configuration Guide* and *Cisco IOS Apollo Domain, Banyan VINES, DECnet, ISO CLNS, and XNS Configuration Guide*.

IP Addressing and Services

IP addressing features such as Address Resolution Protocol (ARP), Next Hop Resolution Protocol (NHRP), and Network Address Translation (NAT) are described in the “Configuring IP Addressing” chapter. Dynamic Host Configuration Protocol (DHCP) is described in the “Configuring DHCP” chapter.

IP services such as IP access lists, Internet Control Message Protocol (ICMP), Hot Standby Router Protocol (HSRP), IP accounting, performance parameters, and MultiNode Balancing (MNLB) Forwarding Agent are described in the “Configuring IP Services” chapter.

Server load balancing allows a network administrator to define a virtual server to represent a group of real servers. For more information on this feature, see the "Configuring Server Load Balancing" chapter.

Mobile IP, which allows users to roam and maintain connectivity beyond their home subnet while consistently maintaining their IP address, is described in the "Configuring Mobile IP" chapter.

IP Routing Protocols

The Cisco implementation of each IP routing protocol is discussed at the beginning of the individual protocol chapters in this publication.

With any of the IP routing protocols, you must create the routing process, associate networks with the routing process, and customize the routing protocol for your particular network. You will need to perform some combination of the tasks in the respective chapters to configure one or more IP routing protocols.

Determining a Routing Process

Choosing a routing protocol is a complex task. When choosing a routing protocol, consider at least the following factors:

- Internetwork size and complexity
- Support for variable-length subnet masks (VLSMs). Enhanced Interior Gateway Routing Protocol (Enhanced IGRP), Intermediate System-to-Intermediate System (IS-IS), static routes, and Open Shortest Path First (OSPF) support VLSMs.
- Internetwork traffic levels
- Security needs
- Reliability needs
- Internetwork delay characteristics
- Organizational policies
- Organizational acceptance of change

The chapters in this publication describe the configuration tasks associated with each supported routing protocol or service. This publication does not provide in-depth information on how to choose routing protocols; you must choose routing protocols that best suit your needs.

Interior and Exterior Gateway Protocols

IP routing protocols are divided into two classes: Interior Gateway Protocols (IGPs) and Exterior Gateway Protocols (EGPs). The IGPs and EGPs that Cisco supports are listed in the following sections:

- Interior Gateway Protocols
- Exterior Gateway Protocols

Note Many routing protocol specifications refer to routers as *gateways*, so the word *gateway* often appears as part of routing protocol names. However, a router usually is defined as a Layer 3 internetworking device, whereas a protocol translation gateway usually is defined as a Layer 7 internetworking device. The reader should understand that regardless of whether a routing protocol name contains the word "gateway," routing protocol activities occur at Layer 3 of the Open System Interconnection (OSI) reference model.

Interior Gateway Protocols

Interior gateway protocols are used for routing networks that are under a common network administration. All IP interior gateway protocols must be specified with a list of associated networks before routing activities can begin. A routing process "listens" to updates from other routers on these networks and broadcasts its own routing information on those same networks. Cisco IOS software supports the following interior routing protocols:

- On-Demand Routing (ODR)
- Routing Information Protocol (RIP)
- Interior Gateway Routing Protocol (IGRP)
- Open Shortest Path First (OSPF)
- Enhanced IGRP (EIGRP)
- Integrated IS-IS

Exterior Gateway Protocols

Exterior gateway protocols are used to exchange routing information between networks that do not share a common administration. IP Exterior Gateway Protocols require the following three sets of information before routing can begin:

- A list of neighbor (or peer) routers with which to exchange routing information
- A list of networks to advertise as directly reachable
- The autonomous system number of the local router

The exterior gateway protocol that is supported by Cisco IOS software is Border Gateway Protocol (BGP).

Multiprotocol BGP is an enhanced BGP that carries routing information for multiple network-layer protocols and IP multicast routes. BGP carries two sets of routes, one set for unicast routing and one set for multicast routing. The routes associated with multicast routing are used by Protocol Independent Multicast (PIM) to build data distribution trees.

Multiple Routing Protocols

You can configure multiple routing protocols in a single router to connect networks that use different routing protocols. You can, for example, run RIP on one subnetted network and IGRP on another subnetted network, and exchange routing information between them in a controlled fashion. The available routing protocols were not designed to interoperate, so each protocol collects different types of information and reacts to topology changes in its own way.

For example, RIP uses a hop-count metric and IGRP uses a five-element vector of metric information. If routing information is being exchanged between different networks that use different routing protocols, you can use many configuration options to filter the exchange of routing information.

The Cisco IOS software can handle simultaneous operation of up to 30 dynamic IP routing processes. The combination of routing processes on a router consists of the following protocols (with the limits noted):

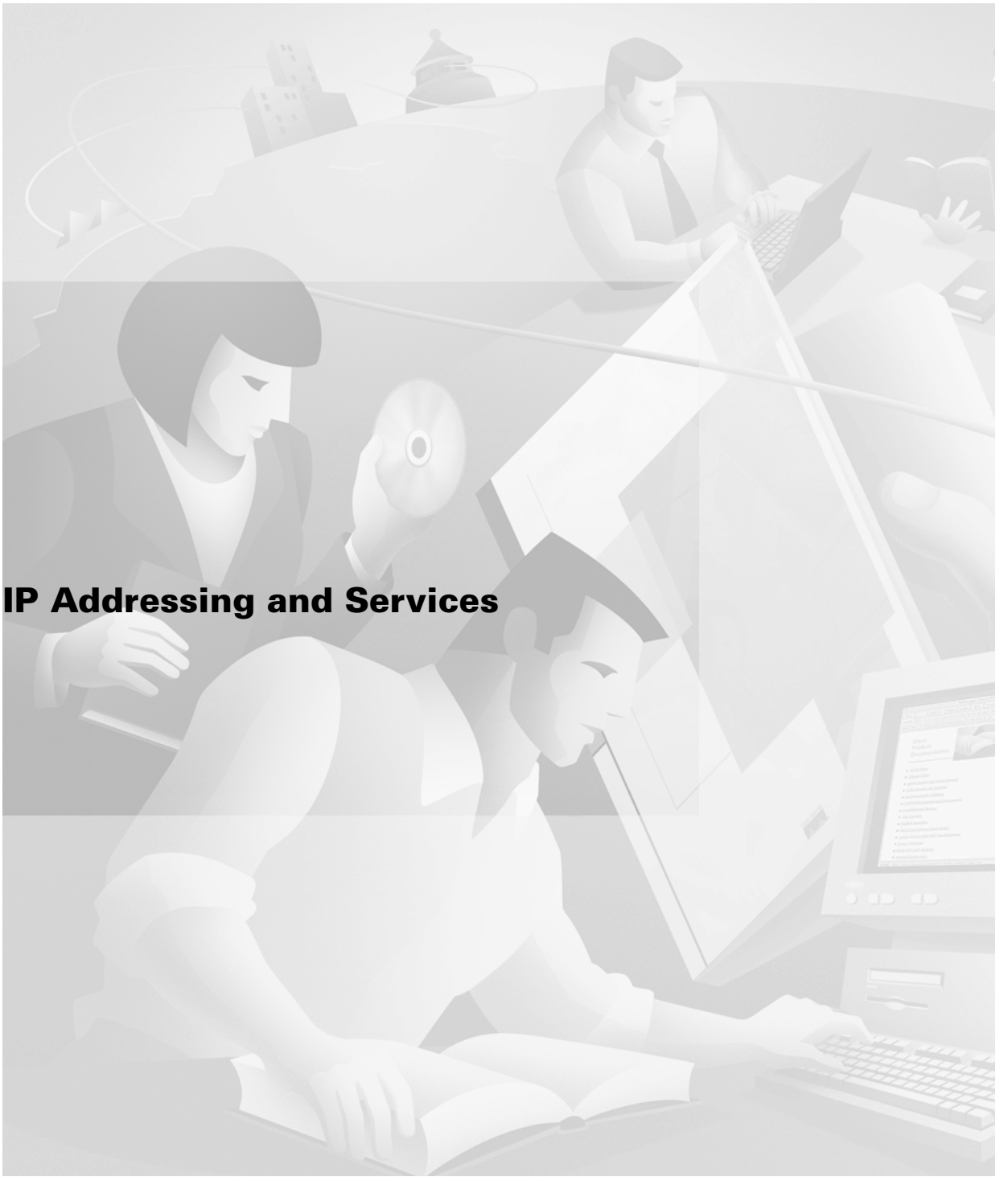
- Up to 30 IGRP routing processes
- Up to 30 EIGRP routing processes
- Up to 30 OSPF routing processes
- One RIP routing process
- One IS-IS process
- One BGP routing process

IP Multicast

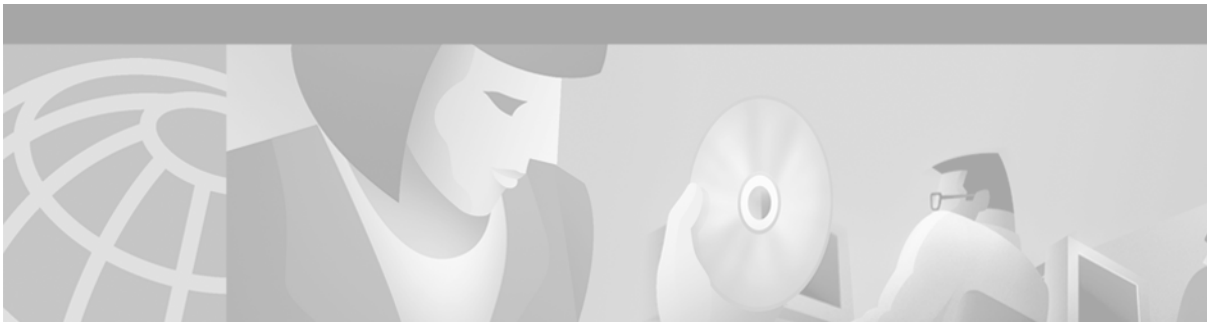
IP multicast routing provides an alternative to unicast and broadcast transmission. It allows a host to send packets to a subset of all hosts, known as *group transmission*. IP multicast runs on top of the other IP routing protocols.

In addition to IP multicast routing itself, other multicast features are available, each discussed in a separate chapter, as follows:

- Source Specific Multicast (SSM) is an extension of IP multicast where datagram traffic is forwarded to receivers from only those multicast sources to which the receivers have explicitly joined.
- Bidirectional PIM is a variant of the PIM suite of routing protocols for IP multicast. In bidirectional mode, datagram traffic is routed only along a bidirectional shared tree that is rooted at the rendezvous point (RP) for the multicast group.
- Multicast Source Discovery Protocol (MSDP) is a mechanism for the router to discover multicast sources in other PIM domains.
- Pragmatic General Multicast (PGM) is a reliable multicast transport protocol for applications that require ordered, duplicate-free, multicast data delivery from multiple sources to multiple receivers. The PGM Host feature is the Cisco implementation of the transport layer of the PGM protocol, and the PGM Router Assist feature is the Cisco implementation of the network layer of the PGM protocol.
- Unidirectional link routing (UDLR) provides a way to forward multicast packets over a physical unidirectional interface, such as a satellite link.
- The Multicast Routing Monitor (MRM) feature is a management diagnostic tool that provides network fault detection and isolation in a large multicast routing infrastructure. This feature is described in the “Using IP Multicast Tools” chapter.
- Router-Port Group Management Protocol (RGMP) is a Layer 2 protocol that enables a router to communicate to a switch (or a networking device that is functioning as a Layer 2 switch) the multicast group for which the router would like to receive or forward traffic.



IP Addressing and Services



Configuring IP Addressing

This chapter describes how to configure IP addressing. For a complete description of the IP addressing commands in this chapter, refer to the "IP Addressing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services* publication. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

IP Addressing Task List

A basic and required task for configuring IP is to assign IP addresses to network interfaces. Doing so enables the interfaces and allows communication with hosts on those interfaces using IP. Associated with this task are decisions about subnetting and masking the IP addresses.

To configure various IP addressing features, perform the tasks described in the following sections. The task in the first section is required; the tasks in remaining sections are optional.

- Assigning IP Addresses to Network Interfaces (Required)
- Configuring Address Resolution Methods (Optional)
- Enabling IP Routing (Optional)
- Enabling IP Bridging (Optional)
- Enabling Integrated Routing and Bridging (Optional)
- Configuring a Routing Process (Optional)
- Configuring Broadcast Packet Handling (Optional)
- Configuring Network Address Translation (Optional)
- Monitoring and Maintaining IP Addressing (Optional)

At the end of this chapter, the examples in the "IP Addressing Examples" section illustrate how you might establish IP addressing in your network.

Assigning IP Addresses to Network Interfaces

An IP address identifies a location to which IP datagrams can be sent. Some IP addresses are reserved for special uses and cannot be used for host, subnet, or network addresses. Table 3 lists ranges of IP addresses, and shows which addresses are reserved and which are available for use.

Table 3 Reserved and Available IP Addresses

Class	Address or Range	Status
A	0.0.0.0 1.0.0.0 to 126.0.0.0 127.0.0.0	Reserved Available Reserved
B	128.0.0.0 to 191.254.0.0 191.255.0.0	Available Reserved
C	192.0.0.0 192.0.1.0 to 223.255.254 223.255.255.0	Reserved Available Reserved
D	224.0.0.0 to 239.255.255.255	Multicast group addresses
E	240.0.0.0 to 255.255.255.254 255.255.255.255	Reserved Broadcast

The official description of IP addresses is found in RFC 1166, *Internet Numbers*.

To receive an assigned network number, contact your Internet service provider (ISP).

An interface can have one primary IP address. To assign a primary IP address and a network mask to a network interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip address ip-address mask`	Sets a primary IP address for an interface.

A mask identifies the bits that denote the network number in an IP address. When you use the mask to subnet a network, the mask is then referred to as a *subnet mask*.

Note We only support network masks that use contiguous bits that are flush left against the network field.

The tasks to enable or disable additional, optional, IP addressing features are contained in the following sections:

- Assigning Multiple IP Addresses to Network Interfaces
- Enabling Use of Subnet Zero
- Disabling Classless Routing Behavior
- Enabling IP Processing on a Serial Interface

Assigning Multiple IP Addresses to Network Interfaces

Cisco IOS software supports multiple IP addresses per interface. You can specify an unlimited number of secondary addresses. Secondary IP addresses can be used in a variety of situations. The following are the most common applications:

- There might not be enough host addresses for a particular network segment. For example, suppose your subnetting allows up to 254 hosts per logical subnet, but on one physical subnet you must have 300 host addresses. Using secondary IP addresses on the routers or access servers allows you to have two logical subnets using one physical subnet.
- Many older networks were built using Level 2 bridges, and were not subnetted. The judicious use of secondary addresses can aid in the transition to a subnetted, router-based network. Routers on an older, bridged segment can easily be made aware that many subnets are on that segment.
- Two subnets of a single network might otherwise be separated by another network. You can create a single network from subnets that are physically separated by another network by using a secondary address. In these instances, the first network is *extended*, or layered on top of the second network. Note that a subnet cannot appear on more than one active interface of the router at a time.

Note If any router on a network segment uses a secondary address, all other routers on that same segment must also use a secondary address from the same network or subnet.

To assign multiple IP addresses to network interfaces, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip address` *ip-address mask* **secondary**	Assigns multiple IP addresses to network interfaces.

Note IP routing protocols sometimes treat secondary addresses differently when sending routing updates. See the description of IP split horizon in the "Configuring IP Enhanced IGRP," "Configuring IGRP," or "Configuring RIP" chapters for details.

See the "Creating a Network from Separated Subnets Example" section at the end of this chapter for an example of creating a network from separated subnets.

Enabling Use of Subnet Zero

Subnetting with a subnet address of 0 is illegal and strongly discouraged (as stated in RFC 791) because of the confusion that can arise between a network and a subnet that have the same addresses. For example, if network 131.108.0.0 is subnetted as 255.255.255.0, subnet 0 would be written as 131.108.0.0—which is identical to the network address.

You can use the all 0s and all 1s subnet (131.108.255.0), even though it is discouraged. Configuring interfaces for the all 1s subnet is explicitly allowed. However, if you need the entire subnet space for your IP address, use the following command in global configuration mode to enable subnet 0:

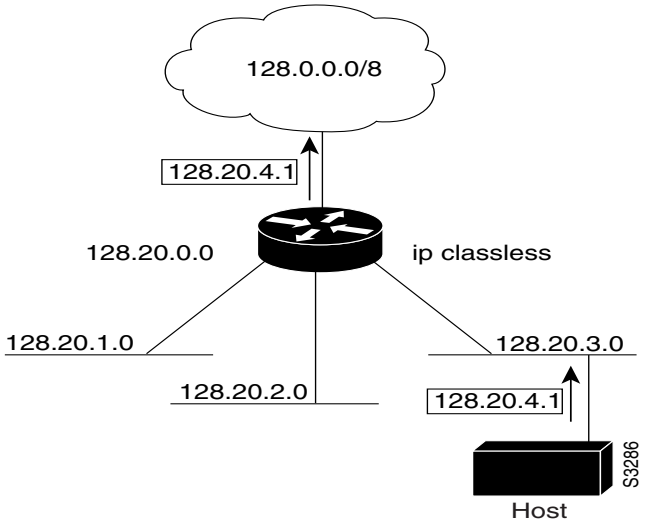
Command	Purpose
`Router(config)# ip subnet-zero`	Enables the use of subnet zero for interface addresses and routing updates.

Disabling Classless Routing Behavior

By default, classless routing behavior is enabled on the router. When classless routing is in effect, if a router receives packets destined for a subnet of a network that has no network default route, the router forwards the packet to the best supernet route.

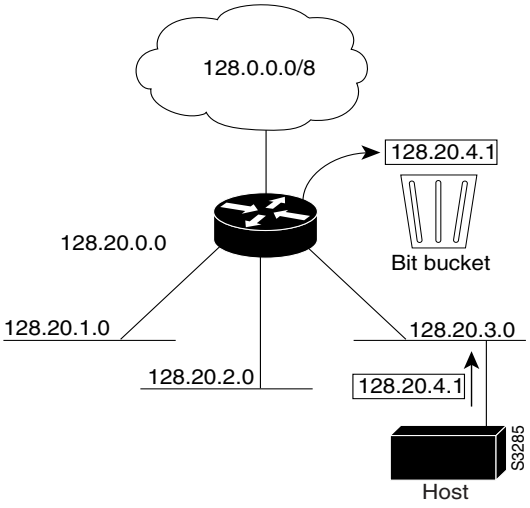
In Figure 1, classless routing is enabled in the router. Therefore, when the host sends a packet to 128.20.4.1, instead of discarding the packet, the router forwards the packet to the best supernet route.

Figure 1 IP Classless Routing



If you disable classless routing, and a router receives packets destined for a subnet of a network that has no network default route, the router discards the packet. Figure 2 shows a router in network 128.20.0.0 connected to subnets 128.20.1.0, 128.20.2.0, and 128.20.3.0. Suppose the host sends a packet to 128.20.4.1. Because there is no network default route, the router discards the packet.

Figure 2 No IP Classless Routing



To prevent the Cisco IOS software from forwarding packets destined for unrecognized subnets to the best supernet route possible, use the following command in global configuration mode:

Command	Purpose
`Router(config)# no ip classless`	Disables classless routing behavior.

Enabling IP Processing on a Serial Interface

You might want to enable IP processing on a serial or tunnel interface without assigning an explicit IP address to the interface. Whenever the unnumbered interface generates a packet (for example, for a routing update), it uses the address of the interface you specified as the source address of the IP packet. It also uses the specified interface address in determining which routing processes are sending updates over the unnumbered interface. Restrictions are as follows:

- Serial interfaces using High-Level Data Link Control (HDLC), PPP, Link Access Procedure, Balanced (LAPB), and Frame Relay encapsulations, as well as Serial Line Internet Protocol (SLIP) tunnel interfaces, can be unnumbered. Serial interfaces using Frame Relay encapsulation can also be unnumbered, but the interface must be a point-to-point subinterface. It is not possible to use the unnumbered interface feature with X.25 or Switched Multimegabit Data Service (SMDS) encapsulations.
- You cannot use the **ping** EXEC command to determine whether the interface is up, because the interface has no IP address. The Simple Network Management Protocol (SNMP) can be used to remotely monitor interface status.
- You cannot netboot a runnable image over an unnumbered serial interface.
- You cannot support IP security options on an unnumbered interface.

If you are configuring Intermediate System-to-Intermediate System (IS-IS) across a serial line, you should configure the serial interfaces as unnumbered, which allows you to conform with RFC 1195, which states that IP addresses are not required on each interface.

Note Using an unnumbered serial line between different major networks requires special care. If, at each end of the link, different major networks are assigned to the interfaces you specified as unnumbered, any routing protocols running across the serial line should be configured to not advertise subnet information.

To enable IP processing on an unnumbered serial interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip unnumbered type number`	Enables IP processing on a serial or tunnel interface without assigning an explicit IP address to the interface.

The interface you specify must be the name of another interface in the router that has an IP address, not another unnumbered interface.

The interface you specify also must be enabled (listed as "up" in the **show interfaces** command display).

See the "Serial Interfaces Configuration Example" section at the end of this chapter for an example of how to configure serial interfaces.

Configuring Address Resolution Methods

The Cisco IP implementation allows you to control interface-specific handling of IP addresses by facilitating address resolution, name services, and other functions. The following sections describe how to configure address resolution methods:

- Establishing Address Resolution
- Mapping Host Names to IP Addresses
- Configuring HP Probe Proxy Name Requests
- Configuring the Next Hop Resolution Protocol

Establishing Address Resolution

A device in the IP can have both a local address (which uniquely identifies the device on its local segment or LAN) and a network address (which identifies the network to which the device belongs). The local address is more properly known as a *data link* address because it is contained in the data link layer (Layer 2 of the OSI model) part of the packet header and is read by data-link devices (bridges and all device interfaces, for example). The more technically inclined person will refer to local addresses as *MAC addresses*, because the MAC sublayer within the data link layer processes addresses for the layer.

To communicate with a device on Ethernet, for example, the Cisco IOS software first must determine the 48-bit MAC or local data-link address of that device. The process of determining the local data-link address from an IP address is called *address resolution.* The process of determining the IP address from a local data-link address is called *reverse address resolution.*

The software uses three forms of address resolution: Address Resolution Protocol (ARP), proxy ARP, and Probe (similar to ARP). The software also uses the Reverse Address Resolution Protocol (RARP). ARP, proxy ARP, and RARP are defined in RFCs 826, 1027, and 903, respectively. Probe is a protocol developed by the Hewlett-Packard Company (HP) for use on IEEE-802.3 networks.

ARP is used to associate IP addresses with media or MAC addresses. Taking an IP address as input, ARP determines the associated media address. Once a media or MAC address is determined, the IP address or media address association is stored in an ARP cache for rapid retrieval. Then the IP datagram is encapsulated in a link-layer frame and sent over the network. Encapsulation of IP datagrams and ARP requests and replies on IEEE 802 networks other than Ethernet is specified by the Subnetwork Access Protocol (SNAP).

RARP works the same way as ARP, except that the RARP request packet requests an IP address instead of a local data-link address. Use of RARP requires a RARP server on the same network segment as the router interface. RARP often is used by diskless nodes that do not know their IP addresses when they boot. The Cisco IOS software attempts to use RARP if it does not know the IP address of an interface at startup. Also, Cisco routers can act as RARP servers by responding to RARP requests that they are able to answer. See the "Configure Additional File Transfer Functions" chapter in the *Cisco IOS Configuration Fundamentals Configuration Guide* to learn how to configure a router as a RARP server.

The tasks required to set address resolution are contained in the following sections:

- Defining a Static ARP Cache
- Setting ARP Encapsulations
- Enabling Proxy ARP
- Configuring Local-Area Mobility

Defining a Static ARP Cache

ARP and other address resolution protocols provide a dynamic mapping between IP addresses and media addresses. Because most hosts support dynamic address resolution, generally you need not specify static ARP cache entries. If you must define them, you can do so globally. Performing this task installs a permanent entry in the ARP cache. The Cisco IOS software uses this entry to translate 32-bit IP addresses into 48-bit hardware addresses.

Optionally, you can specify that the software respond to ARP requests as if it were the owner of the specified IP address. In case you do not want the ARP entries to be permanent, you have the option of specifying an ARP entry timeout period when you define ARP entries.

The following two tables list the tasks to provide static mapping between IP addresses and a media address.

Use either of the following commands in global configuration mode to specify that the software respond to ARP requests:

Command	Purpose
`Router(config)# arp ip-address hardware-address type`	Globally associates an IP address with a media (hardware) address in the ARP cache.
`Router(config)# arp ip-address hardware-address type alias`	Specifies that the software responds to ARP requests as if it were the owner of the specified IP address.

Use the following command in interface configuration mode to set the length of time an ARP cache entry will stay in the cache:

Command	Purpose
`Router(config-if)# arp timeout seconds`	Sets the length of time an ARP cache entry will stay in the cache.

To display the type of ARP being used on a particular interface and also display the ARP timeout value, use the **show interfaces** EXEC command. Use the **show arp** EXEC command to examine the contents of the ARP cache. Use the **show ip arp** EXEC command to show IP entries. To remove all nonstatic entries from the ARP cache, use the **clear arp-cache** privileged EXEC command.

Setting ARP Encapsulations

By default, standard Ethernet-style ARP encapsulation (represented by the **arpa** keyword) is enabled on the IP interface. You can change this encapsulation method to SNAP or HP Probe, as required by your network, to control the interface-specific handling of IP address resolution into 48-bit Ethernet hardware addresses.

When you set HP Probe encapsulation, the Cisco IOS software uses the Probe protocol whenever it attempts to resolve an IEEE-802.3 or Ethernet local data-link address. The subset of Probe that performs address resolution is called Virtual Address Request and Reply. Using Probe, the router can communicate transparently with HP IEEE-802.3 hosts that use this type of data encapsulation. You must explicitly configure all interfaces for Probe that will use Probe.

To specify the ARP encapsulation type, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# arp {arpa | probe | snap}`	Specifies one of three ARP encapsulation methods for a specified interface.

Enabling Proxy ARP

The Cisco IOS software uses proxy ARP (as defined in RFC 1027) to help hosts with no knowledge of routing determine the media addresses of hosts on other networks or subnets. For example, if the router receives an ARP request for a host that is not on the same interface as the ARP request sender, and if the router has all of its routes to that host through other interfaces, then it generates a proxy ARP reply packet giving its own local data-link address. The host that sent the ARP request then sends its packets to the router, which forwards them to the intended host. Proxy ARP is enabled by default.

To enable proxy ARP if it has been disabled, use the following command in interface configuration mode (as needed) for your network:

Command	Purpose
`Router(config-if)# ip proxy-arp`	Enables proxy ARP on the interface.

Configuring Local-Area Mobility

Local-area mobility provides the ability to relocate IP hosts within a limited area without reassigning host IP addresses and without changes to the host software. Local-area mobility is supported on Ethernet, Token Ring, and FDDI interfaces only.

To create a mobility area with only one router, use the following commands in the interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# interface type number`	Enters interface configuration mode.
Step 2	`Router(config-if)# ip mobile arp [timers keepalive hold-time] [access-group access-list-number | name]`	Enables local-area mobility.

To create larger mobility areas, you must first redistribute the mobile routes into your Interior Gateway Protocol (IGP). The IGP must support host routes. You can use Enhanced Interior Gateway Routing Protocol (IGRP), Open Shortest Path First (OSPF), IS-IS, or RIPv2. To redistribute the mobile routes into your existing IGP configuration, use the following commands in configuration mode:

	Command	Purpose
Step 1	`Router(config)# router {eigrp autonomous-system | isis [tag] | ospf process-id | rip}`	Enters router configuration mode.

Step 2	`Router(config)# default-metric number`
	
	or
	
	`Router(config)# default-metric bandwidth delay reliability loading mtu`
		Sets default metric values.

Step 3	`Router(config)# redistribute mobile`	Redistributes the mobile routes.

Mobile routes will always be preferred over a subnet boundary or summarized route because they are more specific. It is important to ensure that configured or redistributed static routes do not include any host routes for the potentially mobile hosts; otherwise, a longest match could come up with two routes and cause ambiguity. Mobile routes will be seen as external routes to the configured routing protocol, even within a summarization area; therefore, they will not be properly summarized by default. This is the case even when these routes are advertised at a summarization boundary, if mobile hosts are not on their home subnet.

Mapping Host Names to IP Addresses

Each unique IP address can have an associated host name. The Cisco IOS software maintains a cache of host name-to-address mappings for use by the **connect**, **telnet**, and **ping** EXEC commands, and related Telnet support operations. This cache speeds the process of converting names to addresses.

IP defines a naming scheme that allows a device to be identified by its location in the IP. This is a hierarchical naming scheme that provides for *domains*. Domain names are pieced together with periods (.) as the delimiting characters. For example, Cisco is a commercial organization that the IP identifies by a *com* domain name, so its domain name is *cisco.com*. A specific device in this domain, the File Transfer Protocol (FTP) system, for example, is identified as *ftp.cisco.com*.

To keep track of domain names, IP has defined the concept of a *name server*, whose job is to hold a cache (or database) of names mapped to IP addresses. To map domain names to IP addresses, you must first identify the host names, then specify a name server, and enable the Domain Naming System (DNS), the global naming scheme of the Internet that uniquely identifies network devices. These tasks are described in the following sections:

- Assigning Host Names to IP Addresses
- Specifying the Domain Name
- Specifying a Name Server
- Enabling the DNS
- Using the DNS to Discover ISO CLNS Addresses

Assigning Host Names to IP Addresses

The Cisco IOS software maintains a table of host names and their corresponding addresses, also called a *host name-to-address mapping*. Higher-layer protocols such as Telnet use host names to identify network devices (hosts). The router and other network devices must be able to associate host names with IP addresses to communicate with other IP devices. Host names and IP addresses can be associated with one another through static or dynamic means.

Manually assigning host names to addresses is useful when dynamic mapping is not available.

To assign host names to addresses, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip host` *name* [*tcp-port-number*] *address1* [*address2...address8*]	Statically associates host names with IP addresses.

Specifying the Domain Name

You can specify a default domain name that the Cisco IOS software will use to complete domain name requests. You can specify either a single domain name or a list of domain names. Any IP host name that does not contain a domain name will have the domain name you specify appended to it before being added to the host table.

To specify a domain name or names, use either of the following commands in global configuration mode:

Command	Purpose
`Router(config)# ip domain name` *name*	Defines a default domain name that the Cisco IOS software will use to complete unqualified host names.
`Router(config)# ip domain list` *name*	Defines a list of default domain names to complete unqualified host names.

See the "IP Domains Example" section at the end of this chapter for an example of establishing IP domains.

Specifying a Name Server

To specify one or more hosts (up to six) that can function as a name server to supply name information for the DNS, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip name-server server-address1 [server-address2...server-address6]`	Specifies one or more hosts that supply name information.

Enabling the DNS

If your network devices require connectivity with devices in networks for which you do not control name assignment, you can assign device names that uniquely identify your devices within the entire internetwork. The global naming scheme of the Internet, the DNS, accomplishes this task. This service is enabled by default.

To re-enable DNS if it has been disabled, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip domain lookup`	Enables DNS-based host name-to-address translation.

See the "Dynamic Lookup Example" section at the end of this chapter for an example of enabling the DNS.

Using the DNS to Discover ISO CLNS Addresses

If your router has both IP and ISO Connectionless Network Service (ISO CLNS) enabled and you want to use ISO CLNS network service access point (NSAP) addresses, you can use the DNS to query these addresses, as documented in RFC 1348. This feature is enabled by default.

To disable DNS queries for ISO CLNS addresses, use the following command in global configuration mode:

Command	Purpose
`Router(config)# no ip domain-lookup nsap`	Disables DNS queries for ISO CLNS addresses.

Configuring HP Probe Proxy Name Requests

HP Probe Proxy support allows the Cisco IOS software to respond to HP Probe Proxy name requests. These requests are typically used at sites that have HP equipment and are already using HP Probe Proxy. Tasks associated with HP Probe Proxy are shown in the following two tables.

To configure HP Probe Proxy, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip probe proxy`	Allows the Cisco IOS software to respond to HP Probe Proxy name requests.

To configure HP Probe Proxy, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip hp-host hostname ip-address`	Enters the host name of an HP host (for which the router is acting as a proxy) into the host table.

See the "HP Hosts on a Network Segment Example" section at the end of this chapter for an example of configuring HP hosts on a network segment.

Configuring the Next Hop Resolution Protocol

Routers, access servers, and hosts can use Next Hop Resolution Protocol (NHRP) to discover the addresses of other routers and hosts connected to a nonbroadcast multiaccess (NBMA) network. Partially meshed NBMA networks are typically configured with multiple logical networks to provide full network layer connectivity. In such configurations, packets might make several hops over the NBMA network before arriving at the exit router (the router nearest the destination network). In addition, such NBMA networks (whether partially or fully meshed) typically require tedious static configurations. These static configurations provide the mapping between network layer addresses (such as IP) and NBMA addresses (such as E.164 addresses for SMDS).

NHRP provides an ARP-like solution that alleviates these NBMA network problems. With NHRP, systems attached to an NBMA network dynamically learn the NBMA address of the other systems that are part of that network, allowing these systems to directly communicate without requiring traffic to use an intermediate hop.

The NBMA network is considered nonbroadcast either because it technically does not support broadcasting (for example, an X.25 network) or because broadcasting is too expensive (for example, an SMDS broadcast group that would otherwise be too large).

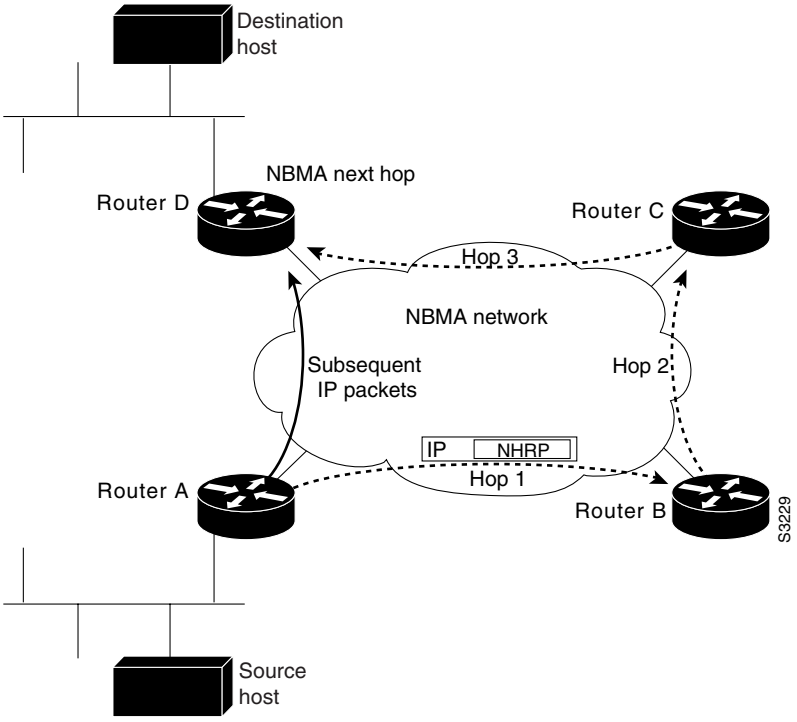
The Cisco Implementation of NHRP

The Cisco implementation of NHRP supports the IETF draft version 11 of *NBMA Next Hop Resolution Protocol (NHRP)*.

The Cisco implementation of NHRP supports IP Version 4, Internet Packet Exchange (IPX) network layers, and, at the link layer, ATM, Ethernet, SMDS, and multipoint tunnel networks. Although NHRP is available on Ethernet, NHRP need not be implemented over Ethernet media because Ethernet is capable of broadcasting. Ethernet support is unnecessary (and not provided) for IPX.

Figure 3 illustrates four routers connected to an NBMA network. Within the network are ATM or SMDS switches necessary for the routers to communicate with each other. Assume that the switches have virtual circuit (VC) connections represented by hops 1, 2, and 3 of the figure. When Router A attempts to forward an IP packet from the source host to the destination host, NHRP is triggered. On behalf of the source host, Router A sends an NHRP request packet encapsulated in an IP packet, which takes three hops across the network to reach Router D, connected to the destination host. After receiving a positive NHRP reply, Router D is determined to be the "NBMA next hop," and Router A sends subsequent IP packets for the destination to Router D in one hop.

Figure 3 Next Hop Resolution Protocol



With NHRP, once the NBMA next hop is determined, the source either starts sending data packets to the destination (in a connectionless NBMA network such as SMDS) or establishes a virtual circuit VC connection to the destination with the desired bandwidth and quality of service (QoS) characteristics (in a connection-oriented NBMA network such as ATM).

Other address resolution methods can be used while NHRP is deployed. IP hosts that rely upon the Logical IP Subnet (LIS) model might require ARP servers and services over NBMA networks, and deployed hosts might not implement NHRP, but might continue to support ARP variations. NHRP is designed to eliminate the suboptimal routing that results from the LIS model, and can be deployed with existing ARP services without interfering with them.

NHRP is used to facilitate building a Virtual Private Network (VPN). In this context, a VPN consists of a virtual Layer 3 network that is built on top of an actual Layer 3 network. The topology you use over the VPN is largely independent of the underlying network, and the protocols you run over it are completely independent of it.

Connected to the NBMA network are one or more stations that implement NHRP, and are known as *Next Hop Servers*. All routers running Cisco IOS Release 10.3 or later releases can implement NHRP and, thus, can act as Next Hop Servers.

Each Next Hop Server serves a set of destination hosts, which might be directly connected to the NBMA network. Next Hop Servers cooperatively resolve the NBMA next hop addresses within their NBMA network. Next Hop Servers typically also participate in protocols used to disseminate routing information across (and beyond the boundaries of) the NBMA network, and might support ARP service.

A Next Hop Server maintains a "next hop resolution" cache, which is a table of network layer address to NBMA address mappings. The table is created from information gleaned from NHRP register packets extracted from NHRP request or reply packets that traverse the Next Hop Server as they are forwarded, or through other means such as ARP and preconfigured tables.

Protocol Operation

NHRP requests traverse one or more hops within an NBMA subnetwork before reaching the station that is expected to generate a response. Each station (including the source station) chooses a neighboring Next Hop Server to forward the request to. The Next Hop Server selection procedure typically involves performing a routing decision based upon the network layer destination address of the NHRP request. Ignoring error situations, the NHRP request eventually arrives at a station that generates an NHRP reply. This responding station either serves the destination, is the destination itself, or is a client that specified it should receive NHRP requests when it registered with its server. The responding station generates a reply using the source address from within the NHRP packet to determine where the reply should be sent.

NHRP Configuration Task List

To configure NHRP, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Enabling NHRP on an Interface (Required)
- Configuring a Static IP-to-NBMA Address Mapping for a Station (Optional)
- Statically Configuring a Next Hop Server (Optional)
- Configuring NHRP Authentication (Optional)
- Controlling the Triggering of NHRP (Optional)
- Triggering NHRP Based on Traffic Thresholds (Optional)
- Controlling the NHRP Packet Rate (Optional)
- Suppressing Forward and Reverse Record Options (Optional)
- Specifying the NHRP Responder Address (Optional)
- Changing the Time Period NBMA Addresses Are Advertised as Valid (Optional)
- Configuring a GRE Tunnel for Multipoint Operation (Optional)
- Configuring NHRP Server-Only Mode (Optional)

Enabling NHRP on an Interface

To enable NHRP for an interface on a router, use the following command in interface configuration mode. In general, all NHRP stations within a logical NBMA network must be configured with the same network identifier.

Command	Purpose
`Router(config-if)# ip nhrp network-id number`	Enables NHRP on an interface.

See the "Logical NBMA Example" section and the "NHRP over ATM Example" section at the end of this chapter for examples of enabling NHRP.

Configuring a Static IP-to-NBMA Address Mapping for a Station

To participate in NHRP, a station connected to an NBMA network should be configured with the IP and NBMA addresses of its Next Hop Servers. The format of the NBMA address depends on the medium you are using. For example, ATM uses an NSAP address, Ethernet uses a MAC address, and SMDS uses an E.164 address.

These Next Hop Servers may also be the default or peer routers of the station, so their addresses can be obtained from the network layer forwarding table of the station.

If the station is attached to several link layer networks (including logical NBMA networks), the station should also be configured to receive routing information from its Next Hop Servers and peer routers so that it can determine which IP networks are reachable through which link layer networks.

To configure static IP-to-NBMA address mapping on a station (host or router), use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp map ip-address nbma-address`	Configures static IP-to-NBMA address mapping.

Statically Configuring a Next Hop Server

A Next Hop Server normally uses the network layer forwarding table to determine where to forward NHRP packets, and to find the egress point from an NBMA network. A Next Hop Server may alternately be statically configured with a set of IP address prefixes that correspond to the IP addresses of the stations it serves, and their logical NBMA network identifiers.

To statically configure a Next Hop Server, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp nhs nhs-address [net-address [netmask]]`	Statically configures a Next Hop Server.

To configure multiple networks that the Next Hop Server serves, repeat the **ip nhrp nhs** command with the same Next Hop Server address, but different IP network addresses. To configure additional Next Hop Servers, repeat the **ip nhrp nhs** command.

Configuring NHRP Authentication

Configuring an authentication string ensures that only routers configured with the same string can communicate using NHRP. Therefore, if the authentication scheme is to be used, the same string must be configured in all devices configured for NHRP on a fabric. To specify the authentication string for NHRP on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp authentication string`	Specifies an authentication string.

Controlling the Triggering of NHRP

On any platform, there are two ways to control when NHRP is triggered. These methods are described in the following sections:

- Triggering NHRP by IP Packets
- Triggering NHRP on a per-Destination Basis

Triggering NHRP by IP Packets

You can specify an IP access list that is used to decide which IP packets can trigger the sending of NHRP requests. By default, all non-NHRP packets trigger NHRP requests. To limit which IP packets trigger NHRP requests, define an access list and then apply it to the interface.

To define an access list, use the following commands in global configuration mode as needed:

Command	Purpose
`Router(config)# access-list access-list-number {deny | permit} source [source-wildcard]`	Defines a standard IP access list.
`Router(config)# access-list access-list-number {deny | permit} protocol source source-wildcard destination destination-wildcard [precedence precedence] [tos tos] [established] [log]`	Defines an extended IP access list.

To apply the IP access list to the interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp interest access-list-number`	Specifies an IP access list that controls NHRP requests.

Triggering NHRP on a per-Destination Basis

By default, when the software attempts to send a data packet to a destination for which it has determined that NHRP can be used, it sends an NHRP request for that destination. To configure the system to wait until a specified number of data packets have been sent to a particular destination before NHRP is attempted, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp use` *usage-count*	Specifies how many data packets are sent to a destination before NHRP is attempted.

Triggering NHRP Based on Traffic Thresholds

NHRP can run on Cisco Express Forwarding (CEF) platforms when NHRP runs with BGP over ATM media. You can configure NHRP to initiate switched virtual circuits (SVCs) once a configured traffic rate is reached. Similarly, SVCs can be torn down when traffic falls to another configured rate.

Prior to Cisco IOS Release 12.0, a single packet could trigger an SVC. Now you can configure the traffic rate that must be reached before NHRP sets up or tears down an SVC. Because SVCs are created only for burst traffic, you can conserve resources.

Restrictions

Cisco IOS releases prior to Release 12.0 implemented NHRP draft version 4. Cisco IOS Release 12.0 and later implements NHRP draft version 11. These versions are not compatible. Therefore, all routers running NHRP in a network must run the same version of NHRP in order to communicate with each other. All routers must run Cisco IOS Release 12.0 and later, or all routers must run a release prior to Release 12.0, but not a combination of the two.

Additional restrictions:

- They work on CEF platforms only.
- They work on ATM media only.
- BGP must be configured in the network where these enhancements are running.

Prerequisites

Before you configure the feature whereby NHRP initiation is based on traffic rate, the following conditions must exist in the router:

- ATM must be configured.
- CEF switching or distributed CEF (dCEF) switching must be enabled.
- BGP must be configured on all routers in the network.

If you have CEF switching or dCEF switching and you want NHRP to work (whether with default values or changed values), the **ip cef accounting non-recursive** command must be configured.

NHRP Configuration Task List

To configure the NHRP triggering and teardown of SVCs based on traffic rate, perform the tasks described in the following sections. The tasks in the first section are required, the tasks in the remaining section are optional.

- Changing the Rate for Triggering SVCs (Required)
- Applying the Rates to Specific Destinations (Optional)

Changing the Rate for Triggering SVCs

When NHRP runs with BGP over ATM media, there is an additional way to control the triggering of NHRP packets. This method consists of SVCs being initiated based on the input traffic rate to a given BGP next hop.

When BGP discovers a BGP next hop and enters this BGP route into the routing table, an NHRP request is sent to the BGP next hop. When an NHRP reply is received, a subsequent route is put in the NHRP cache that directly corresponds to the BGP next hop.

A new NHRP request is sent to the same BGP next hop to repopulate the NHRP cache. When an NHRP cache entry is generated, a subsequent ATM map statement to the same BGP next hop is also created.

Aggregate traffic to each BGP next hop is measured and monitored. Once the aggregate traffic has met or exceeded the configured trigger rate, NHRP creates an ATM SVC and sends traffic directly to that destination router. The router tears down the SVC to the specified destination(s) when the aggregate traffic rate falls to or below the configured teardown rate.

By default, NHRP will set up an SVC for a destination when aggregate traffic for that destination is more than 1 kbps over a running average of 30 seconds. Similarly, NHRP will tear down the SVC when the traffic for that destination drops to 0 kbps over a running average of 30 seconds. There are several ways to change the rate at which SVC set or teardown occurs. You can change the number of kbps thresholds, or the load interval, or both.

To change the number of kbps at which NHRP sets up or tears down the SVC to this destination, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp trigger-svc` *trigger-threshold teardown-threshold*	Changes the point at which NHRP sets up or tears down SVCs.

You can change the sampling time period; that is, you can change the length of time over which the average trigger rate or teardown rate is calculated. By default, the period is 30 seconds; the range is from 30 to 300 seconds in 30-second increments. This period is for calculations of aggregate traffic rate internal to Cisco IOS software only, and it represents a worst case time period for taking action. In some cases, the software will act sooner, depending on the ramp-up and fall-off rate of the traffic.

To change the sampling time period during which threshold rates are averaged, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip cef traffic-statistics [load-interval` *seconds*`]`	Changes the length of time in a sampling period during which trigger and teardown thresholds are averaged.

If your Cisco hardware has a Virtual Interface Processor, version 2 adapter, you must perform the following task to change the sampling time. By default, the port adapter sends the traffic statistics to the Route Processor every 10 seconds. If you are using NHRP in dCEF switching mode, you must change this update rate to 5 seconds. To do so, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip cef traffic-statistics [update-rate seconds]`	Changes the rate at which the port adapter sends traffic statistics to the RP.

Applying the Rates to Specific Destinations

By default, all destinations are measured and monitored for NHRP triggering. However, you can choose to impose the triggering and teardown rates on certain destinations. To do so, use the following commands beginning in global configuration mode:

	Command	Purpose

Step 1	`Router(config)# access-list access-list-number {deny | permit} source [source-wildcard]`
	or
	`access-list access-list-number {deny | permit} protocol source source-wildcard destination destination-wildcard [precedence precedence] [tos tos] [log]`
		Defines a standard or extended IP access list.

Step 2	`Router(config)# interface type number`	Enters interface configuration mode.
Step 3	`Router(interface config)# ip nhrp interest access-list`	Assigns the access list created in Step 1 that determines which destinations are included in or excluded from the SVC triggering.

For an example of setting the load interval, see the section "Changing the Rate for Triggering SVCs Example" at the end of this chapter. For an example of applying rates to destinations, see the section "Applying NHRP Rates to Specific Destinations Example" at the end of this chapter.

Controlling the NHRP Packet Rate

By default, the maximum rate at which the software sends NHRP packets is 5 packets per 10 seconds. The software maintains a per- interface quota of NHRP packets (whether generated locally or forwarded) that can be sent. To change this maximum rate, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp max-send pkt-count every interval`	Changes the NHRP packet rate per interface.

Suppressing Forward and Reverse Record Options

To dynamically detect link layer filtering in NBMA networks (for example, SMDS address screens), and to provide loop detection and diagnostic capabilities, NHRP incorporates a Route Record in request and reply packets. The Route Record options contain the network (and link layer) addresses of all intermediate Next Hop Servers between source and destination (in the forward direction) and between destination and source (in the reverse direction).

By default, Forward Record options and Reverse Record options are included in NHRP request and reply packets. To suppress the use of these options, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# no ip nhrp record`	Suppresses Forward and Reverse Record options.

Specifying the NHRP Responder Address

If an NHRP requester wants to know which Next Hop Server generates an NHRP reply packet, it can request that information by including the responder address option in its NHRP request packet. The Next Hop Server that generates the NHRP reply packet then complies by inserting its own IP address in the NHRP reply. The Next Hop Server uses the primary IP address of the specified interface.

To specify which interface the Next Hop Server uses for the NHRP responder IP address, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp responder` *type number*	Specifies which interface the Next Hop Server uses to determine the NHRP responder address.

If an NHRP reply packet being forwarded by a Next Hop Server contains the IP address of that server, the Next Hop Server generates an error indication of type “NHRP Loop Detected” and discards the reply.

Changing the Time Period NBMA Addresses Are Advertised as Valid

You can change the length of time that NBMA addresses are advertised as valid in positive NHRP responses. In this context, *advertised* means how long the Cisco IOS software tells other routers to keep the addresses it is providing in NHRP responses. The default length of time is 7200 seconds (2 hours). To change the length of time, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp holdtime` *seconds*	Specifies the number of seconds that NBMA addresses are advertised as valid in positive NHRP responses.

Configuring a GRE Tunnel for Multipoint Operation

You can enable a generic routing encapsulation (GRE) tunnel to operate in multipoint fashion. A tunnel network of multipoint tunnel interfaces can be thought of as an NBMA network. To configure the tunnel, use the following commands in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# tunnel mode gre ip multipoint`	Enables a GRE tunnel to be used in multipoint fashion.
Step 2	`Router(config-if)# tunnel key` *key-number*	Configures a tunnel identification key.

The tunnel key should correspond to the NHRP network identifier specified in the **ip nhrp network-id** interface configuration command. See the "NHRP on a Multipoint Tunnel Example" section at the end of this chapter for an example of NHRP configured on a multipoint tunnel.

Configuring NHRP Server-Only Mode

You can configure an interface so that it cannot initiate NHRP requests or set up NHRP shortcut SVCs but can only respond to NHRP requests. Configure NHRP server-only mode on routers you do not want placing NHRP requests.

If an interface is placed in NHRP server-only mode, you have the option to specify the **non-caching** keyword. In this case, NHRP does not store information in the NHRP cache, such as NHRP responses that could be used again. To save memory, the non caching option is generally used on a router located between two other routers.

To configure NHRP server-only mode, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip nhrp server-only [non-caching]`	Configures NHRP server-only mode.

Enabling IP Routing

IP routing is automatically enabled in the Cisco IOS software. If you choose to set up the router to bridge rather than route IP datagrams, you must disable IP routing. To re-enable IP routing if it has been disabled, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip routing`	Enables IP routing.

When IP routing is disabled, the router will act as an IP end host for IP packets destined for or sourced by it, whether or not bridging is enabled for those IP packets not destined for the device. To re-enable IP routing, use the **ip routing** command.

Routing Assistance When IP Routing Is Disabled

The Cisco IOS software provides three methods by which the router can learn about routes to other networks when IP routing is disabled and the device is acting as an IP host. These methods are described in the sections that follow:

- Proxy ARP
- Default Gateway (also known as *default router*)
- ICMP Router Discovery Protocol

When IP routing is disabled, the default gateway feature and the router discovery client are enabled, and proxy ARP is disabled. When IP routing is enabled, the default gateway feature is disabled and you can configure proxy ARP and the router discovery servers.

Proxy ARP

The most common method of learning about other routes is by using proxy ARP. Proxy ARP, defined in RFC 1027, enables an Ethernet host with no knowledge of routing to communicate with hosts on other networks or subnets. Such a host assumes that all hosts are on the same local Ethernet, and that it can use ARP to determine their hardware addresses.

Under proxy ARP, if a device receives an ARP request for a host that is not on the same network as the ARP request sender, the Cisco IOS software evaluates whether it has the best route to that host. If it does, the device sends an ARP reply packet giving its own Ethernet hardware address. The host that sent the ARP request then sends its packets to the device, which forwards them to the intended host. The software treats all networks as if they are local and performs ARP requests for every IP address. This feature is enabled by default. If it has been disabled, see the section "Enabling Proxy ARP" earlier in this chapter.

Proxy ARP works as long as other routers support it. Many other routers, especially those loaded with host-based routing software, do not support it.

Default Gateway

Another method for locating routes is to define a default router (or gateway). The Cisco IOS software sends all nonlocal packets to this router, which either routes them appropriately or sends an IP Control Message Protocol (ICMP) redirect message back, telling the router of a better route. The ICMP redirect message indicates which local router the host should use. The software caches the redirect messages and routes each packet thereafter as efficiently as possible. The limitations of this method are that there is no means of detecting when the default router has gone down or is unavailable, and there is no method of picking another device if one of these events should occur.

To set up a default gateway for a host, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip default-gateway ip-address`	Sets up a default gateway (router).

To display the address of the default gateway, use the **show ip redirects** EXEC command.

ICMP Router Discovery Protocol

The Cisco IOS software provides a third method, called *router discovery*, by which the router dynamically learns about routes to other networks using the ICMP Router Discovery Protocol IRDP). IRDP allows hosts to locate routers. When the device operates as a client, router discovery packets are generated. When the device operates as a host, router discovery packets are received. The Cisco IRDP implementation fully conforms to the router discovery protocol outlined in RFC 1256.

The software is also capable of wire-tapping Routing Information Protocol (RIP) and Interior Gateway Routing Protocol (IGRP) routing updates and inferring the location of routers from those updates. The client/server implementation of router discovery does not actually examine or store the full routing tables sent by routing devices, it merely keeps track of which systems are sending such data.

You can configure the four protocols in any combination. We recommend that you use IRDP when possible because it allows each router to specify *both* a priority and the time after which a device should be assumed down if no further packets are received. Devices discovered using IGRP are assigned an arbitrary priority of 60. Devices discovered through RIP are assigned a priority of 50. For IGRP and RIP, the software attempts to measure the time between updates, and assumes that the device is down if no updates are received for 2.5 times that interval.

Each device discovered becomes a candidate for the default router. The list of candidates is scanned and a new highest-priority router is selected when any of the following events occurs:

- When a higher-priority router is discovered (the list of routers is polled at 5-minute intervals).
- When the current default router is declared down.
- When a TCP connection is about to time out because of excessive retransmissions. In this case, the server flushes the ARP cache and the ICMP redirect cache, and picks a new default router in an attempt to find a successful route to the destination.

Enabling IRDP Processing

Only one task for configuring IRDP routing on a specified interface is required. To enable IRDP processing on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip irdp`	Enables IRDP processing on an interface.

Changing IRDP Parameters

When you enable IRDP processing, the default parameters will apply. To optionally change any of these IRDP parameters, use the following commands in interface configuration mode, as needed:

Command	Purpose
`Router(config-if)# ip irdp multicast`	Sends IRDP advertisements to the all-systems multicast address (224.0.0.1) on a specified interface.
`Router(config-if)# ip irdp holdtime` *seconds*	Sets the IRDP period for which advertisements are valid.
`Router(config-if)# ip irdp maxadvertinterval` *seconds*	Sets the IRDP maximum interval between advertisements.
`Router(config-if)# ip irdp minadvertinterval` *seconds*	Sets the IRDP minimum interval between advertisements.

Command	Purpose
`Router(config-if)# ip irdp preference number`	Sets the IRDP preference level of the device.
`Router(config-if)# ip irdp address address [number]`	Specifies an IRDP address and preference to proxy-advertise.

The Cisco IOS software can proxy-advertise other machines that use IRDP; however, this practice is not recommended because it is possible to advertise nonexistent machines or machines that are down.

Enabling IP Bridging

To transparently bridge IP on an interface, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# no ip routing`	Disables IP routing.
Step 2	`Router(config)# interface type number`	Specifies an interface and enters interface configuration mode.
Step 3	`Router(config-if)# bridge-group group`	Adds the interface to a bridge group.

Enabling Integrated Routing and Bridging

With integrated routing and bridging (IRB), you can route IP traffic between routed interfaces and bridge groups, or route IP traffic between bridge groups. Specifically, local or unroutable traffic is bridged among the bridged interfaces in the same bridge group, while routable traffic is routed to other routed interfaces or bridge groups. IRB can be used to switch packets in the following ways:

- From a bridged interface to a routed interface
- From a routed interface to a bridged interface
- Within the same bridge group

For more information about configuring integrated routing and bridging, refer to the "Configuring Transparent Bridging" chapter in the *Cisco IOS Bridging and IBM Networking Configuration Guide*.

Configuring a Routing Process

At this point in the configuration process, you can choose to configure one or more of the many routing protocols that are available, based on your individual network needs. Routing protocols provide topology information of an internetwork. Refer to subsequent chapters in this document for the tasks involved in configuring IP routing protocols such as BGP, On-Demand Routing (ODR), RIP, IGRP, OSPF, IP Enhanced IGRP, Integrated IS-IS, and IP multicast routing. If you want to continue to perform IP addressing tasks, continue reading the following sections.

Configuring Broadcast Packet Handling

A *broadcast* is a data packet destined for all hosts on a particular physical network. Network hosts recognize broadcasts by special addresses. Broadcasts are heavily used by some protocols, including several important Internet protocols. Control of broadcast messages is an essential responsibility of the IP network administrator.

The Cisco IOS software supports two kinds of broadcasting: *directed broadcasting* and *flooding*. A directed broadcast is a packet sent to a specific network or series of networks, while a flooded broadcast packet is sent to every network. A directed broadcast address includes the network or subnet fields.

Several early IP implementations do not use the current broadcast address standard. Instead, they use the old standard, which calls for all 0s instead of all 1s to indicate broadcast addresses. Many of these implementations do not recognize an all-1s broadcast address and fail to respond to the broadcast correctly. Others forward all-1s broadcasts, which causes a serious network overload known as a *broadcast storm*. Implementations that exhibit these problems include systems based on versions of Berkeley Standard Distribution (BSD) UNIX prior to Version 4.3.

Routers provide some protection from broadcast storms by limiting their extent to the local cable. Bridges (including intelligent bridges), because they are Layer 2 devices, forward broadcasts to all network segments, thus propagating all broadcast storms.

The best solution to the broadcast storm problem is to use a single broadcast address scheme on a network. Most modern IP implementations allow the network manager to set the address to be used as the broadcast address. Many implementations, including the one in the Cisco IOS software, accept and interpret all possible forms of broadcast addresses.

For detailed discussions of broadcast issues in general, see RFC 919, *Broadcasting Internet Datagrams*, and RFC 922, *Broadcasting IP Datagrams in the Presence of Subnets*. The support for Internet broadcasts generally complies with RFC 919 and RFC 922; it does not support multisubnet broadcasts as defined in RFC 922.

The current broadcast address standard provides specific addressing schemes for forwarding broadcasts. To enable these schemes, perform the tasks described in the following sections. The task in the first section is required; the tasks in the remaining sections are optional.

- Enabling Directed Broadcast-to-Physical Broadcast Translation (Required)
- Forwarding UDP Broadcast Packets and Protocols (Optional)
- Establishing an IP Broadcast Address (Optional)
- Flooding IP Broadcasts (Optional)

See the "Broadcasting Examples" section at the end of this chapter for broadcasting configuration examples.

Enabling Directed Broadcast-to-Physical Broadcast Translation

By default, IP directed broadcasts are dropped; they are not forwarded. Dropping IP directed broadcasts makes routers less susceptible to denial-of-service attacks.

You can enable forwarding of IP directed broadcasts on an interface where the broadcast becomes a physical broadcast. If such forwarding is enabled, only those protocols configured using the **ip forward-protocol** global configuration command are forwarded.

You can specify an access list to control which broadcasts are forwarded. When an access list is specified, only those IP packets permitted by the access list are eligible to be translated from directed broadcasts to physical broadcasts.

To enable forwarding of IP directed broadcasts, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip directed-broadcast [access-list-number]`	Enables directed broadcast-to-physical broadcast translation on an interface.

Forwarding UDP Broadcast Packets and Protocols

Network hosts occasionally use User Datagram Protocol (UDP) broadcasts to determine address, configuration, and name information. If such a host is on a network segment that does not include a server, UDP broadcasts normally are not forwarded. You can remedy this situation by configuring the interface of your router to forward certain classes of broadcasts to a helper address. You can use more than one helper address per interface.

You can specify a UDP destination port to control which UDP services are forwarded. You can specify multiple UDP protocols. You can also specify the Network Disk (ND) protocol, which is used by older diskless Sun workstations, and you can specify the network security protocol, Software Defined Network Service (SDNS). By default, both UDP and ND forwarding are enabled if a helper address has been defined for an interface. The description for the **ip forward-protocol** global configuration command in the *Cisco IOS IPCommand Reference, Volume 1 of 3: Addressing and Services* publication lists the ports that are forwarded by default if you do not specify any UDP ports.

If you do not specify any UDP ports when you configure the forwarding of UDP broadcasts, you are configuring the router to act as a BOOTP forwarding agent. BOOTP packets carry Dynamic Host Configuration Protocol (DHCP) information, which means that the Cisco IOS software is compatible with DHCP clients. (DHCP is defined in RFC 1531.)

To enable forwarding and to specify the destination address, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip helper-address address`	Enables forwarding and specifies the destination address for forwarding UDP broadcast packets, such as BOOTP and DHCP.

To specify which protocols will be forwarded, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip forward-protocol {udp [port] | nd | sdns}`	Specifies which protocols will be forwarded over which ports.

See the "Helper Addresses Example" section at the end of this chapter for an example of how to configure helper addresses.

Establishing an IP Broadcast Address

The Cisco IOS software supports IP broadcasts on both LANs and WANs. There are several ways to indicate an IP broadcast address. Currently, the most popular way, and the default, is an address consisting of all 1s (255.255.255.255), although the software can be configured to generate any form of IP broadcast address. Cisco software can receive and understand any form of IP broadcast.

To set the IP broadcast address, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip broadcast-address [ip-address]`	Establishes a different broadcast address (other than 255.255.255.255).

If the router does not have nonvolatile memory, and you need to specify the broadcast address to use before the software is configured, you must change the IP broadcast address by setting jumpers in the processor configuration register. Setting bit 10 causes the device to use all 0s. Bit 10 interacts with bit 14, which controls the network and subnet portions of the broadcast address. Setting bit 14 causes the device to include the network and subnet portions of its address in the broadcast address. Table 4 shows the combined effect of setting bits 10 and 14.

Table 4 Configuration Register Settings for Broadcast Address Destination

Bit 14	Bit 10	Address (<net><host>)
Out	Out	<ones><ones>
Out	In	<zeros><zeros>
In	In	<net><zeros>
In	Out	<net><ones>

Some router platforms allow the configuration register to be set through the software; see the "Rebooting" chapter of the *Cisco IOS Configuration Fundamentals Configuration Guide* for details. For other router platforms, the configuration register must be changed through hardware; see the appropriate hardware installation and maintenance manual for your system.

Flooding IP Broadcasts

You can allow IP broadcasts to be flooded throughout your internetwork in a controlled fashion using the database created by the bridging spanning-tree protocol. Turning on this feature also prevents loops. In order to support this capability, the routing software must include the transparent bridging, and bridging must be configured on each interface that is to participate in the flooding. If bridging is not configured on an interface, it still will be able to receive broadcasts. However, the interface will never forward broadcasts it receives, and the router will never use that interface to send broadcasts received on a different interface.

Packets that are forwarded to a single network address using the IP helper address mechanism can be flooded. Only one copy of the packet is sent on each network segment.

In order to be considered for flooding, packets must meet the following criteria. (Note that these are the same conditions used to consider packet forwarding using IP helper addresses.)

- The packet must be a MAC-level broadcast.
- The packet must be an IP-level broadcast.
- The packet must be a Trivial File Transfer Protocol (TFTP), DNS, Time, NetBIOS, ND, or BOOTP packet, or a UDP protocol specified by the **ip forward-protocol udp** global configuration command.
- The time-to-live (TTL) value of the packet must be at least two.

A flooded UDP datagram is given the destination address you specified with the **ip broadcast-address** command in the interface configuration mode on the output interface. The destination address can be set to any desired address. Thus, the destination address may change as the datagram propagates through the network. The source address is never changed. The TTL value is decremented.

After a decision has been made to send the datagram out on an interface (and the destination address possibly changed), the datagram is handed to the normal IP output routines and is, therefore, subject to access lists, if they are present on the output interface.

To use the bridging spanning-tree database to flood UDP datagrams, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip forward-protocol spanning-tree`	Uses the bridging spanning-tree database to flood UDP datagrams.

If no actual bridging is desired, you can configure a type-code bridging filter that will deny all packet types from being bridged. Refer to the "Configuring Transparent Bridging" chapter of the *Cisco IOS Bridging and IBM Networking Configuration Guide* for more information about using access lists to filter bridged traffic. The spanning-tree database is still available to the IP forwarding code to use for the flooding.

Speeding Up Flooding of UDP Datagrams

You can speed up flooding of UDP datagrams using the spanning-tree algorithm. Used in conjunction with the **ip forward-protocol spanning-tree** command in global configuration mode, this feature boosts the performance of spanning tree-based UDP flooding by a factor of about four to five times. The feature, called *turbo flooding*, is supported over Ethernet interfaces configured for Advanced Research Projects Agency (ARPA) encapsulated, FDDI, and HDLC-encapsulated serial interfaces. However, it is not supported on Token Ring interfaces. As long as the Token Rings and the non-HDLC serial interfaces are not part of the bridge group being used for UDP flooding, turbo flooding will behave normally.

To enable turbo flooding, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip forward-protocol turbo-flood`	Uses the bridging spanning-tree database to speed up flooding of UDP datagrams.

Configuring Network Address Translation

Two key problems facing the Internet are depletion of IP address space and scaling in routing. Network Address Translation (NAT) is a feature that allows the IP network of an organization to appear from the outside to use different IP address space than what it is actually using. Thus, NAT allows an organization with nonglobally routable addresses to connect to the Internet by translating those addresses into globally routable address space. NAT also allows a more graceful renumbering strategy for organizations that are changing service providers or voluntarily renumbering into classless interdomain routing (CIDR) blocks. NAT is also described in RFC 1631.

Beginning with Cisco IOS Release 12.1(5)T, NAT supports all H.225 and H.245 message types, including FastConnect and Alerting as part of the H.323 version 2 specification. Any product that makes use of these message types will be able to pass through a Cisco IOS NAT configuration without any static configuration. Full support for NetMeeting Directory (Internet Locator Service) is also provided through Cisco IOS NAT.

NAT Applications

NAT has several applications. Use it for the following purposes:

- You want to connect to the Internet, but not all your hosts have globally unique IP addresses. NAT enables private IP internetworks that use nonregistered IP addresses to connect to the Internet. NAT is configured on the router at the border of a stub domain (referred to as the *inside network*) and a public network such as the Internet (referred to as the *outside network*). NAT translates the internal local addresses to globally unique IP addresses before sending packets to the outside network.
- You must change your internal addresses. Instead of changing them, which can be a considerable amount of work, you can translate them by using NAT.
- You want to do basic load sharing of TCP traffic. You can map a single global IP address to many local IP addresses by using the TCP load distribution feature.

As a solution to the connectivity problem, NAT is practical only when relatively few hosts in a stub domain communicate outside of the domain at the same time. When this is the case, only a small subset of the IP addresses in the domain must be translated into globally unique IP addresses when outside communication is necessary, and these addresses can be reused when no longer in use.

Benefits

A significant advantage of NAT is that it can be configured without requiring changes to hosts or routers other than those few routers on which NAT will be configured. As discussed previously, NAT may not be practical if large numbers of hosts in the stub domain communicate outside of the domain. Furthermore, some applications use embedded IP addresses in such a way that it is impractical for a NAT device to translate. These applications may not work transparently or at all through a NAT device. NAT also hides the identity of hosts, which may be an advantage or a disadvantage.

A router configured with NAT will have at least one interface to the inside and one to the outside. In a typical environment, NAT is configured at the exit router between a stub domain and backbone. When a packet is leaving the domain, NAT translates the locally significant source address into a globally unique address. When a packet is entering the domain, NAT translates the globally unique destination address into a local address. If more than one exit point exists, each NAT must have the same translation table. If the software cannot allocate an address because it has run out of addresses, it drops the packet and sends an ICMP host unreachable packet.

A router configured with NAT must not advertise the local networks to the outside. However, routing information that NAT receives from the outside can be advertised in the stub domain as usual.

NAT Terminology

As mentioned previously, the term *inside* refers to those networks that are owned by an organization and that must be translated. Inside this domain, hosts will have addresses in the one address space, while on the outside, they will appear to have addresses in another address space when NAT is configured. The first address space is referred to as the *local* address space and the second is referred to as the *global* address space.

Similarly, *outside* refers to those networks to which the stub network connects, and which are generally not under the control of the organization. Hosts in outside networks can be subject to translation also, and can thus have local and global addresses.

To summarize, NAT uses the following definitions:

- Inside local address—The IP address that is assigned to a host on the inside network. The address is probably not a legitimate IP address assigned by the Network Information Center (NIC) or service provider.
- Inside global address—A legitimate IP address (assigned by the NIC or service provider) that represents one or more inside local IP addresses to the outside world.
- Outside local address—The IP address of an outside host as it appears to the inside network. Not necessarily a legitimate address, it was allocated from address space routable on the inside.
- Outside global address—The IP address assigned to a host on the outside network by the owner of the host. The address was allocated from globally routable address or network space.

NAT Configuration Task List

Before configuring any NAT translation, you must know your inside local addresses and inside global addresses. To configure NAT, perform the optional tasks described in the following sections:

- Translating Inside Source Addresses (Optional)
- Overloading an Inside Global Address Optional)
- Translating Overlapping Addresses (Optional)
- Providing TCP Load Distribution (Optional)
- Changing Translation Timeouts (Optional)
- Monitoring and Maintaining NAT(Optional)
- Deploying NAT Between an IP Phone and Cisco CallManager (Optional)

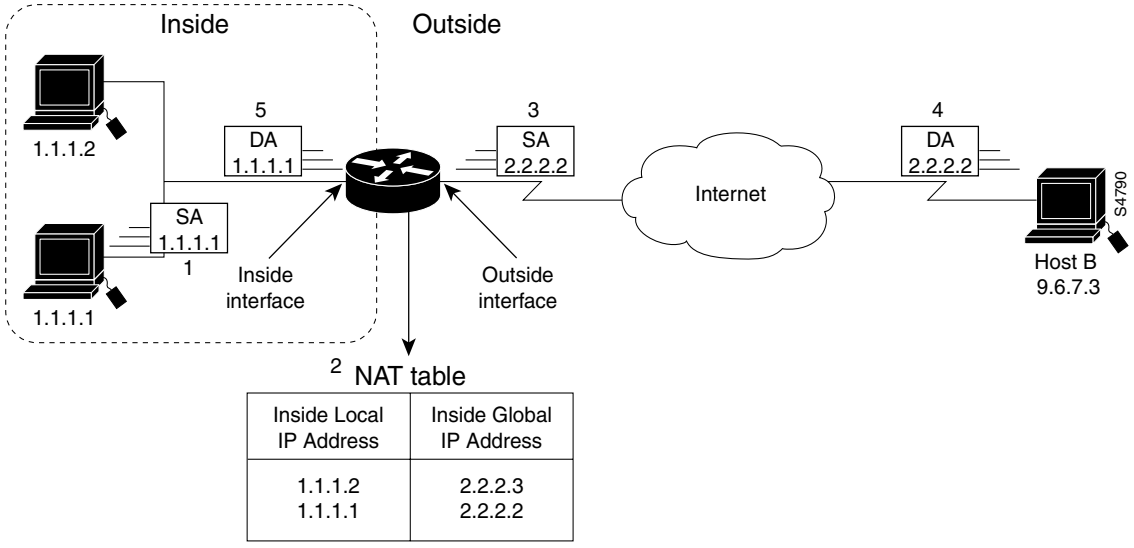
Translating Inside Source Addresses

You can translate your own IP addresses into globally unique IP addresses when communicating outside of your network. You can configure static or dynamic inside source translation as follows:

- *Static translation* establishes a one-to-one mapping between your inside local address and an inside global address. Static translation is useful when a host on the inside must be accessible by a fixed address from the outside.
- *Dynamic translation* establishes a mapping between an inside local address and a pool of global addresses. An access-list or a route-map can be specified for dynamic translations. Route maps allow you to match any combination of access-list, new-hop IP address, and output interface to determine which pool to use.

Figure 4 illustrates a router that is translating a source address inside a network to a source address outside the network.

Figure 4 NAT Inside Source Translation



The following process describes inside source address translation, as shown in Figure 4:

1. The user at host 1.1.1.1 opens a connection to host B.
2. The first packet that the router receives from host 1.1.1.1 causes the router to check its NAT table:
   - If a static translation entry was configured, the router goes to Step 3.
   - If no translation entry exists, the router determines that Source-Address (SA) 1.1.1.1 must be translated dynamically, selects a legal, global address from the dynamic address pool, and creates a translation entry. This type of entry is called a *simple entry.*
3. The router replaces the inside local source address of host 1.1.1.1 with the global address of the translation entry and forwards the packet.
4. Host B receives the packet and responds to host 1.1.1.1 by using the inside global IP Destination-Address (DA) 2.2.2.2.
5. When the router receives the packet with the inside global IP address, it performs a NAT table lookup by using the inside global address as a key. It then translates the address to the inside local address of host 1.1.1.1 and forwards the packet to host 1.1.1.1.

Host 1.1.1.1 receives the packet and continues the conversation. The router performs Steps 2 through 5 for each packet.

Configuring Static Translation

To configure static inside source address translation, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip nat inside source static local-ip global-ip`	Establishes static translation between an inside local address and an inside global address.
Step 2	`Router(config)# interface type number`	Specifies the inside interface and enters interface configuration mode.
Step 3	`Router(config-if)# ip nat inside`	Marks the interface as connected to the inside.
Step 4	`Router(config)# interface type number`	Specifies the outside interface and enters interface configuration mode.
Step 5	`Router(config-if)# ip nat outside`	Marks the interface as connected to the outside.

The previous steps are the minimum you must configure. You could also configure multiple inside and outside interfaces.

Configuring Dynamic Translation with an Access List

To configure dynamic inside source address translation with an access list, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip nat pool name start-ip end-ip {netmask netmask | prefix-length prefix-length}`	Defines a pool of global addresses to be allocated as needed.
Step 2	`Router(config)# access-list access-list-number permit source [source-wildcard]`	Defines a standard access list permitting those addresses that are to be translated.
Step 3	`Router(config)# ip nat inside source list access-list-number pool name`	Establishes dynamic source translation, specifying the access list defined in the prior step.
Step 4	`Router(config)# interface type number`	Specifies the inside interface and enters interface configuration mode.
Step 5	`Router(config-if)# ip nat inside`	Marks the interface as connected to the inside.
Step 6	`Router(config)# interface type number`	Specifies the outside interface and enters interface configuration mode.
Step 7	`Router(config-if)# ip nat outside`	Marks the interface as connected to the outside.

Note The access list must permit only those addresses that are to be translated. (Remember that there is an implicit “deny all” at the end of each access list.) An access list that is too permissive can lead to unpredictable results.

Packets that enter the router through the inside interface and packets sourced from the router are checked against the access list for possible NAT candidates. The access list is used to specify which traffic is to be translated.

Configuring Dynamic Translation with a Route Map

To configure dynamic inside source address translation with a route map, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip nat pool name start-ip end-ip {netmask netmask | prefix-length prefix-length}`	Defines a pool of global addresses to be allocated as needed.
Step 2	`Router(config)# route-map name permit sequence`	Defines a route map permitting those addresses that are to be translated.
Step 3	`Router(config)# ip nat inside source route-map name pool name`	Establishes dynamic source translation, specifying the route map defined in the prior step.
Step 4	`Router(config)# interface type number`	Specifies the inside interface and enters interface configuration mode.
Step 5	`Router(config-if)# ip nat inside`	Marks the interface as connected to the inside.
Step 6	`Router(config)# interface type number`	Specifies the outside interface and enters interface configuration mode.
Step 7	`Router(config-if)# ip nat outside`	Marks the interface as connected to the outside.

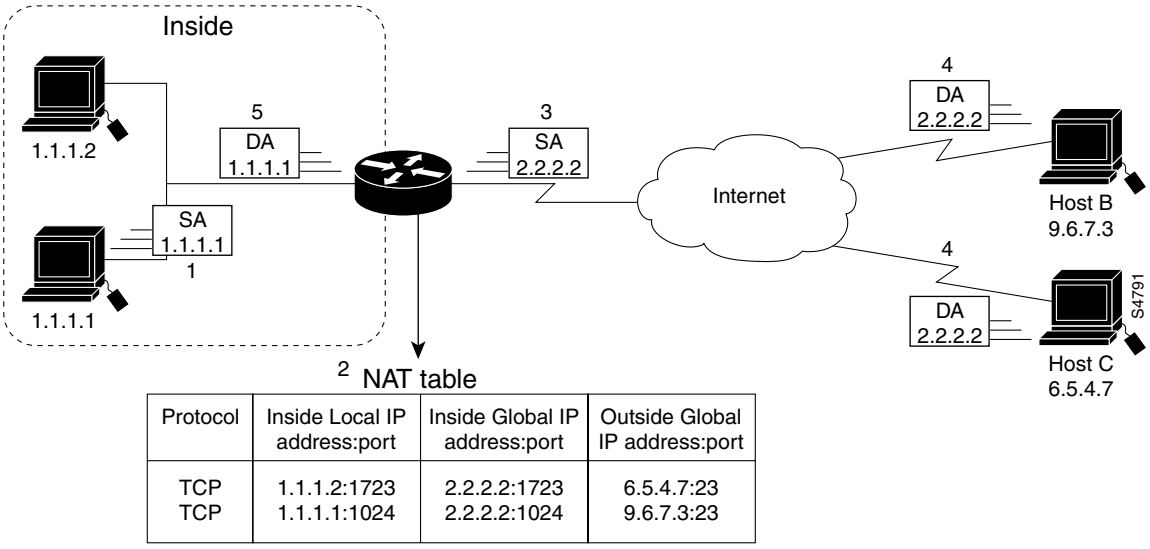
See the "Dynamic Inside Source Translation Example" section at the end of this chapter for examples of dynamic inside source translation.

Overloading an Inside Global Address

You can conserve addresses in the inside global address pool by allowing the router to use one global address for many local addresses. When this overloading is configured, the router maintains enough information from higher-level protocols (for example, TCP or UDP port numbers) to translate the global address back to the correct local address. When multiple local addresses map to one global address, the TCP or UDP port numbers of each inside host distinguish between the local addresses.

Figure 5 illustrates NAT operation when one inside global address represents multiple inside local addresses. The TCP port numbers act as differentiators.

Figure 5 NAT Overloading Inside Global Addresses



Protocol	Inside Local IP address:port	Inside Global IP address:port	Outside Global IP address:port
TCP	1.1.1.2:1723	2.2.2.2:1723	6.5.4.7:23
TCP	1.1.1.1:1024	2.2.2.2:1024	9.6.7.3:23

The router performs the following process in overloading inside global addresses, as shown in Figure 5. Both host B and host C believe they are communicating with a single host at address 2.2.2.2. They are actually communicating with different hosts; the port number is the differentiator. In fact, many inside hosts could share the inside global IP address by using many port numbers.

1. The user at host 1.1.1.1 opens a connection to host B.
2. The first packet that the router receives from host 1.1.1.1 causes the router to check its NAT table:
   - If no translation entry exists, the router determines that address 1.1.1.1 must be translated, and sets up a translation of inside local address 1.1.1.1 to a legal global address.
   - If overloading is enabled, and another translation is active, the router reuses the global address from that translation and saves enough information to be able to translate back. This type of entry is called an *extended entry.*
3. The router replaces the inside local source address 1.1.1.1 with the selected global address and forwards the packet.
4. Host B receives the packet and responds to host 1.1.1.1 by using the inside global IP address 2.2.2.2.
5. When the router receives the packet with the inside global IP address, it performs a NAT table lookup, using the protocol, inside global address and port, and outside address and port as a key; translates the address to inside local address 1.1.1.1; and forwards the packet to host 1.1.1.1.

Host 1.1.1.1 receives the packet and continues the conversation. The router performs Steps 2 through 5 for each packet.

To configure overloading of inside global addresses, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip nat pool` *name start-ip end-ip* {**netmask** *netmask* | **prefix-length** *prefix-length*}	Defines a pool of global addresses to be allocated as needed.
Step 2	`Router(config)# access-list` *access-list-number* **permit** *source* [*source-wildcard*]	Defines a standard access list.

	Command	Purpose
Step 3	`Router(config)# ip nat inside source list access-list-number pool name overload`	Establishes dynamic source translation, specifying the access list defined in the prior step.
Step 4	`Router(config)# interface type number`	Specifies the inside interface.
Step 5	`Router(config-if)# ip nat inside`	Marks the interface as connected to the inside.
Step 6	`Router(config)# interface type number`	Specifies the outside interface.
Step 7	`Router(config-if)# ip nat outside`	Marks the interface as connected to the outside.

Note The access list must permit only those addresses that are to be translated. (Remember that there is an implicit "deny all" at the end of each access list.) An access list that is too permissive can lead to unpredictable results.
Packets that enter the router through the inside interface and packets sourced from the router are checked against the access list for possible NAT candidates. The access list is used to specify which traffic is to be translated.

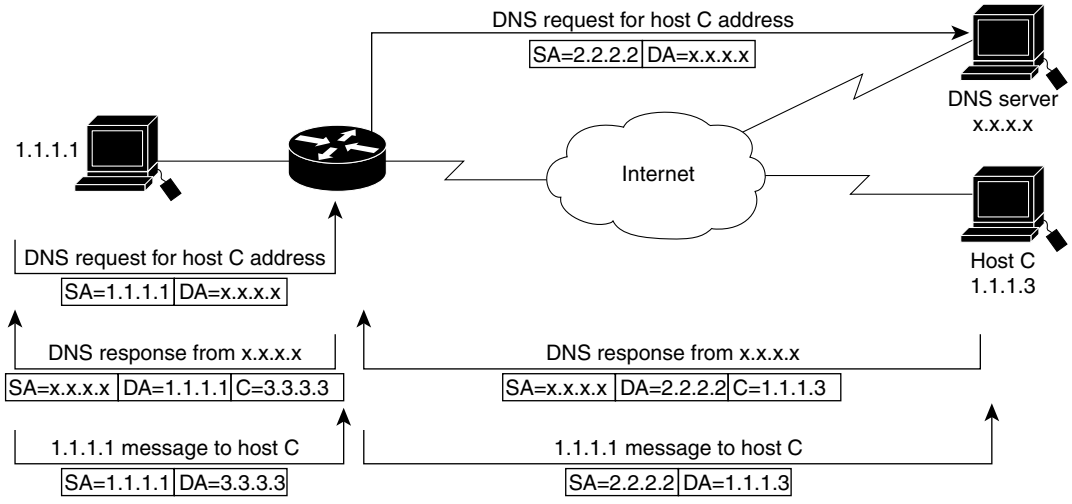
See the "Overloading Inside Global Addresses Example" section at the end of this chapter for an example of overloading inside global addresses.

Translating Overlapping Addresses

The NAT overview discusses translating IP addresses, which could occur because your IP addresses are not legal, officially assigned IP addresses. Perhaps you chose IP addresses that officially belong to another network. The case of an address used both illegally and legally is called *overlapping*. You can use NAT to translate inside addresses that overlap with outside addresses. Use this feature if your IP addresses in the stub network are legitimate IP addresses belonging to another network, and you want to communicate with those hosts or routers.

Figure 6 shows how NAT translates overlapping networks.

Figure 6 NAT Translating Overlapping Addresses



NAT table

Inside Local IP Address	Inside Global IP Address	Outside Global IP Address	Outside Local IP Address
1.1.1.1	2.2.2.2	1.1.1.3	3.3.3.3

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The router performs the following process when translating overlapping addresses:

1. The user at host 1.1.1.1 opens a connection to host C by name, requesting a name-to-address lookup from a DNS server.
2. The router intercepts the DNS reply and translates the returned address if there is an overlap (that is, the resulting legal address resides illegally in the inside network). To translate the return address, the router creates a simple translation entry mapping the overlapping address 1.1.1.3 to an address from a separately configured, outside local address pool.

   The router examines every DNS reply from everywhere, ensuring that the IP address is not in the stub network. If it is, the router translates the address.
3. Host 1.1.1.1 opens a connection to 3.3.3.3.
4. The router sets up translations mapping inside local and global addresses to each other, and outside global and local addresses to each other.
5. The router replaces the SA with the inside global address and replaces the DA with the outside global address.
6. Host C receives the packet and continues the conversation.
7. The router does a lookup, replaces the DA with the inside local address, and replaces the SA with the outside local address.
8. Host 1.1.1.1 receives the packet and the conversation continues, using this translation process.

Configuring Static Translation

To configure static SA address translation, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip nat outside source static global-ip local-ip`	Establishes static translation between an outside local address and an outside global address.
Step 2	`Router(config)# interface type number`	Specifies the inside interface.
Step 3	`Router(config-if)# ip nat inside`	Marks the interface as connected to the inside.
Step 4	`Router(config)# interface type number`	Specifies the outside interface.
Step 5	`Router(config-if)# ip nat outside`	Marks the interface as connected to the outside.

Configuring Dynamic Translation

To configure dynamic outside source address translation, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip nat pool name start-ip end-ip {netmask netmask | prefix-length prefix-length}`	Defines a pool of local addresses to be allocated as needed.
Step 2	`Router(config)# access-list access-list-number permit source [source-wildcard]`	Defines a standard access list.
Step 3	`Router(config)# ip nat outside source list access-list-number pool name`	Establishes dynamic outside source translation, specifying the access list defined in the prior step.
Step 4	`Router(config)# interface type number`	Specifies the inside interface.
Step 5	`Router(config-if)# ip nat inside`	Marks the interface as connected to the inside.
Step 6	`Router(config)# interface type number`	Specifies the outside interface.
Step 7	`Router(config-if)# ip nat outside`	Marks the interface as connected to the outside.

Note The access list must permit only those addresses that are to be translated. (Remember that there is an implicit "deny all" at the end of each access list.) An access list that is too permissive can lead to unpredictable results.

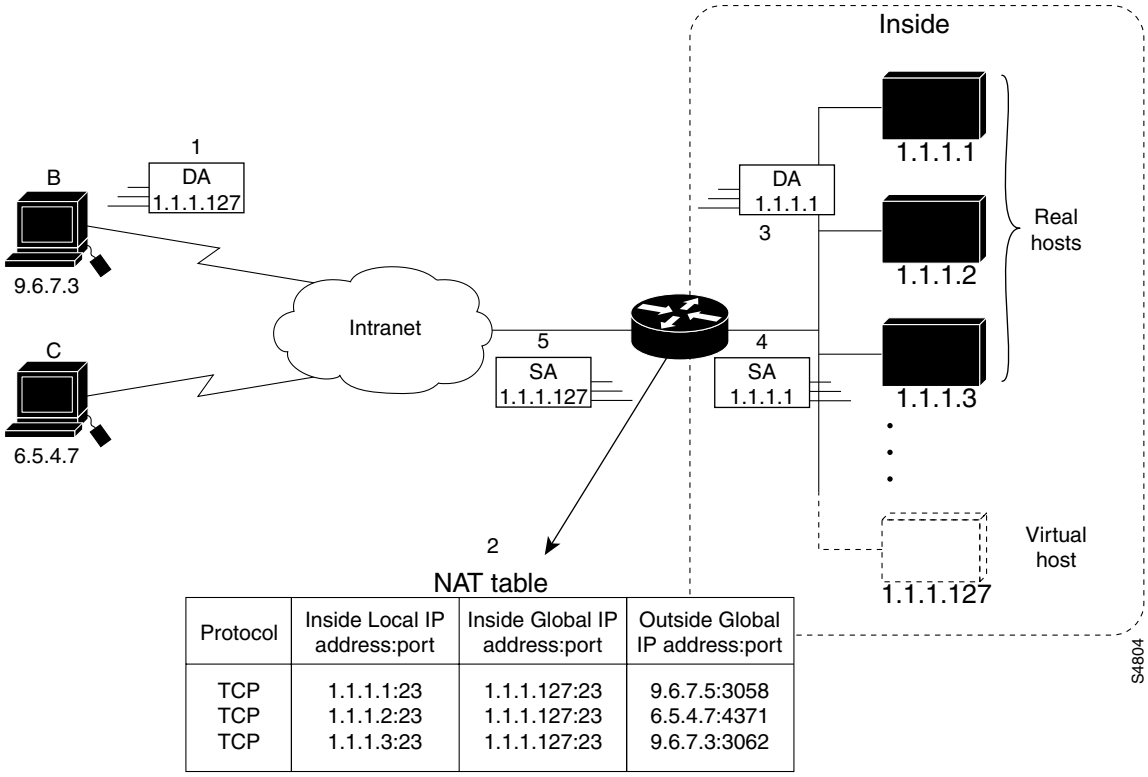
See the "Translating Overlapping Address Example" section at the end of this chapter for an example of translating an overlapping address.

Providing TCP Load Distribution

Another use of NAT is unrelated to Internet addresses. Your organization may have multiple hosts that must communicate with a heavily used host. Using NAT, you can establish a virtual host on the inside network that coordinates load sharing among real hosts. DAs that match an access list are replaced with

addresses from a rotary pool. Allocation is done on a round-robin basis, and only when a new connection is opened from the outside to the inside. Non-TCP traffic is passed untranslated (unless other translations are in effect). Figure 7 illustrates this feature.

Figure 7 NAT TCP Load Distribution



Protocol	Inside Local IP address:port	Inside Global IP address:port	Outside Global IP address:port
TCP	1.1.1.1:23	1.1.1.127:23	9.6.7.5:3058
TCP	1.1.1.2:23	1.1.1.127:23	6.5.4.7:4371
TCP	1.1.1.3:23	1.1.1.127:23	9.6.7.3:3062

The router performs the following process when translating rotary addresses:

1. The user on host B (9.6.7.3) opens a connection to the virtual host at 1.1.1.127.
2. The router receives the connection request and creates a new translation, allocating the next real host (1.1.1.1) for the inside local IP address.
3. The router replaces the destination address with the selected real host address and forwards the packet.
4. Host 1.1.1.1 receives the packet and responds.
5. The router receives the packet, performs a NAT table lookup using the inside local address and port number, and the outside address and port number as the key. The router then translates the source address to the address of the virtual host and forwards the packet.

The next connection request will cause the router to allocate 1.1.1.2 for the inside local address.

To configure destination address rotary translation, use the following commands beginning in global configuration mode. These commands allow you to map one virtual host to many real hosts. Each new TCP session opened with the virtual host will be translated into a session with a different real host.

	Command	Purpose
Step 1	`Router(config)# ip nat pool name start-ip end-ip {netmask netmask | prefix-length prefix-length} type rotary`	Defines a pool of addresses containing the addresses of the real hosts.
Step 2	`Router(config)# access-list access-list-number permit source [source-wildcard]`	Defines an access list permitting the address of the virtual host.
Step 3	`Router(config)# ip nat inside destination list access-list-number pool name`	Establishes dynamic inside destination translation, specifying the access list defined in the prior step.
Step 4	`Router(config)# interface type number`	Specifies the inside interface.
Step 5	`Router(config-if)# ip nat inside`	Marks the interface as connected to the inside.
Step 6	`Router(config)# interface type number`	Specifies the outside interface.
Step 7	`Router(config-if)# ip nat outside`	Marks the interface as connected to the outside.

Note The access list must permit only those addresses that are to be translated. (Remember that there is an implicit "deny all" at the end of each access list.) An access list that is too permissive can lead to unpredictable results.

See the "ping Command Example" section at the end of this chapter for an example of rotary translation.

Changing Translation Timeouts

By default, dynamic address translations time out after some period of nonuse. You can change the default values on timeouts, if necessary. When overloading is not configured, simple translation entries time out after 24 hours. To change this value, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip nat translation timeout seconds`	Changes the timeout value for dynamic address translations that do not use overloading.

If you have configured overloading, you have more control over translation entry timeout, because each entry contains more context about the traffic using it. To change timeouts on extended entries, use the following commands in global configuration mode as needed:

Command	Purpose
`Router(config)# ip nat translation udp-timeout seconds`	Changes the UDP timeout value from 5 minutes.
`Router(config)# ip nat translation dns-timeout seconds`	Changes the DNS timeout value from 1 minute.
`Router(config)# ip nat translation tcp-timeout seconds`	Changes the TCP timeout value from 24 hours.
`Router(config)# ip nat translation finrst-timeout seconds`	Changes the Finish and Reset timeout value from 1 minute.

Command	Purpose
`Router(config)# ip nat translation icmp-timeout seconds`	Changes the ICMP timeout value from 1 minute.
`Router(config)# ip nat translation syn-timeout seconds`	Changes the Synchronous (SYN) timeout value from 1 minute.

Monitoring and Maintaining NAT

By default, dynamic address translations will time out from the NAT translation table at some point. To clear the entries before the timeout, use the following commands in EXEC mode as needed:

Command	Purpose
`Router# clear ip nat translation *`	Clears all dynamic address translation entries from the NAT translation table.
`Router# clear ip nat translation inside global-ip local-ip [outside local-ip global-ip]`	Clears a simple dynamic translation entry containing an inside translation, or both inside and outside translation.
`Router# clear ip nat translation outside local-ip global-ip`	Clears a simple dynamic translation entry containing an outside translation.
`Router# clear ip nat translation protocol inside global-ip global-port local-ip local-port [outside local-ip local-port global-ip global-port]`	Clears an extended dynamic translation entry.

To display translation information, use either of the following commands in EXEC mode:

Command	Purpose
`Router# show ip nat translations [verbose]`	Displays active translations.
`Router# show ip nat statistics`	Displays translation statistics.

Deploying NAT Between an IP Phone and Cisco CallManager

Cisco IP phones use the Selsius Skinny Station Protocol to connect with and register to the Cisco CallManager (CCM). Messages flow back and forth that include IP address and port information used to identify other IP phone users with which a call can be placed.

To be able to deploy Cisco IOS NAT between the IP phone and CCM in a scalable environment, NAT needs to be able to detect the Selsius Skinny Station Protocol and understand the information passed within the messages.

When an IP phone attempts to connect to the CCM and it matches the configured NAT translation rules, NAT will translate the original source IP address and replace it with one from the configured pool. This new address will be reflected in the CCM and be visible to other IP phone users.

To specify a port other than the default port, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip nat service skinny tcp port number`	Displays port number on which the CCM is listening for skinny messages.

Monitoring and Maintaining IP Addressing

To monitor and maintain your network, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Clearing Caches, Tables, and Databases (Required)
- Specifying the Format of Network Masks (Optional)
- Displaying System and Network Statistics (Optional)
- Monitoring and Maintaining NHRP (Optional)

Clearing Caches, Tables, and Databases

You can remove all contents of a particular cache, table, or database. Clearing a cache, table, or database can become necessary when the contents of the particular structure have become or are suspected to be invalid.

To clear caches, tables, and databases, use the following commands in EXEC mode, as needed:

Command	Purpose
`Router# clear arp-cache`	Clears the IP ARP cache and the fast-switching cache.
`Router# clear host {name | *}`	Removes one or all entries from the host name and address cache.
`Router# clear ip route {network [mask] | *}`	Removes one or more routes from the IP routing table.

Specifying the Format of Network Masks

IP uses a 32-bit mask, called a *netmask,* that indicates which address bits belong to the network and subnetwork fields, and which bits belong to the host field. This is called a *netmask*. By default, **show** commands display an IP address and then its netmask in dotted decimal notation. For example, a subnet would be displayed as 131.108.11.55 255.255.255.0.

You might find it more convenient to display the network mask in hexadecimal format or bit count format instead. The hexadecimal format is commonly used on UNIX systems. The previous example would be displayed as 131.108.11.55 0XFFFFFF00.

The bit count format for displaying network masks is to append a slash (/) and the total number of bits in the netmask to the address itself. The previous example would be displayed as 131.108.11.55/24.

To specify the format in which netmasks appear for the current session, use the following command in EXEC mode:

Command	Purpose
`Router# term ip netmask-format {bitcount | decimal | hexadecimal}`	Specifies the format of network masks for the current session.

To configure the format in which netmasks appear for an individual line, use the following command in line configuration mode:

Command	Purpose
`Router(config-line)# ip netmask-format {bitcount | decimal | hexadecimal}`	Configures the format of network masks for a line.

Displaying System and Network Statistics

You can display specific statistics such as the contents of IP routing tables, caches, and databases. The resulting information can be used to determine resource utilization and to solve network problems. You also can display information about node reachability and discover the routing path that the packets of your device are taking through the network.

These tasks are summarized in the table that follows. See the "IP Addressing Commands" chapter in the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services* publication for details about the commands listed in these tasks. Use the following commands in privileged EXEC mode to display specific statistics, as needed:

Command	Purpose
`Router# show arp`	Displays the entries in the ARP table.
`Router# show hosts`	Displays the default domain name, style of lookup service, the name server hosts, and the cached list of host names and addresses.
`Router# show ip aliases`	Displays IP addresses mapped to TCP ports (aliases).
`Router# show ip arp`	Displays the IP ARP cache.
`Router# show ip interface [type number]`	Displays the usability status of interfaces.
`Router# show ip irdp`	Displays IRDP values.
`Router# show ip masks address`	Displays the masks used for network addresses and the number of subnets using each mask.
`Router# show ip redirects`	Displays the address of a default gateway.
`Router# show ip route [address [mask] [longer-prefixes]] | [protocol [process-id]]`	Displays the current state of the routing table.
`Router# show ip route summary`	Displays the current state of the routing table in summary form.
`Router# ping [protocol] {host | address}`	Tests network node reachability (privileged mode).
`Router# ping [protocol] {host | address}`	Tests network node reachability using a simple ping facility (user mode).

Command	Purpose
Router# **trace** [*destination*]	Traces packet routes through the network (privileged mode).
Router# **trace ip** *destination*	Traces packet routes through the network (user mode).

See the "ping Command Example" section at the end of this chapter for an example of pinging.

Monitoring and Maintaining NHRP

To monitor the NHRP cache or traffic, use either of the following commands in EXEC mode:

Command	Purpose
Router# **show ip nhrp** [**dynamic** | **static**] [*type number*]	Displays the IP NHRP cache, optionally limited to dynamic or static cache entries for a specific interface.
Router# **show ip nhrp traffic**	Displays NHRP traffic statistics.

The NHRP cache can contain static entries caused by statically configured addresses and dynamic entries caused by the Cisco IOS software learning addresses from NHRP packets. To clear static entries, use the **no ip nhrp map** command in interface configuration mode. To clear the NHRP cache of dynamic entries, use the following command in EXEC mode:

Command	Purpose
Router# **clear ip nhrp**	Clears the IP NHRP cache of dynamic entries.

In a dual hub Dynamic Multipoint VPN (DMVPN) environment, when using the **clear ip nhrp** command on the hub, you may see the following error message on the spokes:

```
%NHRP-3-PAKERROR: Receive Error Indication for our Error Indication, code: protocol
generic error(7), offset: 0, data: 00 01 08 00 00 00 00 00 00 FF 00 44 5F F6 00 34
```

This is only an informational message generated as a part of the NHRP purge notification processing and will not cause any other issues.

IP Addressing Examples

The following sections provide IP configuration examples:

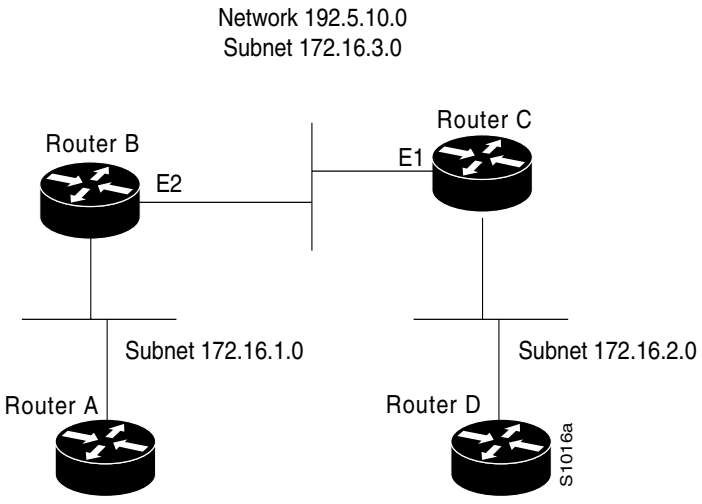
- Creating a Network from Separated Subnets Example
- Serial Interfaces Configuration Example
- IP Domains Example
- Dynamic Lookup Example
- HP Hosts on a Network Segment Example
- Logical NBMA Example
- NHRP over ATM Example

- Changing the Rate for Triggering SVCs Example
- Applying NHRP Rates to Specific Destinations Example
- NHRP on a Multipoint Tunnel Example
- Broadcasting Examples
- NAT Configuration Examples
- ping Command Example

Creating a Network from Separated Subnets Example

In the following example, subnets 1 and 2 of network 131.108.0.0 are separated by a backbone, as shown in Figure 8. The two networks are brought into the same logical network through the use of secondary addresses.

Figure 8 Creating a Network from Separated Subnets



The following examples show the configurations for routers B and C:

Router B Configuration

```
interface ethernet 2
 ip address 192.5.10.1 255.255.255.0
 ip address 131.108.3.1 255.255.255.0 secondary
```

Router C Configuration

```
interface ethernet 1
 ip address 192.5.10.2 255.255.255.0
 ip address 131.108.3.2 255.255.255.0 secondary
```

Serial Interfaces Configuration Example

In the following example, the second serial interface (serial 1) is given the address of Ethernet interface 0. The serial interface is unnumbered.

```
interface ethernet 0
```

```
 ip address 145.22.4.67 255.255.255.0
interface serial 1
 ip unnumbered ethernet 0
```

IP Domains Example

The following example establishes a domain list with several alternate domain names:

```
ip domain list csi.com
ip domain list telecomprog.edu
ip domain-list merit.edu
```

Dynamic Lookup Example

A cache of host name-to-address mappings is used by **connect**, **telnet**, **ping**, **trace**, **write net**, and **configure net** EXEC commands to speed the process of converting names to addresses. The commands used in this example specify the form of dynamic name lookup to be used. Static name lookup also can be configured.

The following example configures the host name-to-address mapping process. IP DNS-based translation is specified, the addresses of the name servers are specified, and the default domain name is given.

```
! IP Domain Name System (DNS)-based host name-to-address translation is enabled
ip domain lookup
! Specifies host 131.108.1.111 as the primary name server and host 131.108.1.2
! as the secondary server
ip name-server 131.108.1.111 131.108.1.2
! Defines cisco.com as the default domain name the router uses to complete
! unqualified host names
ip domain name cisco.com
```

HP Hosts on a Network Segment Example

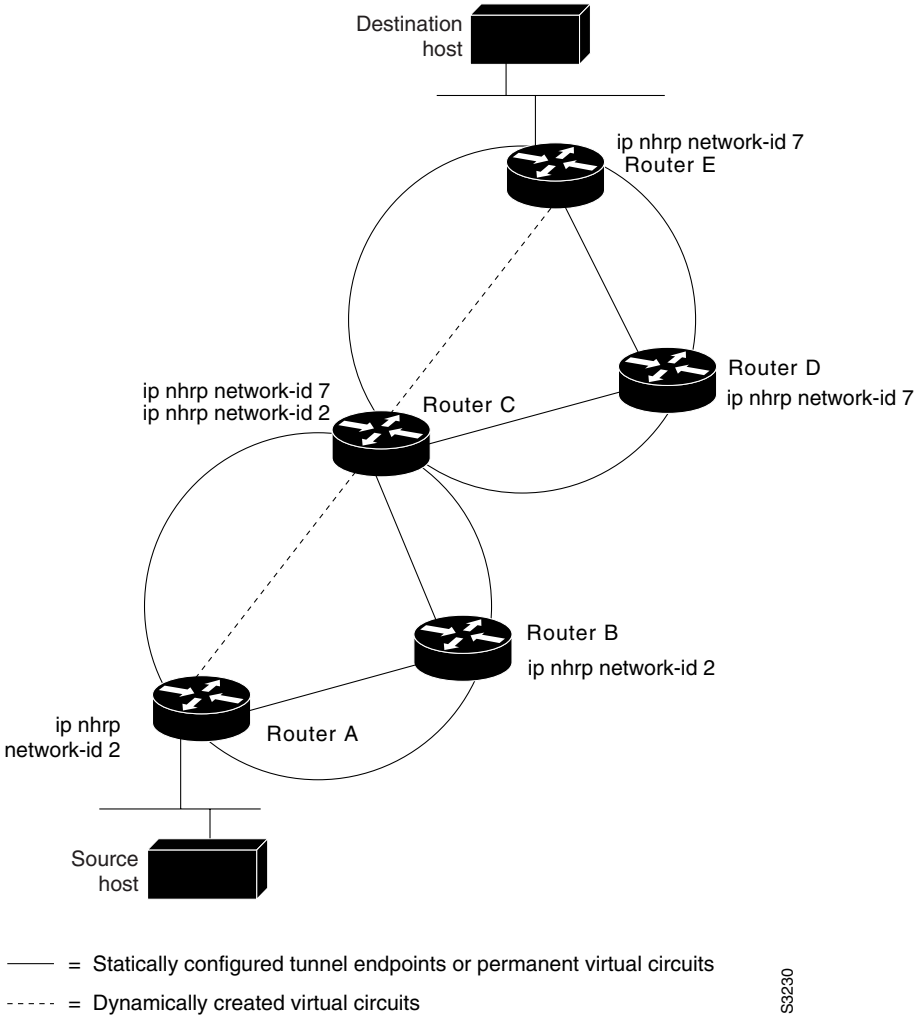
The following example has a network segment with HP devices on it. The commands in this example customize the first Ethernet port to respond to Probe name requests for the host name, and to use Probe and ARP.

```
ip hp-host bl4zip 131.24.6.27
interface ethernet 0
arp probe
ip probe proxy
```

Logical NBMA Example

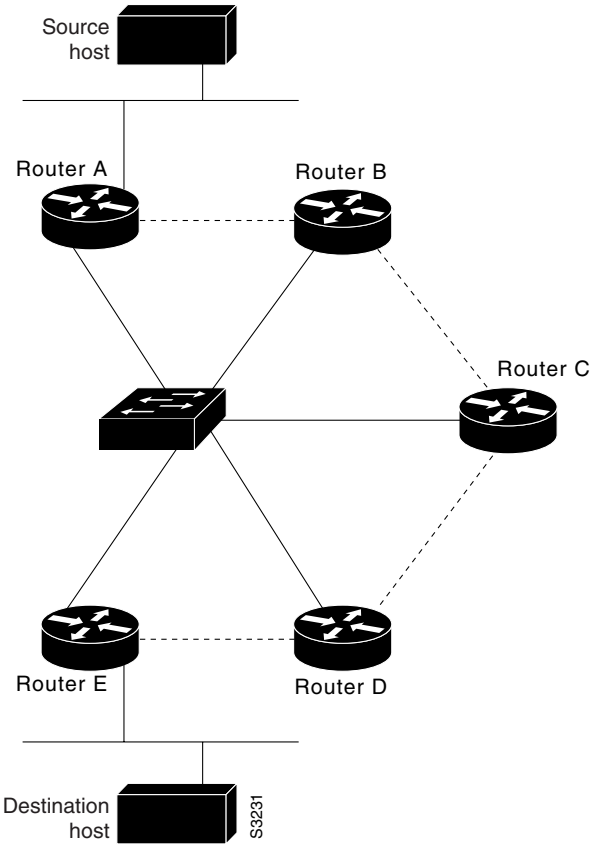
A logical NBMA network is considered the group of interfaces and hosts participating in NHRP and having the same network identifier. Figure 9 illustrates two logical NBMA networks (shown as circles) configured over a single physical NBMA network. Router A can communicate with routers B and C because they share the same network identifier (2). Router C can also communicate with routers D and E because they share network identifier 7. After address resolution is complete, router A can send IP packets to router C in one hop, and router C can send them to router E in one hop, as shown by the dotted lines.

Figure 9 Two Logical NBMA Networks over One Physical NBMA Network



The physical configuration of the five routers in Figure 9 might actually be that shown in Figure 10. The source host is connected to Router A and the destination host is connected to Router E. The same switch serves all five routers, making one physical NBMA network.

Figure 10 Physical Configuration of a Sample NBMA Network



Refer again to Figure 9. Initially, before NHRP has resolved any NBMA addresses, IP packets from the source host to the destination host travel through all five routers connected to the switch before reaching the destination. When Router A first forwards the IP packet toward the destination host, Router A also generates an NHRP request for the IP address of the destination host. The request is forwarded to Router C, whereupon a reply is generated. Router C replies because it is the egress router between the two logical NBMA networks.

Similarly, Router C generates an NHRP request of its own, to which Router E replies. In this example, subsequent IP traffic between the source and the destination still requires two hops to traverse the NBMA network, because the IP traffic must be forwarded between the two logical NBMA networks. Only one hop would be required if the NBMA network were not logically divided.

NHRP over ATM Example

The following example shows a configuration of three routers using NHRP over ATM. Subinterfaces and dynamic routing also are used. Router A obtains an OSPF route that it can use to reach the LIS where Router B resides. Router A can then initially reach Router B through Router C. Router A and Router B are able to directly communicate without Router C once NHRP has resolved the respective NSAP addresses of Router A and Router C.

The significant portions of the configurations for routers A, B, and C follow:

Router A Configuration

```
interface ATM0/0
 ip address 10.1.0.1 255.255.0.0
 ip nhrp network-id 1
 map-group a
 atm nsap-address 11.1111.11.111111.1111.1111.1111.1111.1111.1111.11
 atm rate-queue 1 10
 atm pvc 1 0 5 qsaal

router ospf 1
 network 10.0.0.0 0.255.255.255 area 0

map-list a
 ip 10.1.0.3 atm-nsap 33.3333.33.333333.3333.3333.3333.3333.3333.3333.33
```

Router B Configuration

```
interface ATM0/0
 ip address 10.2.0.2 255.255.0.0
 ip nhrp network-id 1
 map-group a
 atm nsap-address 22.2222.22.222222.2222.2222.2222.2222.2222.2222.22
 atm rate-queue 1 10
 atm pvc 2 0 5 qsaal

router ospf 1
 network 10.0.0.0 0.255.255.255 area 0

map-list a
 ip 10.2.0.3 atm-nsap 33.3333.33.333333.3333.3333.3333.3333.3333.3333.33
```

Router C Configuration

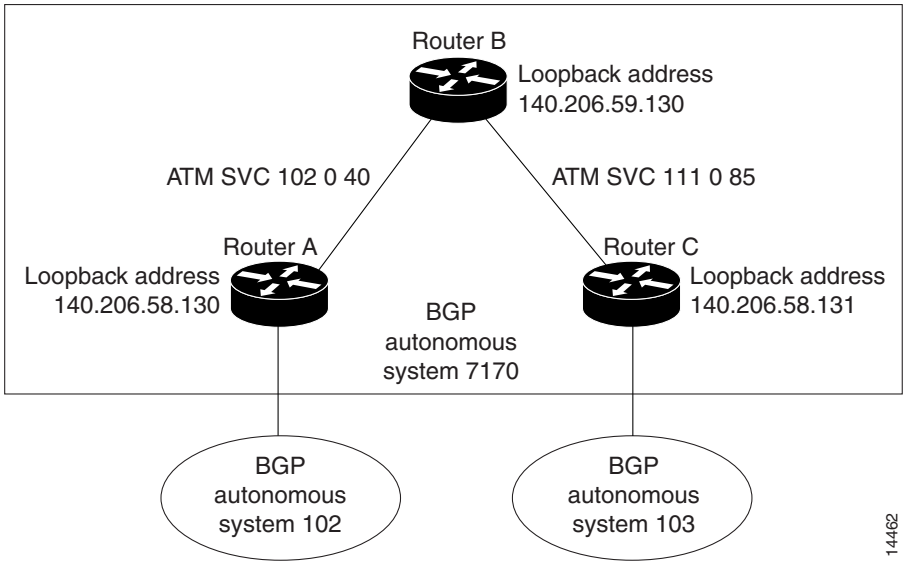
```
interface ATM0/0
 no ip address
 atm rate-queue 1 10
 atm pvc 2 0 5 qsaal

interface ATM0/0.1 multipoint
 ip address 10.1.0.3 255.255.0.0
 ip nhrp network-id 1
 map-group a
 atm nsap-address 33.3333.33.333333.3333.3333.3333.3333.3333.3333.33
 atm rate-queue 1 10

interface ATM0/0.2 multipoint
 ip address 10.2.0.3 255.255.0.0
 ip nhrp network-id 1
 map-group b
 atm nsap-address 33.3333.33.333333.3333.3333.3333.3333.3333.3333.33
 atm rate-queue 1 10

router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
 neighbor 10.1.0.1 priority 1
 neighbor 10.2.0.2 priority 1
```

```
map-list a
 ip 10.1.0.1 atm-nsap 11.1111.11.111111.1111.1111.1111.1111.1111.1111.11

map-list b
ip 10.2.0.2 atm-nsap 22.2222.22.222222.2222.2222.2222.2222.2222.2222.22
```

Changing the Rate for Triggering SVCs Example

Figure 11 and the example configuration following it show how to configure a threshold of 100 kbps for triggering SVCs and 50 kbps for tearing down SVCs.

Figure 11 Using NHRP and Triggering SVCs



Router A Configuration

```
ip cef
ip cef accounting non-recursive
!
interface Loopback0
 ip address 140.206.58.130 255.255.255.255
 no ip directed-broadcast
 no ip mroute-cache
!
interface ATM0/1/0
 no ip address
 no ip directed-broadcast
 no ip mroute-cache
 atm pvc 5 0 5 qsaal
 atm pvc 16 0 16 ilmi
!
interface ATM0/1/0.1 multipoint
 ip address 140.206.58.55 255.255.255.192
 no ip directed-broadcast
 ip nhrp network-id 1
 ip ospf network point-to-multipoint
 atm pvc 102 0 40 aal5snap inarp 5
 atm esi-address 525354555355.01
!
```

```
interface Fddi1/0/0
 ip address 10.2.1.55 255.255.255.0
 no ip directed-broadcast
 no ip mroute-cache
 no keepalive
!
router ospf 1
 passive-interface Fddi1/0/0
 network 10.2.1.0 0.0.0.255 area 1
 network 140.206.58.0 0.0.0.255 area 1
!
router bgp 7170
 no synchronization
 network 140.206.0.0
 neighbor 10.2.1.36 remote-as 102
 neighbor 140.206.59.130 remote-as 7170
 neighbor 140.206.59.130 update-source Loopback0
 neighbor 140.206.59.130 next-hop-self
```

Router B Configuration

```
ip cef
ip cef accounting non-recursive
!
interface Loopback0
 ip address 140.206.59.130 255.255.255.255
 no ip directed-broadcast
 no ip mroute-cache
!
interface ATM0/0
 no ip address
 no ip directed-broadcast
 no ip mroute-cache
 atm pvc 5 0 5 qsaal
 atm pvc 16 0 16 ilmi
!
interface ATM0/0.1 multipoint
 ip address 140.206.58.54 255.255.255.192
 no ip directed-broadcast
 ip nhrp network-id 1
 ip nhrp server-only non-caching
 ip route-cache same-interface
 ip ospf network point-to-multipoint
 atm pvc 102 0 40 aal5snap inarp 5
 atm pvc 111 0 85 aal5snap inarp 5
 atm esi-address 525354555354.01
!
router ospf 1
 network 140.206.58.0 0.0.0.255 area 1
 network 140.206.59.0 0.0.0.255 area 0
 area 0 range 140.206.59.0 255.255.255.0
!
router bgp 7170
 no synchronization
 bgp cluster-id 1
 network 140.206.0.0
 aggregate-address 140.206.0.0 255.255.0.0 summary-only
 neighbor 140.206.58.130 remote-as 7170
 neighbor 140.206.58.130 route-reflector-client
 neighbor 140.206.58.130 update-source Loopback0
 neighbor 140.206.58.131 remote-as 7170
 neighbor 140.206.58.131 route-reflector-client
 neighbor 140.206.58.131 update-source Loopback0
```

Router C Configuration

```
ip cef
ip cef accounting non-recursive
!
interface Loopback0
 ip address 140.206.58.131 255.255.255.255
 no ip directed-broadcast
 no ip mroute-cache
!
interface ATM0/0
 no ip address
 no ip directed-broadcast
 no ip mroute-cache
 atm pvc 5 0 5 qsaal
 atm pvc 16 0 16 ilmi
!
interface ATM0/0.1 multipoint
 ip address 140.206.58.56 255.255.255.192
 no ip directed-broadcast
 ip nhrp network-id 1
 ip nhrp trigger-svc 100 50
 ip ospf network point-to-multipoint
 atm pvc 111 0 85 aal5snap inarp 5
 atm esi-address 525354555356.01
!
!
interface Fddi4/0/0
 ip address 10.3.1.56 255.255.255.0
 no ip directed-broadcast
 no ip mroute-cache
 no keepalive
!
!
router ospf 1
 passive-interface Fddi4/0/0
 network 10.3.1.0 0.0.0.255 area 1
 network 140.206.58.0 0.0.0.255 area 1
!
router bgp 7170
 no synchronization
 network 140.206.0.0
 neighbor 10.3.1.45 remote-as 103
 neighbor 140.206.59.130 remote-as 7170
 neighbor 140.206.59.130 update-source Loopback0
 neighbor 140.206.59.130 next-hop-self
```

Applying NHRP Rates to Specific Destinations Example

In the following example, only the packets that pass extended access list 101 are subject to the default SVC triggering and teardown rates:

```
interface atm0/0/0.1 multipoint
 ip nhrp interest 101
!
access-list 101 permit ip any any
access-list 101 deny ip any 10.3.0.0 0.0.255.255
```

NHRP on a Multipoint Tunnel Example

With multipoint tunnels, a single tunnel interface may be connected to multiple neighboring routers. Unlike point-to-point tunnels, a tunnel destination need not be configured. In fact, if configured, the tunnel destination must correspond to an IP multicast address. Broadcast or multicast packets to be sent over the tunnel interface can then be sent by sending the GRE packet to the multicast address configured as the tunnel destination.

Multipoint tunnels require that you configure a tunnel key. Otherwise, unexpected GRE traffic could easily be received by the tunnel interface. For simplicity, we recommend that the tunnel key correspond to the NHRP network identifier.

In the following example, routers A, B, C, and D all share a common Ethernet segment. Minimal connectivity over the multipoint tunnel network is configured, thus creating a network that can be treated as a partially meshed NBMA network. Due to the static NHRP map entries, Router A knows how to reach Router B, Router B knows how to reach Router C, Router C knows how to reach Router D, and Router D knows how to reach Router A.

When Router A initially attempts to send an IP packet to Router D, the packet is forwarded through Routers B and C. Through NHRP, the routers quickly learn the NBMA addresses of each other (in this case, IP addresses assigned to the underlying Ethernet network). The partially meshed tunnel network readily becomes fully meshed, at which point any of the routers can directly communicate over the tunnel network without their IP traffic requiring an intermediate hop.

The significant portions of the configurations for routers A, B, C, and D follow:

Router A Configuration

```
interface tunnel 0
 no ip redirects
 ip address 11.0.0.1 255.0.0.0
 ip nhrp map 11.0.0.2 10.0.0.2
 ip nhrp network-id 1
 ip nhrp nhs 11.0.0.2
 tunnel source ethernet 0
 tunnel mode gre multipoint
 tunnel key 1

interface ethernet 0
 ip address 10.0.0.1 255.0.0.0
```

Router B Configuration

```
interface tunnel 0
 no ip redirects
 ip address 11.0.0.2 255.0.0.0
 ip nhrp map 11.0.0.3 10.0.0.3
 ip nhrp network-id 1
 ip nhrp nhs 11.0.0.3
 tunnel source ethernet 0
 tunnel mode gre multipoint
 tunnel key 1

interface ethernet 0
 ip address 10.0.0.2 255.0.0.0
```

Router C Configuration

```
interface tunnel 0
 no ip redirects
 ip address 11.0.0.3 255.0.0.0
 ip nhrp map 11.0.0.4 10.0.0.4
```

```
 ip nhrp network-id 1
 ip nhrp nhs 11.0.0.4
 tunnel source ethernet 0
 tunnel mode gre multipoint
 tunnel key 1

interface ethernet 0
 ip address 10.0.0.3 255.0.0.0
```

Router D Configuration

```
interface tunnel 0
 no ip redirects
 ip address 11.0.0.4 255.0.0.0
 ip nhrp map 11.0.0.1 10.0.0.1
 ip nhrp network-id 1
 ip nhrp nhs 11.0.0.1
 tunnel source ethernet 0
 tunnel mode gre multipoint
 tunnel key 1

interface ethernet 0
 ip address 10.0.0.4 255.0.0.0
```

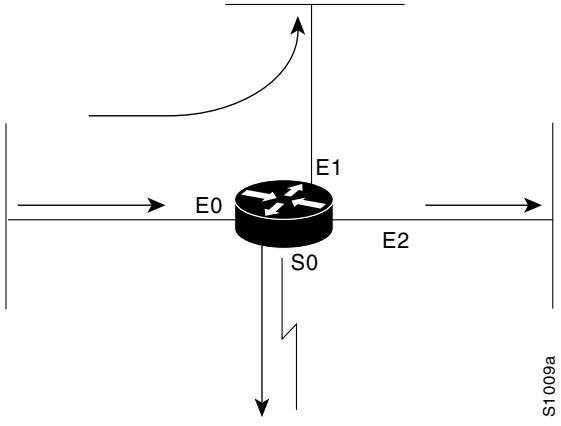
Broadcasting Examples

The Cisco IOS software supports two types of broadcasting: directed broadcasting and flooding. A directed broadcast is a packet sent to a specific network or series of networks, and a flooded broadcast is a packet sent to every network. The following sections describe configurations for both types of broadcasting.

Flooded Broadcast Example

Figure 12 shows a flooded broadcast packet being sent to every network. The packet that is incoming from Ethernet interface 0 is flooded to Ethernet interfaces 1 and 2, and to serial interface 0.

Figure 12 IP Flooded Broadcast



A directed broadcast address includes the network or subnet fields. For example, if the network address is 128.1.0.0, the address 128.1.255.255 indicates all hosts on network 128.1.0.0, which would be a directed broadcast. If network 128.1.0.0 has a subnet mask of 255.255.255.0 (the third octet is the subnet field), the address 128.1.5.255 specifies all hosts on subnet 5 of network 128.1.0.0—another directed broadcast.

Flooding of IP Broadcasts Example

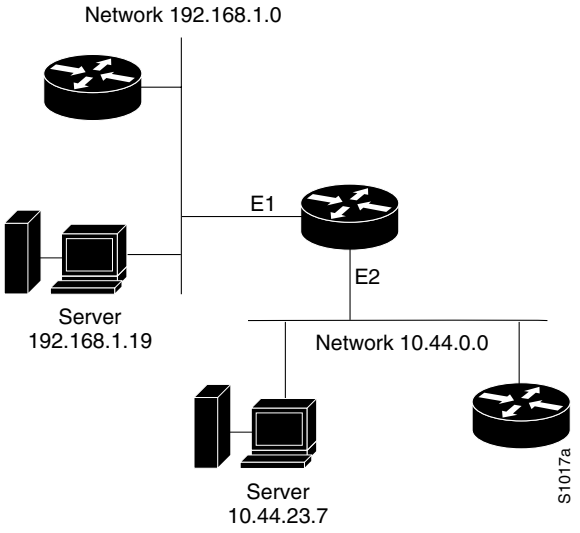
In the following example, flooding of IP broadcasts is enabled on all interfaces (two Ethernet and two serial). No specific UDP protocols are listed by a separate **ip forward-protocol udp** interface configuration command, so the default protocols (TFTP, DNS, Time, NetBIOS, and BOOTP) will be flooded.

```
ip forward-protocol spanning-tree
 bridge 1 protocol dec
access-list 201 deny 0x0000 0xFFFF
 interface ethernet 0
 bridge-group 1
 bridge-group 1 input-type-list 201
 bridge-group 1 input-lsap-list 201
interface ethernet 1
 bridge-group 1
 bridge-group 1 input-type-list 201
 bridge-group 1 input-lsap-list 201
interface serial 0
 bridge-group 1
 bridge-group 1 input-type-list 201
 bridge-group 1 input-lsap-list 201
interface serial 1
 bridge-group 1
 bridge-group 1 input-type-list 201
 bridge-group 1 input-lsap-list 201
```

Helper Addresses Example

In the following example, one router is on network 192.168.1.0 and the other is on network 10.44.0.0, and you want to permit IP broadcasts from hosts on either network segment to reach both servers. Figure 13 illustrates how to configure the router that connects network 10.44.0.0 to network 192.168.1.0.

Figure 13 IP Helper Addresses



The following example shows the configuration:

```
ip forward-protocol udp
!
interface ethernet 1
 ip helper-address 10.44.23.7
interface ethernet 2
 ip helper-address 192.168.1.19
```

NAT Configuration Examples

The following sections show NAT configuration examples.

Dynamic Inside Source Translation Example

The following example translates all source addresses passing access list 1 (having a source address from 192.168.1.0/24) to an address from the pool named net-208. The pool contains addresses from 171.69.233.208 to 171.69.233.223.

```
ip nat pool net-208 171.69.233.208 171.69.233.223 netmask 255.255.255.240
ip nat inside source list 1 pool net-208
!
interface serial 0
 ip address 171.69.232.182 255.255.255.240
 ip nat outside
!
interface ethernet 0
 ip address 192.168.1.94 255.255.255.0
 ip nat inside
!
access-list 1 permit 192.168.1.0 0.0.0.255
```

The following example translates all source addresses using a route map.

```
ip nat pool provider1-space 171.69.232.1 171.69.232.254 prefix-length 24
ip nat pool provider2-space 131.108.43.1 131.108.43.254 prefix-length 24
```

```
ip nat inside source route-map provider1-map pool provider1-space
ip nat inside source route-map provider2-map pool providere2-space
!
interface Serial0/0
ip nat outside
!
interface Serial0/1
ip nat outside
!
route-map provider1-map permit 10
match ip address 1
match interface Serial0/0
!
route-map provider2-map permit 10
match ip address 1
match interface Serial0/1
```

Overloading Inside Global Addresses Example

The following example creates a pool of addresses named net-208. The pool contains addresses from 171.69.233.208 to 171.69.233.223. Access list 1 allows packets having the SA from 192.168.1.0 to 192.168.1.255. If no translation exists, packets matching access list 1 are translated to an address from the pool. The router allows multiple local addresses (192.168.1.0 to 192.168.1.255) to use the same global address. The router retains port numbers to differentiate the connections.

```
ip nat pool net-208 171.69.233.208 171.69.233.223 netmask 255.255.255.240
ip nat inside source list 1 pool net-208 overload
!
interface serial0
 ip address 171.69.232.182 255.255.255.240
 ip nat outside
!
interface ethernet0
 ip address 192.168.1.94 255.255.255.0
 ip nat inside
!
access-list 1 permit 192.168.1.0 0.0.0.255
```

Translating Overlapping Address Example

In the following example, the addresses in the local network are being used legitimately by someone else on the Internet. An extra translation is required to access that external network. Pool net-10 is a pool of outside local IP addresses. The statement, **ip nat outside source list 1 pool net-10**, translates the addresses of hosts from the outside overlapping network to addresses in that pool.

```
ip nat pool net-208 171.69.233.208 171.69.233.223 prefix-length 28
ip nat pool net-10 10.0.1.0 10.0.1.255 prefix-length 24
ip nat inside source list 1 pool net-208
ip nat outside source list 1 pool net-10
!
interface serial 0
 ip address 171.69.232.192 255.255.255.240
 ip nat outside
!
interface ethernet0
 ip address 192.168.1.94 255.255.255.0
 ip nat inside
!
access-list 1 permit 192.168.1.0 0.0.0.255
```

TCP Load Distribution Example

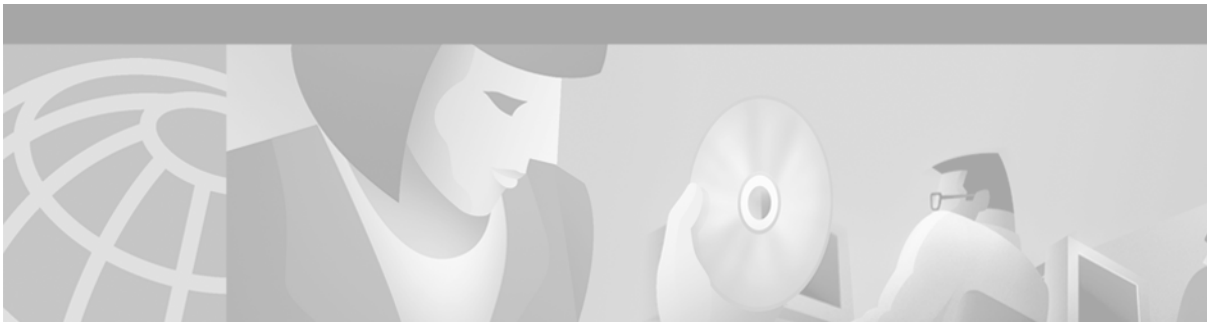
In the following example, the goal is to define a virtual address, connections to which are distributed among a set of real hosts. The pool defines the addresses of the real hosts. The access list defines the virtual address. If a translation does not already exist, TCP packets from serial interface 0 (the outside interface) whose destination matches the access list are translated to an address from the pool.

```
ip nat pool real-hosts 192.168.15.2 192.168.15.15 prefix-length 28 type rotary
ip nat inside destination list 2 pool real-hosts
!
interface serial 0
 ip address 192.168.15.129 255.255.255.240
 ip nat outside
!
interface ethernet 0
 ip address 192.168.15.17 255.255.255.240
 ip nat inside
!
access-list 2 permit 192.168.15.1
```

ping Command Example

You can specify the address to use as the source address for **ping** packets. In the following example, the address is 131.108.105.62:

```
Sandbox# ping
Protocol [ip]:
Target IP address: 131.108.1.111
Repeat count [5]:
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: yes
Source address: 131.108.105.62
Type of service [0]:
Set DF bit in IP header? [no]:
Data pattern [0xABCD]:
Loose, Strict, Record, Timestamp, Verbose[none]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 131.108.1.111, timeout is 2 seconds:
!!!!!
Success rate is 100 percent, round-trip min/avg/max = 4/4/4 ms
```



Configuring DHCP

This chapter describes how to configure Dynamic Host Configuration Protocol (DHCP). For a complete description of the DHCP commands listed in this chapter, refer to the "DHCP Commands" chapter of the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services* publication. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

As explained in RFC 2131, *Dynamic Host Configuration Protocol*, DHCP provides configuration parameters to Internet hosts. DHCP consists of two components: a protocol for delivering host-specific configuration parameters from a DHCP Server to a host and a mechanism for allocating network addresses to hosts. DHCP is built on a client/server model, where designated DHCP Server hosts allocate network addresses and deliver configuration parameters to dynamically configured hosts. By default, Cisco routers running Cisco IOS software include DHCP server and relay agent software.

DHCP supports three mechanisms for IP address allocation:

- Automatic allocation—DHCP assigns a permanent IP address to a client.
- Dynamic allocation—DHCP assigns an IP address to a client for a limited period of time (or until the client explicitly relinquishes the address).
- Manual allocation—The network administrator assigns an IP address to a client and DHCP is used simply to convey the assigned address to the client.

The format of DHCP messages is based on the format of Bootstrap Protocol (BOOTP) messages, which ensures support for BOOTP relay agent functionality and interoperability between BOOTP clients and DHCP Servers. BOOTP relay agents eliminate the need for deploying a DHCP Server on each physical network segment. BOOTP is explained in RFC 951, *Bootstrap Protocol (BOOTP)*, and RFC 1542, *Clarifications and Extensions for the Bootstrap Protocol*.

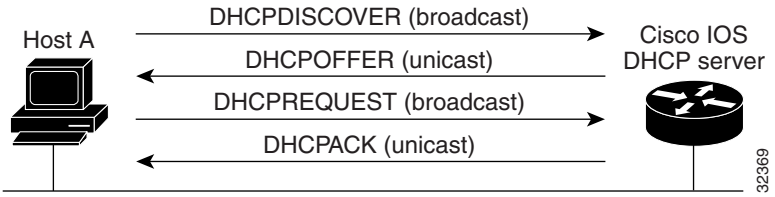
To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

DHCP Server Overview

The Cisco IOS DHCP Server feature is a full DHCP Server implementation that assigns and manages IP addresses from specified address pools within the router to DHCP clients. If the Cisco IOS DHCP Server cannot satisfy a DHCP request from its own database, it can forward the request to one or more secondary DHCP Servers defined by the network administrator.

Figure 14 shows the basic steps that occur when a DHCP client requests an IP address from a DHCP Server. The client, Host A, sends a DHCPDISCOVER broadcast message to locate a Cisco IOS DHCP Server. A DHCP Server offers configuration parameters (such as an IP address, a MAC address, a domain name, and a lease for the IP address) to the client in a DHCPOFFER unicast message.

Figure 14 DHCP Request for an IP Address from a DHCP Server



Note A DHCP client may receive offers from multiple DHCP Servers and can accept any one of the offers; however, the client usually accepts the first offer it receives. Additionally, the offer from the DHCP Server is not a guarantee that the IP address will be allocated to the client; however, the server usually reserves the address until the client has had a chance to formally request the address.

The client returns a formal request for the offered IP address to the DHCP Server in a DHCPREQUEST broadcast message. The DHCP Server confirms that the IP address has been allocated to the client by returning a DHCPACK unicast message to the client.

Note The formal request for the offered IP address (the DHCPREQUEST message) that is sent by the client is broadcast so that all other DHCP Servers that received the DHCPDISCOVER broadcast message from the client can reclaim the IP addresses that they offered to the client.

If the configuration parameters sent to the client in the DHCPOFFER unicast message by the DHCP Server are invalid (a misconfiguration error exists), the client returns a DHCPDECLINE broadcast message to the DHCP Server.

The DHCP Server will send to the client a DHCPNAK denial broadcast message, which means the offered configuration parameters have not been assigned, if an error has occurred during the negotiation of the parameters or the client has been slow in responding to the DHCPOFFER message (the DHCP Server assigned the parameters to another client) of the DHCP Server.

DHCP defines a process by which the DHCP Server knows the IP subnet in which the DHCP client resides, and it can assign an IP address from a pool of valid IP addresses in that subnet.

The DHCP Server identifies which DHCP address pool to use to service a client request as follows:

- If the client is not directly connected (the giaddr field of the DHCPDISCOVER broadcast message is non-zero), the DHCP Server matches the DHCPDISCOVER with a DHCP pool that has the subnet that contains the IP address in the giaddr field.
- If the client is directly connected (the giaddr field is zero), the DHCP Server matches the DHCPDISCOVER with DHCP pool(s) that contain the subnet(s) configured on the receiving interface. If the interface has secondary IP addresses, the subnets associated with the secondary IP addresses are examined for possible allocation only after the subnet associated with the primary IP address (on the interface) is exhausted.

The Cisco IOS DHCP Server feature offers the following benefits:

- Reduced Internet access costs

Using automatic IP address assignment at each remote site substantially reduces Internet access costs. Static IP addresses are considerably more expensive to purchase than are automatically allocated IP addresses.

- Reduced client configuration tasks and costs

  Because DHCP is easy to configure, it minimizes operational overhead and costs associated with device configuration tasks and eases deployment by nontechnical users.

- Centralized management

  Because the DHCP Server maintains configurations for several subnets, an administrator only needs to update a single, central server when configuration parameters change.

Before you configure the Cisco IOS DHCP Server feature, complete the following tasks:

- Identify an external File Transport Protocol (FTP), Trivial File Transfer Protocol (TFTP), or remote copy protocol (rcp) server that you will use to store the DHCP bindings database.
- Identify the IP addresses that you will enable the DHCP Server to assign, and the IP addresses that you will exclude.
- Identify DHCP options for devices where necessary, including the following:
  - Default boot image name
  - Default routers
  - Domain Name System (DNS) servers
  - NetBIOS name server
- Decide on a NetBIOS node type (b, p, m, or h).
- Decide on a DNS domain name.

DHCP Client Overview

The Cisco IOS DHCP client now enables you to obtain an IP address from a DHCP Server dynamically using the DHCP protocol as specified in RFC 2131. In Cisco IOS Release 12.2, only Ethernet interfaces are supported; work is in progress to support all interface types. The Cisco IOS DHCP client offers the following benefits:

- Reduces time to configure and deploy
- Reduces the number of configuration errors
- Enables customers to centrally control the IP address assigned to a Cisco IOS router

DHCP Relay Agent Overview

A DHCP relay agent is any host that forwards DHCP packets between clients and servers. Relay agents are used to forward requests and replies between clients and servers when they are not on the same physical subnet. Relay agent forwarding is distinct from the normal forwarding of an IP router, where IP datagrams are switched between networks somewhat transparently. Relay agents receive DHCP messages and then generate a new DHCP message to send out on another interface.

The Cisco IOS DHCP relay agent supports the use of unnumbered interfaces. The DHCP relay agent automatically adds a static host route specifying the unnumbered interface as the outbound interface.

DHCP Configuration Task List

The DHCP Server database is organized as a tree. The root of the tree is the address pool for natural networks, branches are subnetwork address pools, and leaves are manual bindings to clients. Subnetworks inherit network parameters and clients inherit subnetwork parameters. Therefore, common parameters, for example the domain name, should be configured at the highest (network or subnetwork) level of the tree.

Note Inherited parameters can be overridden. For example, if a parameter is defined in both the natural network and a subnetwork, the definition of the subnetwork is used.

Address leases are not inherited. If a lease is not specified for an IP address, by default, the DHCP Server assigns a one-day lease for the address.

To configure the Cisco IOS DHCP Server feature, perform the tasks described in the following sections. First configure a database agent or disable conflict logging, then specify IP addresses that the DHCP Server should not assign (excluded addresses) and should assign (a pool of available IP addresses) to requesting clients. The tasks in the first three sections are required. The tasks in the remaining sections are optional.

- Enabling the Cisco IOS DHCP Server and Relay Agent Features (Optional)
- Configuring a DHCP Database Agent or Disabling DHCP Conflict Logging (Required)
- Excluding IP Addresses (Required)
- Configuring a DHCP Address Pool (Required)
- Configuring Manual Bindings (Optional)
- Configuring a DHCP Server Boot File (Optional)
- Configuring the Number of Ping Packets (Optional)
- Configuring the Timeout Value for Ping Packets (Optional)
- Enabling the Cisco IOS DHCP Client on Ethernet Interfaces (Optional)
- Configuring DHCP Server Options Import and Autoconfiguration (Optional)
- Configuring the Relay Agent Information Option in BOOTREPLY Messages (Optional)
- Configuring a Relay Agent Information Reforwarding Policy (Optional)
- Enabling the DHCP Smart-Relay Feature (Optional)

Enabling the Cisco IOS DHCP Server and Relay Agent Features

By default, the Cisco IOS DHCP server and relay agent features are enabled on your router. To reenable these features if they are disabled, use the following command in global configuration mode:

Command	Purpose
`Router(config)# service dhcp`	Enables the Cisco IOS DHCP server and relay features on your router. Use the **no** form of this command to disable the Cisco IOS DHCP server and relay features.

Configuring a DHCP Database Agent or Disabling DHCP Conflict Logging

A DHCP database agent is any host—for example, an FTP, TFTP, or rcp server—that stores the DHCP bindings database. You can configure multiple DHCP database agents and you can configure the interval between database updates and transfers for each agent. To configure a database agent and database agent parameters, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp database` *url* [`timeout` *seconds* | `write-delay` *seconds*]	Configures the database agent and the interval between database updates and database transfers.

If you choose not to configure a DHCP database agent, disable the recording of DHCP address conflicts on the DHCP Server. To disable DHCP address conflict logging, use the following command in global configuration mode:

Command	Purpose
`Router(config)# no ip dhcp conflict logging`	Disables DHCP address conflict logging.

Excluding IP Addresses

The DHCP Server assumes that all IP addresses in a DHCP address pool subnet are available for assigning to DHCP clients. You must specify the IP address that the DHCP Server should not assign to clients. To do so, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp excluded-address` *low-address* [*high-address*]	Specifies the IP addresses that the DHCP Server should not assign to DHCP clients.

Configuring a DHCP Address Pool

You can configure a DHCP address pool with a name that is a symbolic string (such as “engineering”) or an integer (such as 0). Configuring a DHCP address pool also places you in DHCP pool configuration mode—identified by the (dhcp-config)# prompt—from which you can configure pool parameters (for example, the IP subnet number and default router list). To configure a DHCP address pool, complete the required tasks in the following sections.

Configuring the DHCP Address Pool Name and Entering DHCP Pool Configuration Mode

To configure the DHCP address pool name and enter DHCP pool configuration mode, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp pool` *name*	Creates a name for the DHCP Server address pool and places you in DHCP pool configuration mode (identified by the dhcp-config# prompt).

Configuring the DHCP Address Pool Subnet and Mask

To configure a subnet and mask for the newly created DHCP address pool, which contains the range of available IP addresses that the DHCP Server may assign to clients, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# network network-number [mask | /prefix-length]`	Specifies the subnet network number and mask of the DHCP address pool. The prefix length specifies the number of bits that comprise the address prefix. The prefix is an alternative way of specifying the network mask of the client. The prefix length must be preceded by a forward slash (/).

Note You can not configure manual bindings within the same pool that is configured with the **network** command. To configure manual bindings, see the "Configuring Manual Bindings" section.

Configuring the Domain Name for the Client

The domain name for a DHCP client places the client in the general grouping of networks that make up the domain. To configure a domain name string for the client, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# domain-name domain`	Specifies the domain name for the client.

Configuring the IP Domain Name System Servers for the Client

DHCP clients query DNS IP servers when they need to correlate host names to IP addresses. To configure the DNS IP servers that are available to a DHCP client, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# dns-server address [address2 ... address8]`	Specifies the IP address of a DNS server that is available to a DHCP client. One IP address is required; however, you can specify up to eight IP addresses in one command line.

Configuring the NetBIOS Windows Internet Naming Service Servers for the Client

Windows Internet Naming Service (WINS) is a name resolution service that Microsoft DHCP clients use to correlate host names to IP addresses within a general grouping of networks. To configure the NetBIOS WINS servers that are available to a Microsoft DHCP client, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# netbios-name-server address [address2 ... address8]`	Specifies the NetBIOS WINS server that is available to a Microsoft DHCP client. One address is required; however, you can specify up to eight addresses in one command line.

Configuring the NetBIOS Node Type for the Client

The NetBIOS node type for Microsoft DHCP clients can be one of four settings: broadcast, peer-to-peer, mixed, or hybrid. To configure the NetBIOS node type for a Microsoft DHCP, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# netbios-node-type type`	Specifies the NetBIOS node type for a Microsoft DHCP client.

Configuring the Default Router for the Client

After a DHCP client has booted, the client begins sending packets to its default router. The IP address of the default router should be on the same subnet as the client. To specify a default router for a DHCP client, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# default-router address [address2 ... address8]`	Specifies the IP address of the default router for a DHCP client. One IP address is required; however, you can specify up to eight addresses in one command line.

Configuring the Address Lease Time

By default, each IP address assigned by a DHCP Server comes with a one-day lease, which is the amount of time that the address is valid. To change the lease value for an IP address, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# lease {days [hours][minutes] | infinite}`	Specifies the duration of the lease. The default is a one-day lease. • Use the **show ip dhcp binding** to display the lease expiration time and date of the IP address of the host.

Configuring Manual Bindings

An address binding is a mapping between the IP address and MAC address of a client. The IP address of a client can be assigned manually by an administrator or assigned automatically from a pool by a DHCP Server.

Manual bindings are IP addresses that have been manually mapped to the MAC addresses of hosts that are found in the DHCP database. Manual bindings are stored in NVRAM on the DHCP Server. Manual bindings are just special address pools. There is no limit on the number of manual bindings but you can only configure one manual binding per host pool.

Automatic bindings are IP addresses that have been automatically mapped to the MAC addresses of hosts that are found in the DHCP database. Automatic bindings are stored on a remote host called a database agent. The bindings are saved as text records for easy maintenance.

To configure a manual binding, first create a host pool, then specify the IP address of the client and hardware address or client identifier. The hardware address is the MAC address. The client identifier, which is required for Microsoft clients (instead of hardware addresses), is formed by concatenating the media type and the MAC address of the client. Refer to the "Address Resolution Protocol Parameters" section of RFC 1700, *Assigned Numbers*, for a list of media type codes.

To configure manual bindings, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip dhcp pool` *name*	Creates a name for the a DHCP Server address pool and places you in DHCP pool configuration mode—identified by the (dhcp-config)# prompt.
Step 2	`Router(dhcp-config)# host` *address* [*mask* | **/***prefix-length*]	Specifies the IP address and subnet mask of the client. The prefix length specifies the number of bits that comprise the address prefix. The prefix is an alternative way of specifying the network mask of the client. The prefix length must be preceded by a forward slash (/).
Step 3	`Router(dhcp-config)# hardware-address` *hardware-address type* or `Router(dhcp-config)# client-identifier` *unique-identifier*	Specifies a hardware address for the client. The *type* value: • Indicates the protocol of the hardware platform. Strings and values are acceptable. The string options are: – ethernet – ieee802 • The value options are: – 1 10Mb Ethernet – 6 IEEE 802 If no type is specified, the default protocol is Ethernet. or Specifies the distinct identification of the client in dotted hexadecimal notation, for example, 01b7.0813.8811.66, where 01 represents the Ethernet media type.
Step 4	`Router(dhcp-config)# client-name` *name*	(Optional) Specifies the name of the client using any standard ASCII character. The client name should not include the domain name. For example, the name **mars** should not be specified as **mars.cisco.com**.

Configuring a DHCP Server Boot File

The boot file is used to store the boot image for the client. The boot image is generally the operating system the client uses to load. To specify a boot file for the DHCP client, use the following command in DHCP pool configuration mode:

Command	Purpose
`Router(dhcp-config)# bootfile filename`	Specifies the name of the file that is used as a boot image.

Configuring the Number of Ping Packets

By default, the DHCP Server pings a pool address twice before assigning a particular address to a requesting client. If the ping is unanswered, the DHCP Server assumes (with a high probability) that the address is not in use and assigns the address to the requesting client. To change the number of ping packets the DHCP Server should send to the pool address before assigning the address, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp ping packets number`	Specifies the number of ping packets the DHCP Server sends to a pool address before assigning the address to a requesting client. The default is two packets. Setting the *count* argument to a value of 0 turns off DHCP Server ping operation completely.

Configuring the Timeout Value for Ping Packets

By default, the DHCP Server waits 500 milliseconds before timing out a ping packet. To change the amount of time the server waits, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp ping timeout milliseconds`	Specifies the amount of time the DHCP Server must wait before timing out a ping packet. The default is 500 milliseconds.

Enabling the Cisco IOS DHCP Client on Ethernet Interfaces

To acquire an IP address via DHCP on an Ethernet interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip address dhcp [client-id interface name] [hostname host-name]`	Specifies that the Ethernet interface acquires an IP address through DHCP.

Configuring DHCP Server Options Import and Autoconfiguration

The Cisco IOS DHCP server can dynamically configure options such as the DNS and WINS addresses to respond to DHCP requests from local clients behind the customer premises equipment (CPE).

Previously, network administrators needed to manually configure the Cisco IOS DHCP server on each device enabled with this feature. The Cisco IOS DHCP server was enhanced to allow configuration information to be updated automatically. Network administrators can configure one or more centralized DHCP servers to update specific DHCP options within the DHCP pools. The remote servers can request or "import" these option parameters from the centralized servers. See the section "DHCP Server Options Import and Autoconfiguration Example" later in this chapter for a configuration example.

To configure the central router to update specific DHCP options within the DHCP pools, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip dhcp pool name`	Creates a name for the a DHCP Server address pool and places you in DHCP pool configuration mode—identified by the (dhcp-config)# prompt.
Step 2	`Router(dhcp-config)# network network-number [mask | /prefix-length]`	Specifies the subnet network number and mask of the DHCP address pool. The prefix length specifies the number of bits that comprise the address prefix. The prefix is an alternative way of specifying the network mask of the client. The prefix length must be preceded by a forward slash (/).
Step 3	`Router(dhcp-config)# dns-server address [address2 ... address8]`	Specifies the IP address of a DNS server that is available to a DHCP client. One IP address is required; however, you can specify up to eight IP addresses in one command line.

To configure the remote router to import DHCP options into the DHCP server database, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip dhcp pool name`	Creates a name for the a DHCP Server address pool and places you in DHCP pool configuration mode—identified by the (dhcp-config)# prompt.
Step 2	`Router(dhcp-config)# network network-number [mask | /prefix-length]`	Specifies the subnet network number and mask of the DHCP address pool. The prefix length specifies the number of bits that comprise the address prefix. The prefix is an alternative way of specifying the network mask of the client. The prefix length must be preceded by a forward slash (/).
Step 3	`Router(dhcp-config)# import all`	Import DHCP option parameters into the DHCP server database.
Step 4	`Router(dhcp-config)# exit`	Exits DHCP pool configuration mode.
Step 5	`Router(config)# interface type number`	Configures an interface and enters interface configuration mode.
Step 6	`Router(config-if)# ip address dhcp [client-id interface name] [hostname host-name]`	Specifies that the interface acquires an IP address through DHCP.

Configuring the Relay Agent Information Option in BOOTREPLY Messages

To configure the DHCP Server to validate the relay agent information option in forwarded BOOTREPLY messages, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp relay information check`	Configures the DHCP Server to check that the relay agent information option in forwarded BOOTREPLY messages is valid.

Configuring a Relay Agent Information Reforwarding Policy

To configure a relay agent information reforwarding policy on the DHCP Server (what the DHCP Server should do if a forwarded message already contains relay information), use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp relay information policy {drop | keep |replace}`	Determines the relay information reforwarding policy in a cable modem termination system.

Enabling the DHCP Smart-Relay Feature

By default, the DHCP smart-relay feature is disabled. To enable the smart-relay functionality, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dhcp smart-relay`	Allows the DHCP relay agent to switch the gateway address (giaddr field of a DHCP packet) to secondary addresses when there is no DHCPOFFER message from a DHCP Server.

Monitoring and Maintaining the DHCP Server

To clear DHCP Server variables, use the following commands in privileged EXEC mode, as needed:

Command	Purpose
`Router# clear ip dhcp binding {address | *}`	Deletes an automatic address binding from the DHCP database. Specifying the *address* argument clears the automatic binding for a specific (client) IP address, whereas specifying an asterisk (*) clears all automatic bindings.
`Router# clear ip dhcp conflict {address | *}`	Clears an address conflict from the DHCP database. Specifying the *address* argument clears the conflict for a specific IP address, whereas specifying an asterisk (*) clears conflicts for all addresses.

Command	Purpose
`Router# clear ip dhcp server statistics`	Resets all DHCP Server counters to 0.
`Router# clear ip route [vrf vrf-name] dhcp [ip-address]`	Removes routes from the routing table added by the Cisco IOS DHCP Server and Relay Agent for the DHCP clients on unnumbered interfaces.

To enable DHCP Server debugging, use the following command in privileged EXEC mode:

Command	Purpose
`Router# debug ip dhcp server {events | packets | linkage}`	Enables debugging on the DHCP Server.

To display DHCP Server information, use the following commands in EXEC mode, as needed:

Command	Purpose
`Router# show ip dhcp binding [address]`	Displays a list of all bindings created on a specific DHCP Server. • Use the **show ip dhcp binding** to display the lease expiration time and date of the IP address of the host and the number. You can also use this command to display the IP addresses that have already been assigned.
`Router# show ip dhcp conflict [address]`	Displays a list of all address conflicts recorded by a specific DHCP Server.
`Router# show ip dhcp database [url]`	Displays recent activity on the DHCP database. **Note** Use this command in privileged EXEC mode.
`Router# show ip dhcp server statistics`	Displays count information about server statistics and messages sent and received.
`Router# show ip dhcp import`	Displays the option parameters that were imported into the DHCP Server database. Imported option parameters are not part of the router configuration and are not saved in NVRAM.
`Router# show ip route [vrf vrf-name] dhcp [ip-address]`	Displays the routes added to the routing table by the Cisco IOS DHCP Server and Relay Agent.

Configuration Examples

This section provides the following configuration examples:

- DHCP Database Agent Configuration Example
- DHCP Address Pool Configuration Example
- Manual Bindings Configuration Example
- Cisco IOS DHCP Client Example
- DHCP Server Options Import and Autoconfiguration Example

DHCP Database Agent Configuration Example

The following example stores bindings on host 172.16.4.253. The file transfer protocol is FTP. The server should wait 2 minutes (120 seconds) before writing database changes.

```
ip dhcp database ftp://user:password@172.16.4.253/router-dhcp write-delay 120
```

DHCP Address Pool Configuration Example

In the following example, three DHCP address pools are created: one in network 172.16.0.0, one in subnetwork 172.16.1.0, and one in subnetwork 172.16.2.0. Attributes from network 172.16.0.0—such as the domain name, DNS server, NetBIOS name server, and NetBIOS node type—are inherited in subnetworks 172.16.1.0 and 172.16.2.0. In each pool, clients are granted 30-day leases and all addresses in each subnetwork, except the excluded addresses, are available to the DHCP Server for assigning to clients. Table 5 lists the IP addresses for the devices in three DHCP address pools.

Table 5 DHCP Address Pool Configuration Example

Pool 0 (Network 172.16.0.0)		**Pool 1 (Subnetwork 172.16.1.0)**		**Pool 2 (Subnetwork 172.16.2.0)**	
Device	**IP Address**	**Device**	**IP Address**	**Device**	**IP Address**
Default routers	–	Default routers	172.16.1.100 172.16.1.101	Default routers	172.16.2.100 172.16.2.101
DNS Server	172.16.1.102 172.16.2.102	—	—	—	—
NetBIOS name server	172.16.1.103 172.16.2.103	—	—	—	—
NetBIOS node type	h-node	—	—	—	—

```
ip dhcp database ftp://user:password@172.16.4.253/router-dhcp write-delay 120
ip dhcp excluded-address 172.16.1.100 172.16.1.103
ip dhcp excluded-address 172.16.2.100 172.16.2.103
!
ip dhcp pool 0
 network 172.16.0.0 /16
 domain-name cisco.com
 dns-server 172.16.1.102 172.16.2.102
 netbios-name-server 172.16.1.103 172.16.2.103
 netbios-node-type h-node
!
ip dhcp pool 1
 network 172.16.1.0 /24
 default-router 172.16.1.100 172.16.1.101
 lease 30
!
ip dhcp pool 2
 network 172.16.2.0 /24
 default-router 172.16.2.100 172.16.2.101
 lease 30
```

Manual Bindings Configuration Example

The following example creates a manual binding for a client named Mars.cisco.com. The MAC address of the client is 02c7.f800.0422 and the IP address of the client is 172.16.2.254.

```
ip dhcp pool Mars
 host 172.16.2.254
 hardware-address 02c7.f800.0422 ieee802
 client-name Mars
```

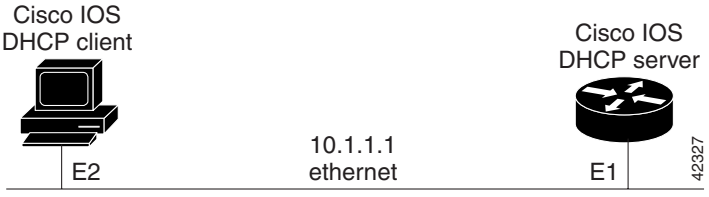
Because attributes are inherited, the previous configuration is equivalent to the following:

```
ip dhcp pool Mars
 host 172.16.2.254 mask 255.255.255.0
 hardware-address 02c7.f800.0422 ieee802
 client-name Mars
 default-router 172.16.2.100 172.16.2.101
 domain-name cisco.com
 dns-server 172.16.1.102 172.16.2.102
 netbios-name-server 172.16.1.103 172.16.2.103
 netbios-node-type h-node
```

Cisco IOS DHCP Client Example

Figure 15 shows a simple network diagram of a DHCP client on an Ethernet LAN.

Figure 15 Topology Showing DHCP Client with Ethernet Interface



On the DHCP Server, the configuration is as follows:

```
ip dhcp pool 1
 network 10.1.1.0 255.255.255.0
 lease 1 6
```

On the DHCP client, the configuration is as follows on interface E2:

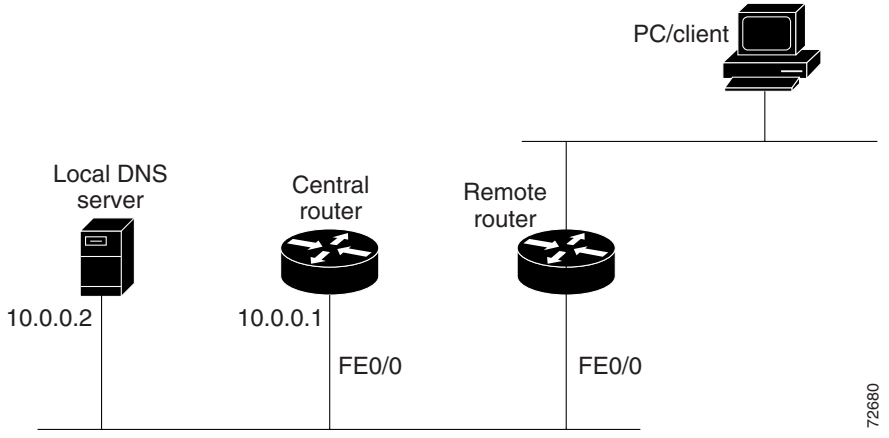
```
interface Ethernet2
 ip address dhcp
```

This configuration allows the DHCP client to aquire an IP address from the DHCP Server through an Ethernet interface.

DHCP Server Options Import and Autoconfiguration Example

The following example shows a remote and central server configured to support DHCP options import and autoconfiguration. The central server is configured to automatically update DHCP options, such as DNS and WINs addresses, within the DHCP pools. In response to a DHCP request from a local client behind CPE equipment, the remote server can request or "import" these option parameters from the centralized server. See Figure 16 for a diagram of the network topology.

Figure 16 DHCP Example Network Topology



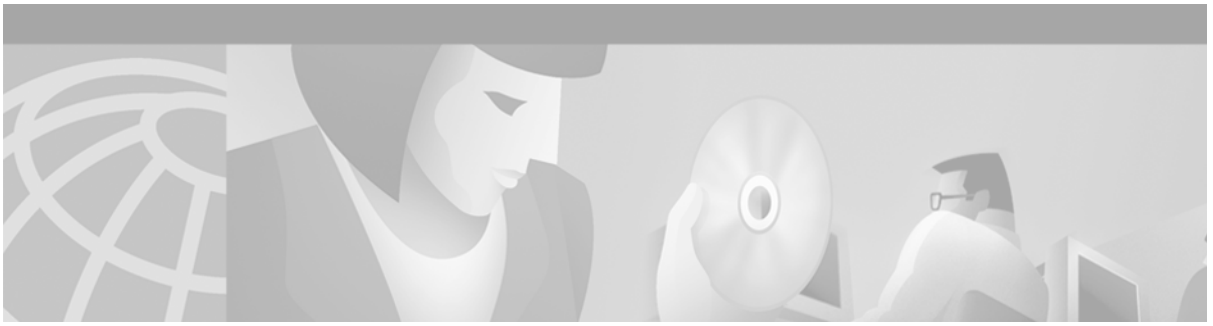
Central Router

```
!do not assign this range to DHCP clients
ip dhcp-excluded address 10.0.0.1 10.0.0.5
!
ip dhcp pool central
! Specifies network number and mask for DHCP clients
 network 10.0.0.0 255.255.255.0
! Specifes the domain name for the client
 domain-name central
! Specifies DNS server that will respond to DHCP clients when they need to correlate host
! name to ip address
 dns-server 10.0.0.2
!Specifies the NETBIOS WINS server
 netbios-name-server 10.0.0.2
!
interface FastEthernet0/0
 ip address 10.0.0.1 255.255.255.0
 duplex auto
 speed auto
```

Remote Router

```
!
ip dhcp pool client
! Imports DHCP options parameters into DHCP server database
 import all
 network 20.0.0.0 255.255.255.0
!
interface FastEthernet0/0
 ip address dhcp
 duplex auto
```

```
 speed auto
```



Configuring IP Services

This chapter describes how to configure optional IP services. For a complete description of the IP services commands in this chapter, refer to the "IP Services Commands" chapter of the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services*. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

IP Services Task List

To configure optional IP services, perform any of the optional tasks described in the following sections:

- Managing IP Connections (Optional)
- Filtering IP Packets Using Access Lists (Optional)
- Configuring the Hot Standby Router Protocol (Optional)
- Configuring IP Accounting (Optional)
- Configuring TCP Performance Parameters (Optional)
- Configuring IP over WANs (Optional)
- Configuring the MultiNode Load Balancing Forwarding Agent (Optional)
- Monitoring and Maintaining the IP Network (Optional)

Remember that not all the tasks in these sections are required. The tasks you must perform will depend on your network and your needs.

At the end of this chapter, the examples in the "IP Services Configuration Examples" section illustrate how you might configure your network using IP.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter of this book.

Managing IP Connections

The IP suite offers a number of services that control and manage IP connections. Internet Control Message Protocol (ICMP) provides many of these services. ICMP messages are sent by routers or access servers to hosts or other routers when a problem is discovered with the Internet header. For detailed information on ICMP, see RFC 792.

To manage various aspects of IP connections, perform the optional tasks described in the following sections:

- Enabling ICMP Protocol Unreachable Messages (Optional)
- Enabling ICMP Redirect Messages (Optional)
- Enabling ICMP Mask Reply Messages (Optional)
- Understanding Path MTU Discovery (Optional)
- Setting the MTU Packet Size (Optional)
- Enabling IP Source Routing (Optional)
- Configuring Simplex Ethernet Interfaces (Optional)
- Configuring a DRP Server Agent (Optional)

See the "ICMP Services Example" section at the end of this chapter for examples of ICMP services.

Enabling ICMP Protocol Unreachable Messages

If the Cisco IOS software receives a nonbroadcast packet destined for itself that uses an unknown protocol, it sends an ICMP protocol unreachable message back to the source. Similarly, if the software receives a packet that it is unable to deliver to the ultimate destination because it knows of no route to the destination address, it sends an ICMP host unreachable message to the source. This feature is enabled by default.

To enable this service if it has been disabled, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip unreachables`	Enables the sending of ICMP protocol unreachable and host unreachable messages.

To limit the rate that ICMP destination unreachable messages are generated, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip icmp rate-limit unreachable [df] milliseconds`	Limits the rate that ICMP destination unreachable messages are generated.

Enabling ICMP Redirect Messages

Routes are sometimes less than optimal. For example, it is possible for the router to be forced to resend a packet through the same interface on which it was received. If the router resends a packet through the same interface on which it was received, the Cisco IOS software sends an ICMP redirect message to the originator of the packet telling the originator that the router is on a subnet directly connected to the receiving device, and that it must forward the packet to another system on the same subnet. The software sends an ICMP redirect message to the originator of the packet because the originating host presumably could have sent that packet to the next hop without involving this device at all. The redirect message instructs the sender to remove the receiving device from the route and substitute a specified device representing a more direct path. This feature is enabled by default.

To enable the sending of ICMP redirect messages if this feature was disabled, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip redirects`	Enables the sending of ICMP redirect messages to learn routes.

Enabling ICMP Mask Reply Messages

Occasionally, network devices must know the subnet mask for a particular subnetwork in the internetwork. To obtain this information, such devices can send ICMP mask request messages. ICMP mask reply messages are sent in reply from devices that have the requested information. The Cisco IOS software can respond to ICMP mask request messages if this function is enabled.

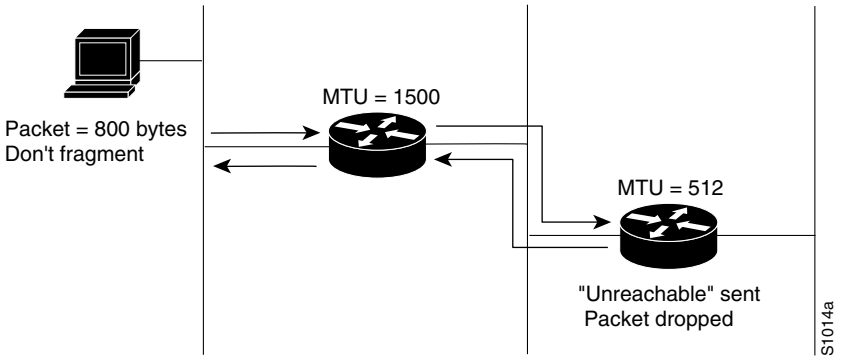
To enable the sending of ICMP mask reply messages, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip mask-reply`	Enables the sending of ICMP mask reply messages.

Understanding Path MTU Discovery

The Cisco IOS software supports the IP Path MTU Discovery mechanism, as defined in RFC 1191. IP Path MTU Discovery allows a host to dynamically discover and cope with differences in the maximum allowable maximum transmission unit (MTU) size of the various links along the path. Sometimes a router is unable to forward a datagram because it requires fragmentation (the packet is larger than the MTU you set for the interface with the **ip mtu** interface configuration command), but the "don't fragment" (DF) bit is set. The Cisco IOS software sends a message to the sending host, alerting it to the problem. The host will need to fragment packets for the destination so that they fit the smallest packet size of all the links along the path. This technique is shown in Figure 17.

Figure 17 IP Path MTU Discovery



IP Path MTU Discovery is useful when a link in a network goes down, forcing the use of another, different MTU-sized link (and different routers). As shown in Figure 17, suppose a router is sending IP packets over a network where the MTU in the first router is set to 1500 bytes, but the second router is set to 512 bytes. If the "Don't fragment" bit of the datagram is set, the datagram would be dropped

because the 512-byte router is unable to forward it. All packets larger than 512 bytes are dropped in this case. The second router returns an ICMP destination unreachable message to the source of the datagram with its Code field indicating, "Fragmentation needed and DF set." To support IP Path MTU Discovery, it would also include the MTU of the next hop network link in the low-order bits of an unused header field.

IP Path MTU Discovery is also useful when a connection is being established and the sender has no information at all about the intervening links. It is always advisable to use the largest MTU that the links will bear; the larger the MTU, the fewer packets the host must send.

Note IP Path MTU Discovery is a process initiated by end hosts. If an end host does not support IP Path MTU Discovery, the receiving device will have no mechanism available to avoid fragmenting datagrams generated by the end host.

If a router that is configured with a small MTU on an outbound interface receives packets from a host that is configured with a large MTU (for example, receiving packets from a Token Ring interface and forwarding them to an outbound Ethernet interface), the router fragments received packets that are larger than the MTU of the outbound interface. Fragmenting packets slows the performance of the router. To keep routers in your network from fragmenting received packets, run IP Path MTU Discovery on all hosts and routers in your network, and always configure the largest possible MTU for each router interface type.

To enable IP Path MTU Discovery for connections initiated by the router (when the router is acting as a host), see the section "Enabling TCP Path MTU Discovery" later in this chapter.

Setting the MTU Packet Size

All interfaces have a default MTU packet size. You can adjust the IP MTU size so that the Cisco IOS software will fragment any IP packet that exceeds the MTU set for an interface.

Changing the MTU value (with the **mtu** interface configuration command) can affect the IP MTU value. If the current IP MTU value is the same as the MTU value and you change the MTU value, the IP MTU value will be modified automatically to match the new MTU. However, the reverse is not true; changing the IP MTU value has no effect on the value for the **mtu** interface configuration command.

Also, all devices on a physical medium must have the same protocol MTU in order to operate.

To set the MTU packet size for a specified interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip mtu` *bytes*	Sets the IP MTU packet size for an interface.

Enabling IP Source Routing

The Cisco IOS software examines IP header options on every packet. It supports the IP header options Strict Source Route, Loose Source Route, Record Route, and Time Stamp, which are defined in RFC 791. If the software finds a packet with one of these options enabled, it performs the appropriate action. If it finds a packet with an invalid option, it sends an ICMP parameter problem message to the source of the packet and discards the packet.

IP provides a provision known as *source routing* that allows the source IP host to specify a route through the IP network. Source routing is specified as an option in the IP header. If source routing is specified, the software forwards the packet according to the specified source route. This feature is employed when you want to force a packet to take a certain route through the network. The default is to perform source routing.

To enable IP source-route header options if they have been disabled, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip source-route`	Enables IP source routing.

Configuring Simplex Ethernet Interfaces

You can configure simplex Ethernet interfaces. This feature is useful for setting up dynamic IP routing over a simplex circuit (a circuit that receives only or sends only). When a route is learned on a receive-only interface, the interface designated as the source of the route is converted to the interface you specify. When packets are routed out this specified interface, they are sent to the IP address of the source of the routing update. To reach this IP address on a transmit-only Ethernet link, a static Address Resolution Protocol (ARP) entry mapping this IP address to the hardware address of the other end of the link is required.

To assign a transmit interface to a receive-only interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# transmit-interface type number`	Assigns a transmit interface to a receive-only interface.

See the "Simplex Ethernet Interfaces Example" section at the end of this chapter for an example of configuring a simplex Ethernet interface.

Configuring a DRP Server Agent

The Director Response Protocol (DRP) is a simple User Datagram Protocol (UDP)-based application developed by Cisco Systems. It enables the Cisco DistributedDirector product to query routers (DRP Server Agents) in the field for Border Gateway Protocol (BGP) and Interior Gateway Protocol (IGP) routing table metrics between distributed servers and clients. DistributedDirector, a separate standalone product, uses DRP to transparently redirect end-user service requests to the topologically closest responsive server. DRP enables DistributedDirector to provide dynamic, scalable, and "network intelligent" Internet traffic load distribution between multiple geographically dispersed servers.

DRP Server Agents are border routers (or peers to border routers) that support the geographically distributed servers for which DistributedDirector service distribution is desired. Note that, because DistributedDirector makes decisions based on BGP and IGP information, all DRP Server Agents must have access to full BGP and IGP routing tables.

Refer to the *Cisco DistributedDirector 2501 Installation and Configuration Guide* or the *Cisco DistributedDirector 4700-M Installation and Configuration Guide* for information on how to configure DistributedDirector.

To configure and maintain the DRP Server Agent, perform the tasks described in the following sections. The task in the first section is required; the tasks in the remaining sections are optional.

- Enabling the DRP Server Agent (Required)
- Limiting the Source of DRP Queries (Optional)
- Configuring Authentication of DRP Queries and Responses (Optional)

To monitor and maintain the DRP Server Agent, see the section "Monitoring and Maintaining the DRP Server Agent" later in this chapter.

For an example of configuring a DRP Server Agent, see the section "DRP Server Agent Example" at the end of this chapter.

Enabling the DRP Server Agent

The DRP Server Agent is disabled by default. To enable it, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip drp server`	Enables the DRP Server Agent.

Limiting the Source of DRP Queries

As a security measure, you can limit the source of valid DRP queries. If a standard IP access list is applied to the interface, the Server Agent will respond only to DRP queries originating from an IP address in the list. If no access list is configured, the Server Agent will answer all queries.

If both an access group and a key chain (described in the next section) have been configured, both security mechanisms must allow access before a request is processed.

To limit the source of valid DRP queries, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip drp access-group` *access-list-number*	Controls the sources of valid DRP queries by applying a standard IP access list.

Configuring Authentication of DRP Queries and Responses

Another available security measure is to configure the DRP Server Agent to authenticate DRP queries and responses. You define a key chain, identify the keys that belong to the key chain, and specify how long each key is valid. To do so, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip drp authentication key-chain` *name-of-chain*	Identifies which key chain to use to authenticate all DRP requests and responses.
Step 2	`Router(config)# key chain` *name-of-chain*	Identifies a key chain (match the name configured in Step 1).
Step 3	`Router(config-keychain)# key` *number*	In key-chain configuration mode, identifies the key number.

	Command	Purpose
Step 4	`Router(config-keychain-key)# key-string text`	In key-chain key configuration mode, identifies the key string.
Step 5	`Router(config-keychain-key)# accept-lifetime start-time {infinite | end-time | duration seconds}`	(Optional) Specifies the time period during which the key can be received.
Step 6	`Router(config-keychain-key)# send-lifetime start-time {infinite | end-time | duration seconds}`	(Optional) Specifies the time period during which the key can be sent.

When configuring your key chains and keys, be aware of the following guidelines:

- The key chain configured for the DRP Server Agent in Step 1 must match the key chain in Step 2.
- The key configured in the primary agent in the remote router must match the key configured in the DRP Server Agent in order for responses to be processed.
- You can configure multiple keys with lifetimes, and the software will rotate through them.
- If authentication is enabled and multiple keys on the key chain happen to be active based on the **send-lifetime** values, the software uses only the first key it encounters for authentication.
- Use the **show key chain** command to display key chain information.

Note To configure lifetimes for DRP authentication, you must configure time services for your router. For information on setting time services, see the Network Time Protocol (NTP) and calendar commands in the "Performing Basic System Management" chapter of the *Cisco IOS Configuration Fundamentals Configuration Guide*.

Filtering IP Packets Using Access Lists

Packet filtering helps control packet movement through the network. Such control can help limit network traffic and restrict network use by certain users or devices. To permit or deny packets from crossing specified interfaces, we provide *access lists.*

You can use access lists in the following ways:

- To control the transmission of packets on an interface
- To control vty access
- To restrict contents of routing updates

This section summarizes how to create IP access lists and how to apply them.

See the "IP Services Configuration Examples" section at the end of this chapter for examples of configuring IP access lists.

An access list is a sequential collection of permit and deny conditions that apply to IP addresses. The Cisco IOS software tests addresses against the conditions in an access list one by one. The first match determines whether the software accepts or rejects the address. Because the software stops testing conditions after the first match, the order of the conditions is critical. If no conditions match, the software rejects the address.

The two main tasks involved in using access lists are as follows:

1. Create an access list by specifying an access list number or name and access conditions.

2. Apply the access list to interfaces or terminal lines.

These and other tasks are described in this section and are labeled as required or optional. Either the first or second task is required, depending on whether you identify your access list with a number or a name.

- Creating Standard and Extended Access Lists Using Numbers (Required)
- Creating Standard and Extended Access Lists Using Names (Required)
- Specifying IP Extended Access Lists with Fragment Control (Optional)
- Enabling Turbo Access Control Lists (Optional)
- Applying Time Ranges to Access Lists (Optional)
- Including Comments About Entries in Access Lists (Optional)
- Applying Access Lists (Required)

Creating Standard and Extended Access Lists Using Numbers

Cisco IOS software supports the following types of access lists for IP:

- Standard IP access lists that use source addresses for matching operations.
- Extended IP access lists that use source and destination addresses for matching operations, and optional protocol type information for finer granularity of control.
- Dynamic extended IP access lists that grant access per user to a specific source or destination host basis through a user authentication process. In essence, you can allow user access through a firewall dynamically, without compromising security restrictions. Dynamic access lists and lock-and-key access are described in the "Configuring Traffic Filters" chapter of the *Cisco IOS Security Configuration Guide*.
- Reflexive access lists that allow IP packets to be filtered based on session information. Reflexive access lists contain temporary entries, and are nested within an extended, named IP access list. For information on reflexive access lists, refer to the "Configuring IP Session Filtering (Reflexive Access Lists)" chapter in the *Cisco IOS Security Configuration Guide* and the "Reflexive Access List Commands" chapter in the *Cisco IOS Security Command Reference*.

Note Release 11.1 introduced substantial changes to IP access lists. These extensions are backward compatible; migrating from a release earlier than Release 11.1 to the current release will convert your access lists automatically. However, the current implementation of access lists is incompatible with Cisco IOS Release 11.1 or earlier. If you create an access list using the current Cisco IOS release and then load older Cisco IOS software, the resulting access list will not be interpreted correctly. This condition could cause you severe security problems. Save your old configuration file before booting Release 11.1 or earlier images.

To create a standard access list, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# access-list access-list-number remark remark`	Indicates the purpose of the **deny** or **permit** statement.[1]

Step 2	`Router(config)# access-list access-list-number {deny | permit} source [source-wildcard] [log]`
	
	or
	
	`Router(config)# access-list access-list-number {deny | permit} any [log]`
		Defines a standard IP access list using a source address and wildcard.
		
		Defines a standard IP access list using an abbreviation for the source and source mask of 0.0.0.0 255.255.255.255.

1. This example configures the remark before the **deny** or **permit** statement. The remark can be configured after the **deny** or **permit** statement.

The Cisco IOS software can provide logging messages about packets permitted or denied by a standard IP access list. That is, any packet that matches the access list will cause an informational logging message about the packet to be sent to the console. The level of messages logged to the console is controlled by the **logging console** global configuration command.

The first packet that triggers the access list causes an immediate logging message, and subsequent packets are collected over 5-minute intervals before they are displayed or logged. The logging message includes the access list number, whether the packet was permitted or denied, the source IP address of the packet, and the number of packets from that source permitted or denied in the prior 5-minute interval.

However, you can use the **ip access-list log-update** command to set the number of packets that, when match an access list (and are permitted or denied), cause the system to generate a log message. You might want to do this to receive log messages more frequently than at 5-minute intervals.

Caution If you set the *number-of-matches* argument to 1, a log message is sent right away, rather than caching it; every packet that matches an access list causes a log message. A setting of 1 is not recommended because the volume of log messages could overwhelm the system.

Even if you use the **ip access-list log-update** command, the 5-minute timer remains in effect, so each cache is emptied at the end of 5 minutes, regardless of the count of messages in each cache. Regardless of when the log message is sent, the cache is flushed and the count reset to 0 for that message the same way it is when a threshold is not specified.

Note The logging facility might drop some logging message packets if there are too many to be handled or if there is more than one logging message to be handled in 1 second. This behavior prevents the router from crashing due to too many logging packets. Therefore, the logging facility should not be used as a billing tool or an accurate source of the number of matches to an access list.

Note If you enable CEF and then create an access list that uses the **log** keyword, the packets that match the access list are not CEF switched. They are fast switched. Logging disables CEF.

For an example of a standard IP access list using logs, see the section "Numbered Access List Examples" at the end of this chapter.

To create an extended access list, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# access-list` *access-list-number* **remark** *remark*	Indicates the purpose of the **deny** or **permit** statement.[1]
Step 2	`Router(config)# access-list` *access-list-number* {**deny** | **permit**} *protocol source source-wildcard destination destination-wildcard* [**precedence** ***precedence***] [**tos** *tos*] [**established**] [**log** | **log-input**] [**time-range** *time-range-name*] [**fragments**]	Defines an extended IP access list number and the access conditions. Specifies a time range to restrict when the **permit** or **deny** statement is in effect. Use the **log** keyword to get access list logging messages, including violations. Use the **log-input** keyword to include input interface, source MAC address, or VC in the logging output.
	or	or
	`Router(config)# access-list` *access-list-number* {**deny** | **permit**} *protocol* **any any** [**log** | **log-input**] [**time-range** *time-range-name*] [**fragments**]	Defines an extended IP access list using an abbreviation for a source and source wildcard of 0.0.0.0 255.255.255.255, and an abbreviation for a destination and destination wildcard of 0.0.0.0 255.255.255.255.
	or	or
	`Router(config)# access-list` *access-list-number* {**deny** | **permit**} *protocol* **host** *source* **host** *destination* [**log** | **log-input**] [**time-range** *time-range-name*][**fragments**]	Defines an extended IP access list using an abbreviation for a source and source wildcard of *source* 0.0.0.0, and an abbreviation for a destination and destination wildcard of *destination* 0.0.0.0.
	or	or
	`Router(config)# access-list` *access-list-number* [**dynamic** *dynamic-name* [**timeout** *minutes*]] {**deny** | **permit**} *protocol source source-wildcard destination destination-wildcard* [**precedence** *precedence*] [**tos** *tos*] [**established**] [**log** | **log-input**] [**time-range** *time-range-name*] [**fragments**]	Defines a dynamic access list. For information about lock-and-key access, refer to the "Configuring Traffic Filters" chapter in the *Cisco IOS Security Configuration Guide*.

1. This example configures the remark before the **deny** or **permit** statement. The remark can be configured after the **deny** or **permit** statement.

Note The **fragments** keyword is described in the Specifying IP Extended Access Lists with Fragment Control section.

After you create an access list, you place any subsequent additions (possibly entered from the terminal) at the end of the list. In other words, you cannot selectively add or remove access list command lines from a specific access list.

Note When creating an access list, remember that, by default, the end of the access list contains an implicit deny statement for everything if it did not find a match before reaching the end.

Note In a standard access list, if you omit the mask from an associated IP host address access list specification, 0.0.0.0 is assumed to be the mask.

Note Autonomous switching is not used when you have extended access lists.

After creating an access list, you must apply it to a line or interface, as shown in the section "Applying Access Lists" later in this chapter. See the "Implicit Masks in Access Lists Examples" section at the end of this chapter for examples of implicit masks.

Creating Standard and Extended Access Lists Using Names

You can identify IP access lists with an alphanumeric string (a name) rather than a number. Named access lists allow you to configure more IP access lists in a router than if you were to use numbered access lists. If you identify your access list with a name rather than a number, the mode and command syntax are slightly different. Currently, only packet and route filters can use a named list.

Consider the following guidelines before configuring named access lists:

- Access lists specified by name are not compatible with Cisco IOS Releases prior to 11.2.
- Not all access lists that accept a number will accept a name. Access lists for packet filters and route filters on interfaces can use a name.
- A standard access list and an extended access list cannot have the same name.
- Numbered access lists are also available, as described in the previous section, "Creating Standard and Extended Access Lists Using Numbers."

Note Named access lists will not be recognized by any software release prior to Cisco IOS Release 11.2.

To create a standard access list, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip access-list standard` *name*	Defines a standard IP access list using a name and enters standard named access list configuration mode.
Step 2	`Router(config-std-nacl)# remark` *remark*	Allows you to comment about the following **deny** or **permit** statement in a named access list.[1]
Step 3	`Router(config-std-nacl)# deny` {*source* [*source-wildcard*] | **any**}[**log**] and/or `Router(config-std-nacl)# permit` {*source* [*source-wildcard*] | **any**}[**log**]	Specifies one or more conditions allowed or denied, which determines whether the packet is passed or dropped.
Step 4	`Router(config-std-nacl)# exit`	Exits access-list configuration mode.

1. This example configures the remark before the **deny** or **permit** statement. The remark can be configured after the **deny** or **permit** statement.

To create an extended access list, use the following commands beginning in global configuration mode:

Step 1	`Router(config)# ip access-list extended` *name*	Defines an extended IP access list using a name and enters extended named access list configuration mode.
Step 2	`Router(config-ext-nacl)# remark` *remark*	Allows you to comment about the following **deny** or **permit** statement in a named access list.[1]
Step 3	`Router(config-ext-nacl)# deny | permit` *protocol source source-wildcard destination destination-wildcard* `[precedence` *precedence*`] [tos` *tos*`] [established] [log | log-input] [time-range` *time-range-name*`] [fragments]`	In access-list configuration mode, specifies the conditions allowed or denied. Specifies a time range to restrict when the **permit** or **deny** statement is in effect. Use the **log** keyword to get access list logging messages, including violations. Use the **log-input** keyword to include input interface, source MAC address, or VC in the logging output.
	or	or
	`Router(config-ext-nacl)# deny | permit` *protocol* **any any** `[log | log-input] [time-range` *time-range-name*`] [fragments]`	Defines an extended IP access list using an abbreviation for a source and source wildcard of 0.0.0.0 255.255.255.255, and an abbreviation for a destination and destination wildcard of 0.0.0.0 255.255.255.255.
	or	or
	`Router(config-ext-nacl) deny | permit` *protocol* **host** *source* **host** *destination* `[log | log-input] [time-range` *time-range-name*`] [fragments]`	Defines an extended IP access list using an abbreviation for a source and source wildcard of *source* 0.0.0.0, and an abbreviation for a destination and destination wildcard of *destination* 0.0.0.0.
	or	or
	`Router(config-ext-nacl)# dynamic` *dynamic-name* `[timeout` *minutes*`] {deny | permit}` *protocol source source-wildcard destination destination-wildcard* `[precedence` *precedence*`] [tos` *tos*`] [established] [log | log-input] [time-range` *time-range-name*`] [fragments]`	Defines a dynamic access list.

1. This example configures the remark before the deny or permit statement. The remark can be configured after the deny or permit statement.

Note Autonomous switching is not used when you have extended access lists.

Note The **fragments** keyword is described in the Specifying IP Extended Access Lists with Fragment Control section.

After you initially create an access list, you place any subsequent additions (possibly entered from the terminal) at the end of the list. In other words, you cannot selectively add access list command lines to a specific access list. However, you can use **no permit** and **no deny** commands to remove entries from a named access list.

Note When making the standard and extended access list, remember that, by default, the end of the access list contains an implicit deny statement for everything if it did not find a match before reaching the end. Further, with standard access lists, if you omit the mask from an associated IP host address access list specification, 0.0.0.0 is assumed to be the mask.

After creating an access list, you must apply it to a line or interface, as shown in section "Applying Access Lists" later in this chapter.

See the "Named Access List Example" section at the end of this chapter for an example of a named access list.

Specifying IP Extended Access Lists with Fragment Control

This section describes the functionality added to IP extended named and numbered access lists. You can now specify whether the system examines noninitial IP fragments of packets when applying an IP extended access list.

Prior to this feature, nonfragmented packets and the initial fragment of a packet were processed by IP extended access lists (if such an access list was applied), but noninitial fragments were permitted by default. The IP Extended Access Lists with Fragment Control feature now allows more granularity of control over noninitial packets.

Because noninitial fragments contain only Layer 3 information, access-list entries containing only Layer 3 information can and now are applied to noninitial fragments. The fragment has all the information the system needs to filter, so the entry is applied to the fragments.

This feature adds the optional **fragments** keyword to four IP access list commands [**access-list (IP extended**), **deny (IP)**, **dynamic**, and **permit (IP)**]. By specifying the **fragments** keyword in an access list entry, that particular access list entry applies only to noninitial fragments of packets; the fragment is either permitted or denied accordingly.

The behavior of access-list entries regarding the presence or absence of the **fragments** keyword can be summarized as follows:

If the Access-List Entry has...	Then..
...no **fragments** keyword, and assuming all of the access-list entry information matches,	For an access-list entry containing only Layer 3 information: • The entry is applied to nonfragmented packets, initial fragments and noninitial fragments. For an access list entry containing Layer 3 and Layer 4 information: • The entry is applied to nonfragmented packets and initial fragments. – If the entry matches and is a **permit** statement, the packet or fragment is permitted. – If the entry matches and is a **deny** statement, the packet or fragment is denied. • The entry is also applied to noninitial fragments in the following manner. Because noninitial fragments contain only Layer 3 information, only the Layer 3 portion of an access-list entry can be applied. If the Layer 3 portion of the access-list entry matches, and – If the entry is a **permit** statement, the noninitial fragment is permitted. – If the entry is a **deny** statement, the next access-list entry is processed. **Note** Note that the **deny** statements are handled differently for noninitial fragments versus nonfragmented or initial fragments.
...the **fragments** keyword, and assuming all of the access-list entry information matches,	The access-list entry is applied only to noninitial fragments. **Note** The **fragments** keyword cannot be configured for an access-list entry that contains any Layer 4 information.

Be aware that you should not simply add the **fragments** keyword to every access list entry because the first fragment of the IP packet is considered a nonfragment and is treated independently of the subsequent fragments. An initial fragment will not match an access list **permit** or **deny** entry that contains the **fragments** keyword, the packet is compared to the next access list entry, and so on, until it is either permitted or denied by an access list entry that does not contain the **fragments** keyword. Therefore, you may need two access list entries for every **deny** entry. The first **deny** entry of the pair will not include the **fragments** keyword, and applies to the initial fragment. The second **deny** entry of the pair will include the **fragments** keyword and applies to the subsequent fragments. In the cases where there are multiple **deny** access list entries for the same host but with different Layer 4 ports, a single **deny** access-list entry with the **fragments** keyword for that host is all that needs to be added. Thus all the fragments of a packet are handled in the same manner by the access list.

The **fragments** keyword can be applied to dynamic access lists also.

Packet fragments of IP datagrams are considered individual packets and each counts individually as a packet in access list accounting and access list violation counts.

Note The **fragments** keyword cannot solve all cases involving access lists and IP fragments.

Turbo Access Lists

A turbo access list treats fragments and uses the **fragments** keyword in the same manner as a nonturbo access list.

Policy Routing

Fragmentation and the fragment control feature affect policy routing if the policy routing is based on the **match ip address** command and the access list had entries that match on Layer 4 through 7 information. It is possible that noninitial fragments pass the access list and are policy routed, even if the first fragment was not policy routed or the reverse.

By using the **fragments** keyword in access list entries as described earlier, a better match between the action taken for initial and noninitial fragments can be made and it is more likely policy routing will occur as intended.

Benefits of Fragment Control in an IP Extended Access List

If the **fragments** keyword is used in additional IP access list entries that deny fragments, the fragment control feature provides the following benefits:

Additional Security

You are able to block more of the traffic you intended to block, not just the initial fragment of such packets. The unwanted fragments no longer linger at the receiver until the reassembly timeout is reached because they are blocked before being sent to the receiver. Blocking a greater portion of unwanted traffic improves security and reduces the risk from potential hackers.

Reduced Cost

By blocking unwanted noninitial fragments of packets, you are not paying for traffic you intended to block.

Reduced Storage

By blocking unwanted noninitial fragments of packets from ever reaching the receiver, that destination does not have to store the fragments until the reassembly timeout period is reached.

Expected Behavior is Achieved

The noninitial fragments will be handled in the same way as the initial fragment, which is what you would expect. There are fewer unexpected policy routing results and fewer fragment of packets being routed when they should not be.

For an example of fragment control in an IP extended access list, see the IP Extended Access List with Fragment Control Example.

Enabling Turbo Access Control Lists

The Turbo Access Control Lists (Turbo ACL) feature processes access lists more expediently than conventional access lists. This feature enables Cisco 7200 and 7500 series routers, and Cisco 12000 series Gigabit Switch Routers, to evaluate ACLs for more expedient packet classification and access checks.

ACLs are normally searched sequentially to find a matching rule, and ACLs are ordered specifically to take this factor into account. Because of the increasing needs and requirements for security filtering and packet classification, ACLs can expand to the point that searching the ACL adds a substantial amount of time and memory when packets are being forwarded. Moreover, the time taken by the router to search the list is not always consistent, adding a variable latency to the packet forwarding. A high CPU load is necessary for searching an access list with several entries.

The Turbo ACL feature compiles the ACLs into a set of lookup tables, while maintaining the first match requirements. Packet headers are used to access these tables in a small, fixed number of lookups, independently of the existing number of ACL entries. The benefits of this feature include the following:

- For ACLs larger than three entries, the CPU load required to match the packet to the predetermined packet-matching rule is lessened. The CPU load is fixed, regardless of the size of the access list, allowing for larger ACLs without incurring any CPU overhead penalties. The larger the access list, the greater the benefit.
- The time taken to match the packet is fixed, so that latency of the packets is smaller (substantially in the case of large access lists) and, more importantly, consistent, allowing better network stability and more accurate transit times.

Note Access lists containing specialized processing characteristics such as evaluate and time-range entries are excluded from Turbo ACL acceleration.

The Turbo ACL builds a set of lookup tables from the ACLs in the configuration; these tables increase the internal memory usage, and in the case of large and complex ACLs, tables containing 2 MB to 4 MB of memory are usually required. Routers enabled with the Turbo ACL feature should allow for this amount of memory usage. The **show access-list compiled** EXEC command displays the memory overhead of the Turbo ACL tables for each access list.

To configure the Turbo ACL feature, perform the tasks described in the following sections. The task in the first section is required; the task in the remaining section is optional:

- Configuring Turbo ACLs (Required)
- Verifying Turbo ACLs (Optional)

Configuring Turbo ACLs

To enable the Turbo ACL feature, use the following command in global configuration mode:

Command	Purpose
`Router(config)# access-list compiled`	Enables the Turbo ACL feature.

Verifying Turbo ACLs

Use the **show access-list compiled** EXEC command to verify that the Turbo ACL feature has been successfully configured on your router. This command also displays the memory overhead of the Turbo ACL tables for each access list. The command output contains the following states:

- Operational—The access list has been compiled by Turbo ACL, and matching to this access list is performed through the Turbo ACL tables at high speed.
- Unsuitable—The access list is not suitable for compiling, perhaps because it has time-range enabled entries, evaluate references, or dynamic entries.
- Deleted—No entries are in this access list.
- Building—The access list is being compiled. Depending on the size and complexity of the list, and the load on the router, the building process may take a few seconds.
- Out of memory—An access list cannot be compiled because the router has exhausted its memory.

The following is sample output from the **show access-lists compiled** EXEC command:

```
Router# show access-lists compiled

Compiled ACL statistics:
12 ACLs loaded, 12 compiled tables
 ACL         State      Tables  Entries  Config  Fragment  Redundant  Memory
1           Operational    1        2        1         0          0      1Kb
2           Operational    1        3        2         0          0      1Kb
3           Operational    1        4        3         0          0      1Kb
4           Operational    1        3        2         0          0      1Kb
5           Operational    1        5        4         0          0      1Kb
9           Operational    1        3        2         0          0      1Kb
20          Operational    1        9        8         0          0      1Kb
21          Operational    1        5        4         0          0      1Kb
101         Operational    1       15        9         7          2      1Kb
102         Operational    1       13        6         6          0      1Kb
120         Operational    1        2        1         0          0      1Kb
199         Operational    1        4        3         0          0      1Kb
First level lookup tables:
Block      Use              Rows       Columns   Memory used
  0   TOS/Protocol            6/16     12/16      66048
  1   IP Source (MS)         10/16     12/16      66048
  2   IP Source (LS)         27/32     12/16      132096
  3   IP Dest (MS)            3/16     12/16      66048
  4   IP Dest (LS)            9/16     12/16      66048
  5   TCP/UDP Src Port        1/16     12/16      66048
  6   TCP/UDP Dest Port       3/16     12/16      66048
  7   TCP Flags/Fragment      3/16     12/16      66048
```

Applying Time Ranges to Access Lists

You can implement access lists based on the time of day and week using the **time-range** global configuration command. To do so, first define the name and times of the day and week of the time range, then reference the time range by name in an access list to apply restrictions to the access list.

Currently, IP and Internetwork Packet Exchange (IPX) named or numbered extended access lists are the only functions that can use time ranges. The time range allows the network administrator to define when the **permit** or **deny** statements in the access list are in effect. Prior to this feature, access list statements were always in effect once they were applied. The **time-range** keyword is referenced in the named and numbered extended access list task tables in the previous sections “Creating Standard and Extended Access Lists Using Numbers” and “Creating Standard and Extended Access Lists Using Names.” The

time-range command is described in the "Performing Basic System Management" chapter of the *Cisco IOS Configuration Fundamentals Configuration Guide*. See the "Time Range Applied to an IP Access List Example" section at the end of this chapter for a configuration example of IP time ranges.

Possible benefits of using time ranges include the following:

- The network administrator has more control over permitting or denying a user access to resources. These resources could be an application (identified by an IP address/mask pair and a port number), policy routing, or an on-demand link (identified as interesting traffic to the dialer).
- Network administrators can set time-based security policy, including the following:
  - Perimeter security using the Cisco IOS Firewall feature set or access lists
  - Data confidentiality with Cisco Encryption Technology or IP Security Protocol (IPSec)
- Policy-based routing (PBR) and queueing functions are enhanced.
- When provider access rates vary by time of day, it is possible to automatically reroute traffic cost effectively.
- Service providers can dynamically change a committed access rate (CAR) configuration to support the quality of service (QoS) service level agreements (SLAs) that are negotiated for certain times of day.
- Network administrators can control logging messages. Access list entries can log traffic at certain times of the day, but not constantly. Therefore, administrators can simply deny access without needing to analyze many logs generated during peak hours.

Including Comments About Entries in Access Lists

You can include comments (remarks) about entries in any named IP access list using the **remark** access-list configuration command. The remarks make the access list easier for the network administrator to understand and scan. Each remark line is limited to 100 characters.

The remark can go before or after a **permit** or **deny** statement. You should be consistent about where you put the remark so it is clear which remark describes which **permit** or **deny** statement. For example, it would be confusing to have some remarks *before* the associated **permit** or **deny** statements and some remarks *after* the associated statements. The standard and extended access list task tables in the previous sections "Creating Standard and Extended Access Lists Using Numbers" and "Creating Standard and Extended Access Lists Using Names" include the **remark** command. See the "Commented IP Access List Entry Examples" section at the end of this chapter for examples of commented IP access list entries.

Remember to apply the access list to an interface or terminal line after the access list is created. See the following section "Applying Access Lists" for more information.

Applying Access Lists

After creating an access list, you must reference the access list to make it work. To use an access list, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional:

- Controlling Access to a Line or Interface (Required)
- Controlling Policy Routing and the Filtering of Routing Information (Optional)
- Controlling Dialer Functions (Optional)

Controlling Access to a Line or Interface

After you create an access list, you can apply it to one or more interfaces. Access lists can be applied on *either* outbound or inbound interfaces. This section describes guidelines on how to accomplish this task for both terminal lines and network interfaces. Remember the following:

- When controlling access to a line, you must use a number.
- When controlling access to an interface, you can use a name or number.

To restrict access to a vty and the addresses in an access list, use the following command in line configuration mode. Only numbered access lists can be applied to lines. Set identical restrictions on all the virtual terminal lines, because a user can attempt to connect to any of them.

Command	Purpose
`Router(config-line)# access-class` *access-list-number* {**in** | **out**}	Restricts incoming and outgoing connections between a particular vty (into a device) and the addresses in an access list.

To restrict access to an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip access-group` {*access-list-number* | *access-list-name*} {**in** | **out**}	Controls access to an interface.

For inbound access lists, after receiving a packet, the Cisco IOS software checks the source address of the packet against the access list. If the access list permits the address, the software continues to process the packet. If the access list rejects the address, the software discards the packet and returns an ICMP host unreachable message.

For outbound access lists, after receiving and routing a packet to a controlled interface, the software checks the source address of the packet against the access list. If the access list permits the address, the software sends the packet. If the access list rejects the address, the software discards the packet and returns an ICMP host unreachable message.

When you apply an access list that has not yet been defined to an interface, the software will act as if the access list has not been applied to the interface and will accept all packets. Remember this behavior if you use undefined access lists as a means of security in your network.

Controlling Policy Routing and the Filtering of Routing Information

To use access lists to control policy routing and the filtering of routing information, see the "Configuring IP Routing Protocol-Independent Features" chapter of this document.

Controlling Dialer Functions

To use access lists to control dialer functions, refer to the "Preparing to Configure DDR" chapter in the *Cisco IOS Dial Technologies Configuration Guide*.

Configuring the Hot Standby Router Protocol

The Hot Standby Router Protocol (HSRP) provides high network availability because it routes IP traffic from hosts on Ethernet, FDDI, or Token Ring networks without relying on the availability of any single router. HSRP is used in a group of routers for selecting an active router and a standby router. (An active router is the router of choice for routing packets; a standby router is a router that takes over the routing duties when an active router fails, or when preset conditions are met.)

HSRP is useful for hosts that do not support a router discovery protocol (such as ICMP Router Discovery Protocol [IRDP]) and cannot switch to a new router when their selected router reloads or loses power. Because existing TCP sessions can survive the *failover*, this protocol also provides a more transparent recovery for hosts that dynamically choose a next hop for routing IP traffic.

When the HSRP is configured on a network segment, it provides a virtual MAC address and an IP address that is shared among a group of routers running HSRP. The address of this HSRP group is referred to as the *virtual IP address*. One of these devices is selected by the protocol to be the active router. The active router receives and routes packets destined for the MAC address of the group. For *n* routers running HSRP, *n* + 1 IP and MAC addresses are assigned.

HSRP detects when the designated active router fails, at which point a selected standby router assumes control of the MAC and IP addresses of the Hot Standby group. A new standby router is also selected at that time.

Devices that are running HSRP send and receive multicast UDP-based hello packets to detect router failure and to designate active and standby routers.

Previously, when HSRP was configured on an interface, ICMP redirect messages were disabled by default. With Cisco IOS Release 12.1(3)T, ICMP redirection on interfaces configured with HSRP are enabled by default. See the “Enabling HSRP Support for ICMP Redirect Messages”section later in this document for more information.

You can configure multiple Hot Standby groups on an interface, thereby making fuller use of redundant routers and load sharing. To do so, specify a group number for each Hot Standby command you configure for the interface.

Note Token Ring interfaces allow up to three Hot Standby groups each, the group numbers being 0, 1, and 2.

Note The Cisco 1000 series, Cisco 2500 series, Cisco 3000 series, Cisco 4000 series, and Cisco 4500 routers that use Lance Ethernet hardware do not support multiple Hot Standby groups on a single Ethernet interface. The Cisco 800 series, Cisco 1000 series, and Cisco 1600 series that use PQUICC Ethernet hardware do not support multiple Hot Standby groups on a single Ethernet interface. You can configure a workaround solution by using the **standby use-bia** interface configuration command, which uses the burned-in address of the interface as its virtual MAC address, instead of the preassigned MAC address.

HSRP is supported over Inter-Switch Link (ISL) encapsulation. Refer to the "Configuring Routing Between VLANs with ISL Encapsulation" chapter in the *Cisco IOS Switching Services Configuration Guide*.

With Cisco IOS Release 12.1(3)T, HSRP can provide support for a Multiprotocol Label Switching (MPLS) Virtual Private Network (VPN) interface. See the section "Enabling HSRP Support for MPLS VPNs" later in this chapter for more information,

To configure HSRP, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Enabling HSRP (Required)
- Configuring HSRP Group Attributes (Optional)
- Changing the HSRP MAC Refresh Interval (Optional)
- Enabling HSRP MIB Traps (Optional)
- Enabling HSRP Support for MPLS VPNs (Optional)
- Enabling HSRP Support for ICMP Redirect Messages (Optional)

For more information about HSRP and how to configure it on a Cisco router, see the chapter "Using HSRP for Fault-Tolerant IP Routing" in the *Cisco CCIE Fundamentals: Case Studies* publication.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

Enabling HSRP

To enable the HSRP on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# standby [group-number] ip [ip-address [secondary]]`	Enables the HSRP.

Configuring HSRP Group Attributes

To configure other Hot Standby group attributes that affect how the local router participates in HSRP, use the following commands in interface configuration mode as needed:

Command	Purpose
`Router(config-if)# standby [group-number] timers [msec] hellotime [msec] holdtime`	Configures the time between hello packets and the hold time before other routers declare the active router to be down.
`Router(config-if)# standby [group-number] priority priority`	Set the Hot Standby priority used in choosing the active router. The priority value range is from 1 to 255, where 1 denotes the lowest priority and 255 denotes the highest priority. Specify that, if the local router has priority over the current active router, the local router should attempt to take its place as the active router.
`Router(config-if)# standby [group-number] preempt [delay {minimum delay | reload delay | sync delay}]`	Configure a preemption delay, after which the Hot Standby router preempts and becomes the active router.
`Router(config-if)# standby [group-number] track type number [interface-priority]`	Configures the interface to track other interfaces, so that if one of the other interfaces goes down, the Hot Standby priority of the device is lowered.
`Router(config-if)# standby [group-number] authentication text string`	Selects an authentication string to be carried in all HSRP messages.
`Router(config-if)# standby delay minimum min-delay reload reload-delay`	Configures the delay period before the initialization of Hot Standby Router Protocol (HSRP) groups.
`Router(config-if)# standby [group-number] mac-address macaddress`	Specifies a virtual MAC address for the virtual router.
`Router(config-if)# standby use-bia [scope interface]`	Configures HSRP to use the burned-in address of an interface as its virtual MAC address instead of the preassigned MAC address (on Ethernet and FDDI) or the functional address (on Token Ring).

Changing the HSRP MAC Refresh Interval

When HSRP runs over FDDI, you can change the interval at which a packet is sent to refresh the MAC cache on learning bridges or switches. HSRP hello packets use the burned-in address (BIA) instead of the MAC virtual address. Refresh packets keep the MAC cache on switches and learning bridges current.

You can change the refresh interval on FDDI rings to a longer or shorter interval, thereby using bandwidth more efficiently. You can prevent the sending of any MAC refresh packets if you do not need them (if you have FDDI but do not have a learning bridge or switch). When changing the HSRP MAC refresh interval, be aware of the following guidelines:

- This feature applies to HSRP running over FDDI only.
- You need not configure the MAC refresh interval if you have the **standby use-bia** interface configuration command configured.

By default, a packet is sent every 10 seconds to refresh the MAC cache on learning bridges or switches. To change the interval, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# standby mac-refresh seconds`	Changes the interval at which refresh packets are sent.

For examples of this feature, see the section "HSRP MAC Refresh Interval Examples" at the end of this chapter.

Enabling HSRP MIB Traps

With Cisco IOS Release 12.0(3)T, the software supports the HSRP Management MIB feature. HSRP MIB supports Simple Network Management Protocol (SNMP) Get operations, to allow network devices to get reports about HSRP groups in a network from the network management station.

Enabling HSRP MIB trap support is done from the command-line interface (CLI), and the MIB is used for getting the reports. A trap notifies the network management station when a router leaves or enters the active or standby state. When an entry is configured from the CLI, the RowStatus for that group in the MIB immediately goes to the active state.

The Cisco IOS software supports a read-only version of the MIB, and set operations are not supported.

This feature supports four MIB tables, as follows:

- cHsrpGrpEntry table defined in CISCO-HSRP-MIB.my
- cHsrpExtIfTrackedEntry, cHsrpExtSecAddrEntry, and cHsrpExtIfEntry defined in CISCO-HSRP-EXT-MIB.my

The cHsrpGrpEntry table consists of all the group information defined in RFC 2281, *Cisco Hot Standby Router Protocol*; the other tables consist of the Cisco extensions to RFC 2281, which are defined in CISCO-HSRP-EXT-MIB.my.

To enable HSRP MIB trap support, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# snmp-server enable traps hsrp`	Enables the router to send SNMP traps and informs, and HSRP notifications.
Step 2	`Router(config)# snmp-server host host community-string hsrp`	Specifies the recipient of an SNMP notification operation, and that HSRP notifications be sent to the host.

See the section "HSRP MIB Trap Example" later in this chapter for an example of how to configure HSRP MIB trap support in your network. See the "Configuring SNMP" chapter in the *Cisco IOS Configuration Fundamentals Configuration Guide* for more information on configuring SNMP.

Enabling HSRP Support for MPLS VPNs

HSRP support on an MPLS VPN interface is useful when an Ethernet is connected between two provider edges (PEs) with either of the following conditions:

- A customer edge (CE) with a default route to the HSRP virtual IP address
- One or more hosts with the HSRP virtual IP address configured as the default gateway

Each VPN is associated with one or more VPN routing/forwarding (VRF) instances. A VRF consists of the following elements:

- IP routing table
- Cisco Express Forwarding (CEF) table
- Set of interfaces that use the CEF forwarding table
- Set of rules and routing protocol parameters to control the information in the routing tables

VPN routing information is stored in the IP routing table and the CEF table for each VRF. A separate set of routing and CEF tables is maintained for each VRF. These tables prevent information from being forwarded outside a VPN and also prevent packets that are outside a VPN from being forwarded to a router within the VPN.

HSRP currently adds ARP entries and IP hash table entries (aliases) using the default routing table instance. However, a different routing table instance is used when VRF forwarding is configured on an interface, causing ARP and ICMP echo requests for the HSRP virtual IP address to fail.

HSRP support for MPLS VPNs ensures that the HSRP virtual IP address is added to the correct IP routing table and not to the default routing table.

To configure this feature, perform the required tasks described in the following sections:

- Defining VPNs (Required)
- Enabling HSRP (Required)

Defining VPNs

To define VPNs, use the following commands on the PE routers beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip vrf vrf-name`	Enters VRF configuration mode and assigns a VRF name.
Step 2	`Router(config-vrf)# rd route-distinguisher`	Creates routing and forwarding tables.
Step 3	`Router(config-vrf)# route-target {import | export | both} route-target-ext-community`	Creates a list of import or export route target communities for the specified VRF.
Step 4	`Router(config-vrf)# exit`	Exits the current configuration mode and enters global configuration mode.
Step 5	`Router(config)# interface type number`	Specifies an interface and enters interface configuration mode.
Step 6	`Router(config-if)# ip vrf forwarding vrf-name`	Associates a VRF with an interface or subinterface.

Enabling HSRP

To enable the HSRP on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router (config-if)# standby [group-number] ip ip-address`	Enables the HSRP.

Verifying HSRP Support for MPLS VPNs

The following example shows how to use **show** EXEC commands to verify that the HSRP virtual IP address is in the correct ARP and CEF tables:

```
Router# show ip arp vrf vrf1

Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  10.2.0.1                -   00d0.bbd3.bc22  ARPA   Ethernet0/2
→ Internet  10.2.0.20               -   0000.0c07.ac01  ARPA   Ethernet0/2

Router# show ip cef vrf vrf1

Prefix              Next Hop             Interface
0.0.0.0/0           10.3.0.4             Ethernet0/3
0.0.0.0/32          receive
10.1.0.0/16         10.2.0.1             Ethernet0/2
10.2.0.0/16         attached             Ethernet0/2
10.2.0.1/32         receive
→ 10.2.0.20/32        receive
224.0.0.0/24        receive
255.255.255.255/32  receive
```

Enabling HSRP Support for ICMP Redirect Messages

Previously, ICMP redirect messages were automatically disabled on interfaces configured with HSRP. ICMP is a network layer Internet protocol that provides message packets to report errors and other information relevant to IP processing. ICMP provides many diagnostic functions and can send and redirect error packets to the host. See the section "Enabling ICMP Redirect Messages" earlier in this chapter for more information on ICMP redirect messages.

When running HSRP, it is important to prevent hosts from discovering the interface (or real) MAC addresses of routers in the HSRP group. If a host is redirected by ICMP to the real MAC address of a router, and that router later fails, then packets from the host will be lost.

With Cisco IOS Release 12.1(3)T and later, ICMP redirect messages are automatically enabled on interfaces configured with HSRP. This functionality works by filtering outgoing ICMP redirect messages through HSRP, where the next hop IP address may be changed to an HSRP virtual IP address.

Redirects to Active HSRP Routers

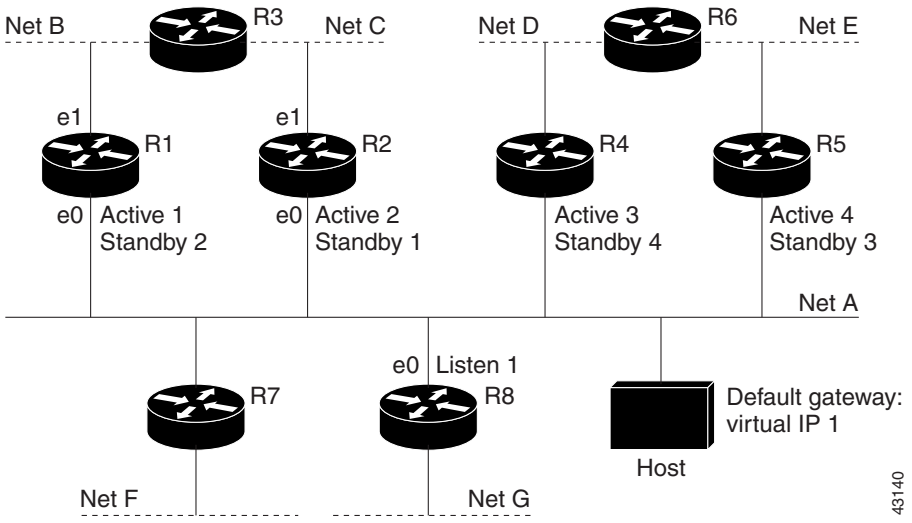
The next-hop IP address is compared to the list of active HSRP routers on that network; if a match is found, then the real next-hop IP address is replaced with a corresponding virtual IP address and the redirect message is allowed to continue.

If no match is found, then the ICMP redirect message is sent only if the router corresponding to the new next hop IP address is not running HSRP. Redirects to passive HSRP routers are not allowed (a passive HSRP router is a router running HSRP, but which contains no active HSRP groups on the interface).

For optimal operation, every router in a network that is running HSRP should contain at least one active HSRP group on an interface to that network. Every HSRP router need not be a member of the same group. Each HSRP router will snoop on all HSRP packets on the network to maintain a list of active routers (virtual IP addresses versus real IP addresses).

Consider the network shown in Figure 18, which supports the HSRP ICMP redirection filter.

Figure 18 Network Supporting the HSRP ICMP Redirection Filter



If the host wants to send a packet to another host on Net D, then it first sends it to its default gateway, the virtual IP address of HSRP group 1.

The following is the packet received from the host:

```
dest MAC         = HSRP group 1 virtual MAC
source MAC       = Host MAC
dest IP          = host-on-netD IP
source IP        = Host IP
```

Router R1 receives this packet and determines that router R4 can provide a better path to Net D, so it prepares to send a redirect message that will redirect the host to the real IP address of router R4 (because only real IP addresses are in its routing table).

The following is the initial ICMP redirect message sent by router R1:

```
dest MAC         = Host MAC
source MAC       = router R1 MAC
dest IP          = Host IP
source IP        = router R1 IP
gateway to use   = router R4 IP
```

Before this redirect occurs, the HSRP process of router R1 determines that router R4 is the active HSRP router for group 3, so it changes the next hop in the redirect message from the real IP address of router R4 to the virtual IP address of group 3. Furthermore, it determines from the destination MAC address of the packet that triggered the redirect message that the host used the virtual IP address of group 1 as its gateway, so it changes the source IP address of the redirect message to the virtual IP address of group 1.

The modified ICMP redirect message showing the two modified fields (*) is as follows:

```
dest MAC         = Host MAC
source MAC       = router R1 MAC
dest IP          = Host IP
source IP*       = HSRP group 1 virtual IP
gateway to use*  = HSRP group 3 virtual IP
```

This second modification is necessary because hosts compare the source IP address of the ICMP redirect message with their default gateway. If these addresses do not match, the ICMP Redirect message is ignored. The routing table of the host now consists of the default gateway, virtual IP address of group 1, and a route to Net D through the virtual IP address of group 3.

Redirects to Passive HSRP Routers

Redirects to passive HSRP routers are not permitted. Redundancy may be lost if hosts learn the real IP addresses of HSRP routers.

In the previous example, redirects to router R8 are not allowed because R8 is a passive HSRP router. In this case, packets from the host to Net D will first go to router R1 and then be forwarded to router R4, that is, they will traverse the network twice.

A network configuration with passive HSRP routers is considered a misconfiguration. For HSRP ICMP redirection to operate optimally, every router on the network that is running HSRP should contain at least one active HSRP group.

Redirects to Non-HSRP Routers

Redirects to routers not running HSRP on their local interface are permitted. No redundancy is lost if hosts learn the real IP address of non-HSRP routers.

In the example, redirection to router R7 is allowed because R7 is not running HSRP. In this case, the next hop IP address is unchanged. The source IP address is changed dependent upon the destination MAC address of the original packet. You can specify the **no standby redirects unknown** command to stop these redirects from being sent.

Passive HSRP Router Advertisements

Passive HSRP routers send out HSRP advertisement messages both periodically and when entering or leaving the passive state. Thus, all HSRP routers can determine the HSRP group state of any HSRP router on the network. These advertisements inform other HSRP routers on the network of the HSRP interface state, as follows:

- Dormant—Interface has no HSRP groups, single advertisements sent once when last group is removed
- Passive—Interface has at least one non-active group and no active groups, advertisements sent out periodically
- Active—Interface has at least one active group, single advertisement sent out when first group becomes active

You can adjust the advertisement interval and holddown time using the **standby redirects timers** command.

Redirects Not Sent

If the HSRP router cannot uniquely determine the IP address used by the host when it sends the packet that caused the redirect, the redirect message will not be sent. The router uses the destination MAC address in the original packet to make this determination. In certain configurations, such as the use of the **standby use-bia** interface configuration command specified on an interface, redirects cannot be sent. In this case, the HSRP groups use the interface MAC address as their virtual MAC address. The router now cannot determine if the default gateway of the host is the real IP address or one of the HSRP virtual IP addresses that are active on the interface.

Using HSRP with ICMP redirects is not possible in the Cisco 800 series, Cisco 1000 series, Cisco 1600 series, Cisco 2500 series, Cisco 3000 series, and Cisco 4500 series routers because the Ethernet controller can only support one MAC address.

The IP source address of an ICMP packet must match the gateway address used by the host in the packet that triggered the ICMP packet, otherwise the host will reject the ICMP redirect packet. An HSRP router uses the destination MAC address to determine the gateway IP address of the host. If the HSRP router is using the same MAC address for multiple IP addresses then it is not possible to uniquely determine the gateway IP address of the host and the redirect message is not sent.

The following is sample output from the **debug standby events icmp** EXEC command if HSRP could not uniquely determine the gateway used by the host:

```
10:43:08: SB: ICMP redirect not sent to 20.0.0.4 for dest 30.0.0.2
10:43:08: SB: could not uniquely determine IP address for mac 00d0.bbd3.bc22
```

Configuring HSRP Support for ICMP Redirect Messages

By default, HSRP filtering of ICMP redirect messages is enabled on routers running HSRP. To reenable this feature on your router if it is disabled, use the following command in interface configuration mode:

Command	Purpose
`Router (config-if)# standby redirects [enable | disable] [timers advertisement holddown] [unknown]`	Enables HSRP filtering of ICMP redirect messages

Configuring IP Accounting

Cisco IP accounting support provides basic IP accounting functions. By enabling IP accounting, users can see the number of bytes and packets switched through the Cisco IOS software on a source and destination IP address basis. Only transit IP traffic is measured and only on an outbound basis; traffic generated by the software or terminating in the software is not included in the accounting statistics. To maintain accurate accounting totals, the software maintains two accounting databases: an active and a checkpointed database.

Cisco IP accounting support also provides information identifying IP traffic that fails IP access lists. Identifying IP source addresses that violate IP access lists alerts you to possible attempts to breach security. The data also indicates that you should verify IP access list configurations. To make this feature available to users, you must enable IP accounting of access list violations using the **ip accounting access-violations** interface configuration command. Users can then display the number of bytes and packets from a single source that attempted to breach security against the access list for the source destination pair. By default, IP accounting displays the number of packets that have passed access lists and were routed.

To enable IP accounting, use one of the following commands for each interface in interface configuration mode:

Command	Purpose
`Router(config-if)# ip accounting`	Enables basic IP accounting.
`Router(config-if)# ip accounting access-violations`	Enables IP accounting with the ability to identify IP traffic that fails IP access lists.

To configure other IP accounting functions, use the following commands in global configuration mode, as needed:

Command	Purpose
`Router(config)# ip accounting-threshold threshold`	Sets the maximum number of accounting entries to be created.
`Router(config)# ip accounting-list ip-address wildcard`	Filters accounting information for hosts.
`Router(config)# ip accounting-transits count`	Controls the number of transit records that will be stored in the IP accounting database.

To display IP access violations for a specific IP accounting database, use the following command in EXEC mode:

Command	Purpose
`Router# show ip accounting [checkpoint] access-violations`	Displays IP access violation information.

To display IP access violations, include the **access-violations** keyword in the **show ip accounting** EXEC command. If you do not specify the keyword, the command defaults to displaying the number of packets that have passed access lists and were routed. The access violations output displays the number of the access list failed by the last packet for the source and destination pair. The number of packets reveals how aggressive the attack is upon a specific destination.

Use the **show ip accounting** EXEC command to display the active accounting database, and traffic coming from a remote site and transiting through a router. To display the checkpointed database, use the **show ip accounting checkpoint** EXEC command. The **clear ip accounting** EXEC command clears the active database and creates the checkpointed database.

Configuring IP MAC Accounting

The MAC address accounting functionality provides accounting information for IP traffic based on the source and destination MAC addresses on LAN interfaces. MAC accounting calculates the total packet and byte counts for a LAN interface that receives or sends IP packets to or from a unique MAC address. It also records a timestamp for the last packet received or sent. For example, with IP MAC accounting, you can determine how much traffic is being sent to and/or received from various peers at NAPS/peering points. IP MAC accounting is supported on Ethernet, FastEthernet, and FDDI interfaces and supports Cisco Express Forwarding (CEF), distributed CEF (dCEF), flow, and optimum switching.

To configure the interface for IP accounting based on the MAC address, perform the following steps beginning in global configuration:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies the interface and enters interface configuration mode.
Step 2	`Router(config-if)# ip accounting mac-address {input | output}`	Configures IP accounting based on the MAC address of received (input) or transmitted (output) packets

To remove IP accounting based on the MAC address from the interface, use the **no ip accounting mac-address** command.

Use the EXEC command **show interface mac** to display MAC accounting information for interfaces configured for MAC accounting.

Configuring IP Precedence Accounting

The precedence accounting feature provides accounting information for IP traffic based on the precedence on any interface. This feature calculates the total packet and byte counts for an interface that receives or sends IP packets and sorts the results based on IP precedence. This feature is supported on all interfaces and subinterfaces and supports CEF, dCEF, flow, and optimum switching.

To configure the interface for IP accounting based on IP precedence, perform the following steps beginning in global configuration model:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies the interface (or subinterface) and enters interface configuration mode.
Step 2	`Router(config-if)# ip accounting precedence {input | output}`	Configures IP accounting based on the precedence of received (input) or transmitted (output) packets

To remove IP accounting based on IP precedence from the interface, use the **no ip accounting precedence** command.

Use the EXEC command **show interface precedence** to display precedence accounting information for interfaces configured for precedence accounting.

Configuring TCP Performance Parameters

To tune IP performance, perform any of the optional tasks described in the following sections. To configure various switching options, refer to the "Cisco IOS Switching Paths" chapter in the *Cisco IOS Switching Services Configuration Guide*.

- Compressing TCP Packet Headers (Optional)
- Setting the TCP Connection Attempt Time (Optional)
- Enabling TCP Path MTU Discovery (Optional)
- Enabling TCP Selective Acknowledgment (Optional)
- Enabling TCP Time Stamp (Optional)
- Setting the TCP Maximum Read Size (Optional)
- Setting the TCP Window Size (Optional)
- Setting the TCP Outgoing Queue Size (Optional)

Compressing TCP Packet Headers

You can compress the headers of your TCP/IP packets in order to reduce their size, thereby increasing performance. Header compression is particularly useful on networks with a large percentage of small packets (such as those supporting many Telnet connections). To enable TCP header compression, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip tcp header-compression [passive]`	Enables TCP header compression.

The **ip tcp header-compression** interface configuration command only compresses the TCP header; it has no effect on UDP packets or other protocol headers. The TCP header compression technique is supported on serial lines using High-Level Data Link Control (HDLC) or PPP encapsulation. You must enable compression on both ends of a serial connection.

By using the **passive** keyword, you can optionally specify outgoing packets to be compressed only if TCP incoming packets on the same interface are compressed. If you specify the command without the **passive** keyword, the software will compress all traffic. Without the command, the default is no compression.

Note Fast processors can handle several fast interfaces, such as T1 lines, that are running header compression. However, you should think carefully about the traffic characteristics of your network before compressing TCP headers. You might want to use the monitoring commands to compare network utilization before and after enabling TCP header compression.

Expressing TCP Header Compression

Before Cisco IOS Release 12.0(7)T, if compression of TCP headers was enabled, compression was performed in the process switching path. Compression performed in the process switching path meant that packets traversing interfaces that had TCP header compression enabled were queued and passed up to the process to be switched. This procedure slowed down transmission of the packet, and therefore some users preferred to fast switch uncompressed TCP packets.

In Cisco IOS Release 12.1, if TCP header compression is enabled, it occurs by default in the fast-switched path or the CEF-switched path, depending on which switching method is enabled on the interface.

If neither fast switching nor CEF switching is enabled, then if TCP header compression is enabled, it will occur in the process-switched path as before.

The Express TCP Header Compression feature reduces network overhead and speeds up transmission of TCP packets. The faster speed provides a greater benefit on slower links than faster links.

In order for Express TCP Header Compression to work, the following conditions must be in place:

- CEF switching or fast switching must be enabled on the interface.
- HDLC, PPP, or Frame Relay encapsulation must be configured.
- TCP header compression must be enabled.

The CEF and fast-switching aspects of the Express TCP Header Compression feature are related to these documents:

- *Cisco IOS Switching Services Configuration Guide*
- *Cisco IOS Switching Services Command Reference*

For information about compressing RTP headers, see the chapter "Configuring IP Multicast Routing" in this document.

Changing the Number of TCP Header Compression Connections

You also can specify the total number of header compression connections that can exist on an interface. You should configure one connection for each TCP connection through the specified interface.

When specifying the total number of header compression connections that can exist on an interface, be aware of the following conditions:

- By default, for Frame Relay encapsulation, there can be 256 TCP header compression connections (128 calls). The maximum value is fixed, not configurable.
- By default, for PPP or HDLC encapsulation, the software allows 32 TCP header compression connections (16 calls). This default can be increased to a maximum of 256 TCP header compression connections.

To specify the number of connections, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip tcp compression-connections` *number*	Specifies the total number of TCP header compression connections that can exist on an interface.

Setting the TCP Connection Attempt Time

You can set the amount of time the Cisco IOS software will wait to attempt to establish a TCP connection. Because the connection attempt time is a host parameter, it does not pertain to traffic going through the device, just to traffic originated at the device.

To set the TCP connection attempt time, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip tcp synwait-time` *seconds*	Sets the amount of time the Cisco IOS software will wait to attempt to establish a TCP connection.The default is 30 seconds.

Enabling TCP Path MTU Discovery

Path MTU Discovery is a method for maximizing the use of available bandwidth in the network between the endpoints of a TCP connection, and is described in RFC 1191. By default, this feature is disabled. Existing connections are not affected when this feature is turned on or off.

To enable Path MTU Discovery, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip tcp path-mtu-discovery [age-timer {minutes | infinite}]`	Enables Path MTU Discovery.

Customers using TCP connections to move bulk data between systems on distinct subnets would benefit most by enabling this feature. Customers using remote source-route bridging (RSRB) with TCP encapsulation, serial tunnel (STUN), X.25 Remote Switching (also known as XOT or X.25 over TCP), and some protocol translation configurations might also benefit from enabling this feature.

The **ip tcp path-mtu-discovery**global configuration command is to enable Path MTU Discovery for connections initiated by the router when it is acting as a host. For a discussion of how the Cisco IOS software supports Path MTU Discovery when the device is acting as a router, see the section "Understanding Path MTU Discovery" earlier in this chapter.

The age-timer is a time interval for how often TCP should reestimate the path MTU with a larger maximum segment size (MSS). The default Path MTU Discovery age-timer is 10 minutes; its maximum is 30 minutes. You can turn off the age timer by setting it to infinite.

Enabling TCP Selective Acknowledgment

The TCP selective acknowledgment feature improves performance in the event that multiple packets are lost from one TCP window of data.

Prior to this feature, with the limited information available from cumulative acknowledgments, a TCP sender could learn about only one lost packet per round-trip time. An aggressive sender could choose to resend packets early, but such re-sent segments might have already been successfully received.

The TCP selective acknowledgment mechanism helps improve performance. The receiving TCP host returns selective acknowledgment packets to the sender, informing the sender of data that have been received. In other words, the receiver can acknowledge packets received out of order. The sender can then resend only the missing data segments (instead of everything since the first missing packet).

Prior to selective acknowledgment, if TCP lost packets 4 and 7 out of an 8-packet window, TCP would receive acknowledgment of only packets 1, 2, and 3. Packets 4 through 8 would need to be re-sent. With selective acknowledgment, TCP receives acknowledgment of packets 1, 2, 3, 5, 6, and 8. Only packets 4 and 7 must be re-sent.

Refer to RFC 2018 for more detailed information on TCP selective acknowledgment.

The feature is used only when multiple packets are dropped within one TCP window. There is no performance impact when the feature is enabled but not used. To enable TCP selective acknowledgment, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip tcp selective-ack`	Enables TCP selective acknowledgment.

Enabling TCP Time Stamp

The TCP time-stamp option provides better TCP round-trip time measurements. Because the time stamps are always sent and echoed in both directions and the time-stamp value in the header is always changing, TCP header compression will not compress the outgoing packet. To allow TCP header compression over a serial link, the TCP time-stamp option is disabled.

Refer to RFC 1323 for more detailed information on TCP time stamp.

To enable TCP time stamp, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip tcp timestamp`	Enables TCP time stamp.

If you want to use TCP header compression over a serial line, TCP time stamp and TCP selective acknowledgment must be disabled. Both features are disabled by default. To disable TCP selective acknowledgment once it is enabled, see the previous "Enabling TCP Selective Acknowledgment" section.

Setting the TCP Maximum Read Size

By default, for Telnet and rlogin, the maximum number of characters that TCP reads from the input queue at once is a very large number (the largest possible 32-bit positive number). We do not recommend that you change this value. However, to change that value, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip tcp chunk-size` *characters*	Sets the TCP maximum read size for Telnet or rlogin.

Setting the TCP Window Size

The default TCP window size is 2144 bytes. We recommend you keep the default value unless you know your router is sending large packets (greater than 536 bytes). To change the default window size, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip tcp window-size` *bytes*	Sets the TCP window size.

Setting the TCP Outgoing Queue Size

The default TCP outgoing queue size per connection is 5 segments if the connection has a TTY associated with it (like a Telnet connection). If no TTY connection is associated with it, the default queue size is 20 segments. To change the 5-segment default value, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip tcp queuemax` *packets*	Sets the TCP outgoing queue size.

Configuring IP over WANs

You can configure IP over X.25, Switched Multimegabit Data Service (SMDS), Frame Relay, and dial-on-demand routing (DDR) networks. When configuring IP over X.25, SMDS, or Frame Relay, configure the address mappings as described in the appropriate chapters of the *Cisco IOS Wide-Area Networking Configuration Guide*. For DDR, refer to the "Preparing to Configure DDR" chapter of the *Cisco IOS Dial Technologies Configuration Guide* publication.

Configuring the MultiNode Load Balancing Forwarding Agent

The MultiNode Load Balancing (MNLB) Forwarding Agent is the Cisco IOS-based packet redirector component of the MNLD Feature Set for LocalDirector, a product in the Cisco family of load balancing solutions.

The Forwarding Agent discovers the destination of specific connection requests and forwards packets between the client and the chosen destination. When a Forwarding Agent receives a connection request, the request is forwarded to the MNLB services manager, the LocalDirector-based component of the MNLD Feature Set for LocalDirector. The services manager makes the load-balancing decision and sends the Forwarding Agent the optimal destination. After the destination is specified, session data is forwarded directly to the destination by the Forwarding Agent, without further services manager participation. There is no limit to the number of Forwarding Agents that can be configured in the MNLD Feature Set for LocalDirector.

The MNLD Feature Set for LocalDirector comprises hardware and software that runs on multiple network components. The services manager runs on the Cisco LocalDirector chassis and makes the load-balancing decisions. The Forwarding Agents run on Cisco IOS router and switch platforms and forward packets to and from the selected destination. Separating the decision-making and packet-forwarding tasks enables much faster packet throughput. The underlying Cisco architecture, ContentFlow architecture, enables the following features:

- High availability
- Unbounded scalability
- Application-aware balancing
- No single point of failure
- Unmatched performance

Configure the Forwarding Agent only if you are installing the MNLD Feature Set for LocalDirector. If you are installing the MNLD Feature Set for LocalDirector, refer to the *MultiNode Load Balancing Feature Set for LocalDirector User Guide* for information about which other hardware and software components are required.

The MNLB Forwarding Agent is an implementation of the Cisco ContentFlow architecture flow delivery agent (FDA).

Refer to the *MultiNode Load Balancing Feature Set for LocalDirector User Guide* for more information about how the Forwarding Agent is configured and for more information about the product.

MNLB Forwarding Agent Configuration Task List

The configure the MNLB Forwarding Agent, perform the tasks described in the following sections. The tasks are all required except for the task in the second section, which is optional but strongly recommended.

- Enabling CEF (Required)
- Enabling NetFlow Switching (Optional but strongly recommended)
- Enabling IP Multicast Routing (Required)
- Configuring the Router as a Forwarding Agent (Required)

Enabling CEF

CEF is advanced Layer 3 IP switching technology. CEF optimizes network performance and scalability for networks with large and dynamic traffic patterns, such as the Internet, on networks characterized by intensive Web-based applications, or interactive sessions.

To enable CEF, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip cef distributed`	Enables CEF.

Note When you enable CEF globally, all interfaces that support CEF are enabled by default. If you want to turn off CEF on a particular interface, you can do so.

Refer to the "Cisco Express Forwarding" part of the *Cisco IOS Switching Services Configuration Guide* for more information on how to configure CEF.

Enabling NetFlow Switching

You must enable NetFlow switching on all interfaces that will carry ContentFlow traffic. To enable NetFlow switching, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# interface` *type slot/port-adapter/port* (Cisco 7500 series routers) or `Router(config-if)# interface` *type slot/port* (Cisco 7200 series routers)	Specifies the interface, and enters interface configuration mode.
Step 2	`Router(config-if)# ip route-cache flow`	Enables flow switching on the interface.

Normally the size of the NetFlow cache will meet your needs. To increase or decrease the number of entries maintained in the cache, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip flow-cache entries` *number*	Changes the number of entries maintained in the NetFlow cache. The number of entries can be from 1024 to 524288. The default is 64536.

Refer to the "Netflow Switching" part of the *Cisco IOS Switching Services Configuration Guide* for more information on how to configure NetFlow switching.

Enabling IP Multicast Routing

You must enable IP multicast routing on all interfaces to the services manager.

To enable multicast routing on all interfaces, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip multicast routing`	Enables multicast routing.

To have the router join a multicast group and enable IGMP, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp join-group` *group-address*	Joins a multicast group. This command must be configured on all interfaces that will listen for the services manager multicasts. The group address must match that configured within the services manager configuration.

See the "Configuring IP Multicast Routing" chapter of this document for more information on how to configure IP multicast routing.

Configuring the Router as a Forwarding Agent

To configure the router as a Forwarding Agent, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip casa control-address igmp-address`	Specifies the IP address and IGMP address of the Forwarding Agent. The recommended IGMP address is 224.0.1.2.
Step 2	`Router(config-casa)# forwarding-agent pools initial-affinity-pool max-affinity-pool`	Adjusts the memory allocated for the affinity pools of the Forwarding Agent. The default pool size is 5000, and there is no maximum pool size.
Step 3	`Router(config-casa)# forwarding-agent port-number [password [timeout]]`	Specifies the port number. The default is port 1637.

Note The Forwarding Agent IGMP address and port must match the IGMP address and port configured on the services manager using the **ip igmp join-group** interface configuration command.

Monitoring and Maintaining the IP Network

To monitor and maintain your network, perform any of the optional tasks described in the following sections:

- Clearing Caches, Tables, and Databases (Optional)
- Monitoring and Maintaining the DRP Server Agent (Optional)
- Clearing the Access List Counters (Optional)
- Displaying System and Network Statistics (Optional)
- Monitoring the MNLB Forwarding Agent (Optional)
- Monitoring and Maintaining HSRP Support for ICMP Redirect Messages (Optional)

Clearing Caches, Tables, and Databases

You can remove all contents of a particular cache, table, or database. Clearing a cache, table, or database can become necessary when the contents of the particular structure have become or are suspected to be invalid.

To clear caches, tables, and databases, use the following commands in EXEC mode, as needed:

Command	Purpose
Router# **clear ip accounting** [**checkpoint**]	Clears the active IP accounting or checkpointed database when IP accounting is enabled.
Router# **clear tcp statistics**	Clears TCP statistics.

Monitoring and Maintaining the DRP Server Agent

To monitor and maintain the DRP Server Agent, use the following commands in EXEC mode:

Command	Purpose
Router# **clear ip drp**	Clears statistics being collected on DRP requests and responses.
Router# **show ip drp**	Displays information about the DRP Server Agent.

Clearing the Access List Counters

The system counts how many packets pass each line of an access list; the counters are displayed by the **show access-lists** EXEC command. To clear the counters of an access list, use the following command in EXEC mode:

Command	Purpose
Router# **clear access-list counters** {*access-list-number* | *access-list-name*}	Clears the access list counters.

Displaying System and Network Statistics

You can display specific statistics such as the contents of IP routing tables, caches, and databases. The resulting information can be used to determine resource utilization and to solve network problems.

To display specific statistics such as the contents of IP routing tables, caches, and databases, use the following commands in privileged EXEC mode, as needed. Refer to the "IP Services Commands" chapter in the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services* for details about the commands listed in these tasks.

Command	Purpose
Router# **show access-lists** [*access-list-number* | *access-list-name*]	Displays the contents of one or all current access lists.
Router# **show access-list compiled**	Displays information regarding compiled access lists, including the state of each compiled access list.
Router# **show ip access-list** [*access-list-number* | *name*]	Displays the contents of current IP access lists.
Router# **show ip accounting** [**checkpoint**]	Displays the active IP accounting or checkpointed database.

Command	Purpose
Router# **show ip redirects**	Displays the address of the default router and the address of hosts for which an ICMP redirect message has been received.
Router# **show ip sockets**	Displays IP socket information.
Router# **show ip tcp header-compression**	Displays statistics on TCP header compression.
Router# **show ip traffic**	Displays IP protocol statistics.
Router# **show standby** [*interface* [*group*]] [**active** | **init** | **listen** | **standby**][**brief**]	Displays the status of the standby router.
Router# **show standby delay** [*type number*]	Displays HSRP information about delay periods
Router# **show tcp statistics**	Displays TCP statistics.

Monitoring the MNLB Forwarding Agent

To monitor the status of the Forwarding Agent, use the following commands in EXEC mode, as needed:

Command	Purpose
Router# **show ip casa affinities**	Displays the status of affinities.
Router# **show ip casa oper**	Displays the operational status of the Forwarding Agent.
Router# **show ip casa stats**	Displays statistical information about the Forwarding Agent.
Router# **show ip casa wildcard**	Displays information about wildcard blocks.

Monitoring and Maintaining HSRP Support for ICMP Redirect Messages

To display the status of ICMP redirect messages, use the following commands in EXEC mode, as needed:

Command	Purpose
Router# **debug standby events icmp**	Displays debug messages for HSRP-filtered ICMP redirect messages.
Router# **debug ip icmp**	Displays information on ICMP transactions.

IP Services Configuration Examples

This section provides the following IP configuration examples:

- ICMP Services Example
- Simplex Ethernet Interfaces Example
- DRP Server Agent Example
- Numbered Access List Examples
- Named Access List Example
- IP Extended Access List with Fragment Control Example

- Time Range Applied to an IP Access List Example
- Commented IP Access List Entry Examples
- IP Accounting Example
- HSRP Load Sharing Example
- HSRP MAC Refresh Interval Examples
- HSRP MIB Trap Example
- HSRP Support for MPLS VPNs Example
- HSRP Support for ICMP Redirect Messages Example
- MNLB Forwarding Agent Examples

ICMP Services Example

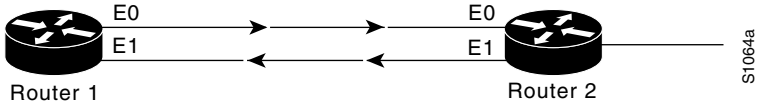
The following example changes some of the ICMP defaults for the first Ethernet interface 0. Disabling the sending of redirects could mean that you do not expect your devices on this segment to ever need to send a redirect message. Disabling the unreachables messages will have a secondary effect—it also will disable IP Path MTU Discovery, because path discovery works by having the Cisco IOS software send Unreachables messages. If you have a network segment with a small number of devices and an absolutely reliable traffic pattern—which could easily happen on a segment with a small number of little-used user devices—you would be disabling options that your device would be unlikely to use anyway.

```
interface ethernet 0
 no ip unreachables
 no ip redirects
```

Simplex Ethernet Interfaces Example

The following is an example of configuring a simplex Ethernet interface. Figure 19 illustrates how to configure IP on two routers sharing transmit-only and receive-only Ethernet connections.

Figure 19 Simplex Ethernet Connections



Router 1 Configuration

```
interface ethernet 0
 ip address 128.9.1.1
!
interface ethernet 1
 ip address 128.9.1.1
 transmit-interface ethernet 0
!
!use show interfaces command to find router2-MAC-address-E0
arp 128.9.1.4 router2-MAC-address-E0 arpa
```

Router 2 Configuration

```
interface ethernet 0
```

```
 ip address 128.9.1.2
 transmit-interface ethernet 1
!
interface ethernet 1
 ip address 128.9.1.2
!
!use show interfaces command to find router1-MAC-address-E1
arp 128.9.1.1 router1-MAC-address-E1 arpa
```

DRP Server Agent Example

The following example enables the DRP Server Agent. Sources of DRP queries are limited by access list 1, which permits only queries from the host at address 33.45.12.4. Authentication is also configured for the DRP queries and responses.

```
ip drp server
access-list 1 permit 33.45.12.4
ip drp access-group 1
ip drp authentication key-chain mktg
key chain mktg
 key 1
  key-string internal
```

Numbered Access List Examples

In the following example, network 36.0.0.0 is a Class A network whose second octet specifies a subnet; that is, its subnet mask is 255.255.0.0. The third and fourth octets of a network 36.0.0.0 address specify a particular host. Using access list 2, the Cisco IOS software would accept one address on subnet 48 and reject all others on that subnet. The last line of the list shows that the software would accept addresses on all other network 36.0.0.0 subnets.

```
access-list 2 permit 36.48.0.3
access-list 2 deny 36.48.0.0  0.0.255.255
access-list 2 permit 36.0.0.0  0.255.255.255
interface ethernet 0
 ip access-group 2 in
```

The following example defines access lists 1 and 2, both of which have logging enabled:

```
interface ethernet 0
 ip address 1.1.1.1 255.0.0.0
 ip access-group 1 in
 ip access-group 2 out
!
access-list 1 permit 5.6.0.0 0.0.255.255 log
access-list 1 deny 7.9.0.0 0.0.255.255 log
!
access-list 2 permit 1.2.3.4 log
access-list 2 deny 1.2.0.0 0.0.255.255 log
```

If the interface receives 10 packets from 5.6.7.7 and 14 packets from 1.2.23.21, the first log will look like the following:

```
list 1 permit 5.6.7.7 1 packet
list 2 deny 1.2.23.21 1 packet
```

Five minutes later, the console will receive the following log:

```
list 1 permit 5.6.7.7 9 packets
list 2 deny 1.2.23.21 13 packets
```

Turbo Access Control List Example

The following is a Turbo ACL configuration example. The **access-list compiled** global configuration command output indicates that Turbo ACL is enabled.

```
interface Ethernet2/7
 no ip address
 ip access-group 20 out
 no ip directed-broadcast
 shutdown
!
no ip classless
ip route 192.168.0.0 255.255.255.0 10.1.1.1
!
access-list compiled
access-list 1 deny   any
access-list 2 deny   192.168.0.0 0.0.0.255
access-list 2 permit any
```

Implicit Masks in Access Lists Examples

IP access lists contain *implicit* masks. For instance, if you omit the mask from an associated IP host address access list specification, 0.0.0.0 is assumed to be the mask. Consider the following example configuration:

```
access-list 1 permit 0.0.0.0
access-list 1 permit 131.108.0.0
access-list 1 deny 0.0.0.0 255.255.255.255
```

For this example, the following masks are implied in the first two lines:

```
access-list 1 permit 0.0.0.0 0.0.0.0
access-list 1 permit 131.108.0.0 0.0.0.0
```

The last line in the configuration (using the **deny** keyword) can be left off, because IP access lists implicitly *deny* all other access. Leaving off the last line in the configuration is equivalent to finishing the access list with the following command statement:

```
access-list 1 deny 0.0.0.0 255.255.255.255
```

The following access list only allows access for those hosts on the three specified networks. It assumes that subnetting is not used; the masks apply to the host portions of the network addresses. Any hosts with a source address that does not match the access list statements will be rejected.

```
access-list 1 permit 192.5.34.0  0.0.0.255
access-list 1 permit 128.88.0.0  0.0.255.255
access-list 1 permit 36.0.0.0  0.255.255.255
! (Note: all other access implicitly denied)
```

To specify a large number of individual addresses more easily, you can omit the address mask that is all 0s from the **access-list** global configuration command. Thus, the following two configuration commands are identical in effect:

```
access-list 2 permit 36.48.0.3
access-list 2 permit 36.48.0.3  0.0.0.0
```

Extended Access List Examples

In the following example, the first line permits any incoming TCP connections with destination ports greater than 1023. The second line permits incoming TCP connections to the Simple Mail Transfer Protocol (SMTP) port of host 128.88.1.2. The last line permits incoming ICMP messages for error feedback.

```
access-list 102 permit tcp 0.0.0.0 255.255.255.255 128.88.0.0 0.0.255.255 gt 1023
access-list 102 permit tcp 0.0.0.0 255.255.255.255 128.88.1.2 0.0.0.0 eq 25
access-list 102 permit icmp 0.0.0.0 255.255.255.255 128.88.0.0 255.255.255.255
interface ethernet 0
 ip access-group 102 in
```

For another example of using an extended access list, suppose you have a network connected to the Internet, and you want any host on an Ethernet to be able to form TCP connections to any host on the Internet. However, you do not want IP hosts to be able to form TCP connections to hosts on the Ethernet except to the mail (SMTP) port of a dedicated mail host.

SMTP uses TCP port 25 on one end of the connection and a random port number on the other end. The same two port numbers are used throughout the life of the connection. Mail packets coming in from the Internet will have a destination port of 25. Outbound packets will have the port numbers reversed. The fact that the secure system behind the router always will be accepting mail connections on port 25 is what makes possible separate control of incoming and outgoing services. The access list can be configured on either the outbound or inbound interface.

In the following example, the Ethernet network is a Class B network with the address 128.88.0.0, and the address of the mail host is 128.88.1.2. The **established** keyword is used only for the TCP protocol to indicate an established connection. A match occurs if the TCP datagram has the ACK or RST bits set, which indicate that the packet belongs to an existing connection.

```
access-list 102 permit tcp 0.0.0.0 255.255.255.255 128.88.0.0 0.0.255.255 established
access-list 102 permit tcp 0.0.0.0 255.255.255.255 128.88.1.2 0.0.0.0 eq 25
interface ethernet 0
 ip access-group 102 in
```

Named Access List Example

The following configuration creates a standard access list named Internet_filter and an extended access list named marketing_group:

```
interface Ethernet0/5
 ip address 2.0.5.1 255.255.255.0
 ip access-group Internet_filter out
 ip access-group marketing_group in
...
ip access-list standard Internet_filter
 permit 1.2.3.4
 deny any
ip access-list extended marketing_group
 permit tcp any 171.69.0.0 0.0.255.255 eq telnet
 deny tcp any any
 permit icmp any any
 deny udp any 171.69.0.0 0.0.255.255 lt 1024
 deny ip any any log
```

IP Extended Access List with Fragment Control Example

The first statement will match and deny only noninitial fragments destined for host 1.1.1.1. The second statement will match and permit only the remaining nonfragmented and initial fragments that are destined for host 1.1.1.1 TCP port 80. The third statement will deny all other traffic. In order to block noninitial fragments for any TCP port, we must block noninitial fragments for all TCP ports, including port 80 for host 1.1.1.1.

```
access-list 101 deny ip any host 1.1.1.1 fragments
access-list 101 permit tcp any host 1.1.1.1 eq 80
access-list 101 deny ip any any
```

Time Range Applied to an IP Access List Example

The following example denies HTTP traffic on Monday through Friday from 8:00 a.m. to 6:00 p.m. on IP. The example allows UDP traffic on Saturday and Sunday from noon to 8:00 p.m. only.

```
time-range no-http
 periodic weekdays 8:00 to 18:00
!
time-range udp-yes
 periodic weekend 12:00 to 20:00
!
ip access-list extended strict
 deny tcp any any eq http time-range no-http
 permit udp any any time-range udp-yes
!

interface ethernet 0
 ip access-group strict in
```

Commented IP Access List Entry Examples

In the following example of a numbered access list, the workstation belonging to Jones is allowed access and the workstation belonging to Smith is not allowed access:

```
access-list 1 remark Permit only Jones workstation through
access-list 1 permit 171.69.2.88
access-list 1 remark Do not allow Smith workstation through
access-list 1 deny 171.69.3.13
```

In the following example of a numbered access list, the Winter and Smith workstations are not allowed to browse the web:

```
access-list 100 remark Do not allow Winter to browse the web
access-list 100 deny host 171.69.3.85 any eq http
access-list 100 remark Do not allow Smith to browse the web
access-list 100 deny host 171.69.3.13 any eq http
```

In the following example of a named access list, the Jones subnet is not allowed access:

```
ip access-list standard prevention
remark Do not allow Jones subnet through
deny 171.69.0.0 0.0.255.255
```

In the following example of a named access list, the Jones subnet is not allowed to use outbound Telnet:

```
ip access-list extended telnetting
remark Do not allow Jones subnet to telnet out
```

```
deny tcp 171.69.0.0 0.0.255.255 any eq telnet
```

IP Accounting Example

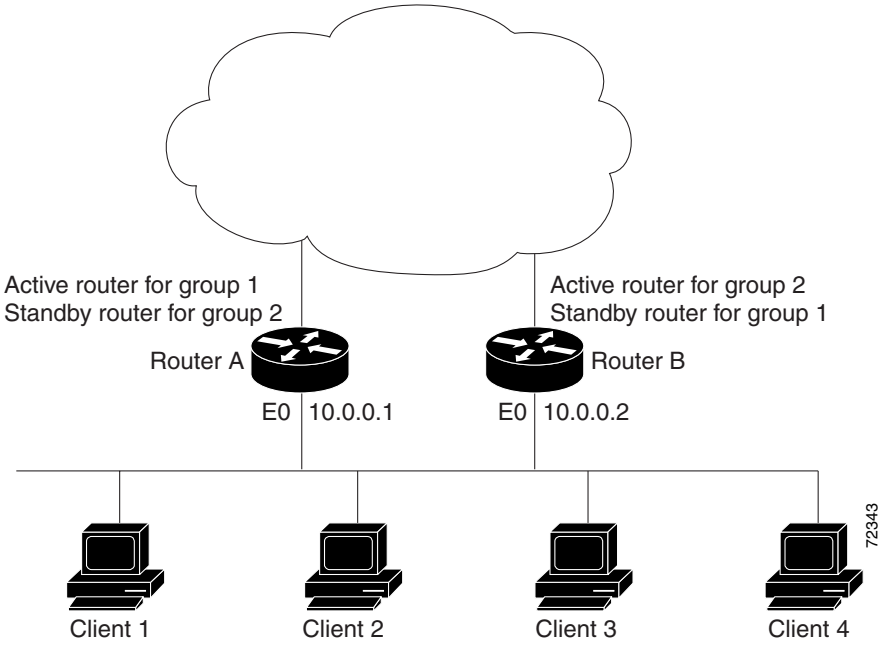
The following example enables IP accounting based on the source and destination MAC address and based on IP precedence for received and transmitted packets:

```
interface Ethernet0/5
 ip accounting mac-address input
 ip accounting mac-address output
 ip accounting precedence input
 ip accounting precedence output
```

HSRP Load Sharing Example

You can use HSRP or Multiple HSRP when you configure load sharing. In Figure 20, half of the clients are configured for Router A, and half of the clients are configured for Router B. Together, the configuration for Routers A and B establish two Hot Standby groups. For group 1, Router A is the default active router because it has the assigned highest priority, and Router B is the standby router. For group 2, Router B is the default active router because it has the assigned highest priority, and Router A is the standby router. During normal operation, the two routers share the IP traffic load. When either router becomes unavailable, the other router becomes active and assumes the packet-transfer functions of the router that is unavailable. The **standby preempt** interface configuration command is necessary so that if a router goes down and then comes back up, preemption occurs and restores load sharing.

Figure 20 HSRP Load Sharing Example



The following example shows Router A configured as the active router for group 1 with a priority of 110 and Router B configured as the active router for group 2 with a priority of 110. The default priority level is 100. Group 1 uses a virtual IP address of 10.0.0.3 and Group 2 uses a virtual IP address of 10.0.0.4.

Router A Configuration

```
hostname RouterA
!
interface ethernet 0
  ip address 10.0.0.1 255.255.255.0
  standby 1 ip 10.0.0.3
  standby 1 priority 110
  standby 1 preempt
  standby 2 ip 10.0.0.4
  standby 2 preempt
```

Router B Configuration

```
hostname RouterB
!
interface ethernet 0
  ip address 10.0.0.2 255.255.255.0
  standby 1 ip 10.0.0.3
  standby 1 preempt
  standby 2 ip 10.0.0.4
  standby 2 priority 110
  standby 2 preempt
```

HSRP MAC Refresh Interval Examples

This section provides the following HSRP MAC refresh interval examples:

- No Switch or Learning Bridge Present Example
- Switch or Learning Bridge Present Example

No Switch or Learning Bridge Present Example

The following HSRP example of changing the MAC refresh interval is applicable if no switch or learning bridge is in your network. It prevents the sending of refresh packets.

```
interface fddi 1/0/0
 ip address 10.1.1.1 255.255.255.0
 standby ip 10.1.1.250
 standby mac-refresh 0
```

Switch or Learning Bridge Present Example

The following HSRP example of changing the MAC refresh interval is applicable if a switch or learning bridge is in your network. It will reduce the number of extra packets you send to refresh the MAC cache on the switch or learning bridge to two per minute.

```
interface fddi 1/0/0
 ip address 10.1.1.1 255.255.255.0
 standby ip 10.1.1.250
 standby mac-refresh 30
```

HSRP MIB Trap Example

The following example shows how to configure HSRP on two routers and enable the HSRP MIB trap feature. As in many environments, one router is preferred as the active one by configuring it at a higher priority level and enabling preemption. In this example, the active router is referred to as the primary router. The second router is referred to as the backup router.

Primary Router Configuration

```
interface Ethernet1
 ip address 15.1.1.1 255.255.0.0
 no ip redirects
 standby priority 200
 standby preempt
 standby ip 15.1.1.3
snmp-server enable traps hsrp
snmp-server host yourhost.cisco.com public hsrp
```

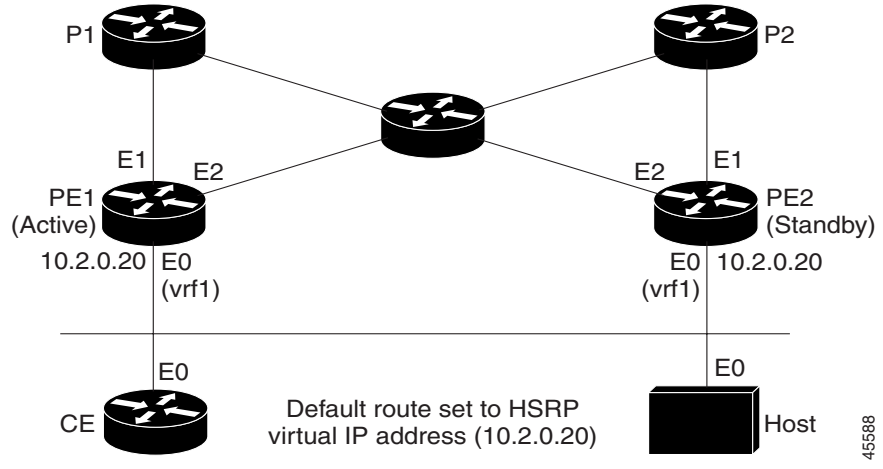
Backup Router Configuration

```
interface Ethernet1
 ip address 15.1.1.2 255.255.0.0
 no ip redirects
 standby priority 101
 standby ip 15.1.1.3
snmp-server enable traps hsrp
snmp-server host myhost.cisco.com public hsrp
```

HSRP Support for MPLS VPNs Example

Figure 21 shows two PEs with HSRP running between their VRF interfaces. The CE is configured with the HSRP virtual IP address as its default route. HSRP is configured to track the interfaces connecting the PEs to the rest of the provider network. For example, if interface E1 of PE1 fails, the HSRP priority will be reduced such that PE2 takes over forwarding packets to the HSRP virtual IP address.

Figure 21 Topology Showing HSRP Support Between Two VRF Interfaces



Router PE1 Configuration

```
configure terminal
 !
 ip cef
 !
 ip vrf vrf1
  rd 100:1
  route-target export 100:1
  route-target import 100:1
 !
 interface ethernet0
  ip vrf forwarding vrf1
  ip address 10.2.0.1 255.255.0.0
  standby 1 ip 10.2.0.20
  standby 1 priority 105
  standby preempt delay minimum 10
  standby 1 timers 3 1
  standby 1 track ethernet1 10
  standby 1 track ethernet2 10
```

Router PE2 Configuration

```
configure terminal
 !
 ip cef
 !
 ip vrf vrf1
  rd 100:1
  route-target export 100:1
  route-target import 100:1
 !
 interface ethernet0
  ip vrf forwarding vrf1
  ip address 10.2.0.2 255.255.0.0
  standby 1 ip 10.2.0.20
  standby 1 priority 100
  standby preempt delay minimum 10
  standby 1 timers 3 1
  standby 1 track ethernet1 10
  standby 1 track ethernet2 10
```

HSRP Support for ICMP Redirect Messages Example

The following is a configuration example for two HSRP groups that allow the filtering of ICMP redirect messages:

Router A Configuration—Active for Group 1 and Standby for Group 2

```
interface Ethernet1
  ip address 1.0.0.10 255.0.0.0
  standby redirects
  standby 1 priority 120
  standby 1 preempt delay minimum 20
  standby 1 ip 1.0.0.1
  standby 2 priority 100
  standby 2 preempt delay minimum 20
  standby 2 ip 1.0.0.2
```

Router B Configuration—Standby for Group 1 and Active for Group 2

```
interface Ethernet1
```

```
ip address 1.0.0.11 255.0.0.0
standby redirects
standby 1 priority 100
standby 1 preempt delay minimum 20
standby 1 ip 1.0.0.1
standby 2 priority 120
standby 2 preempt delay minimum 20
standby 2 ip 1.0.0.2
```

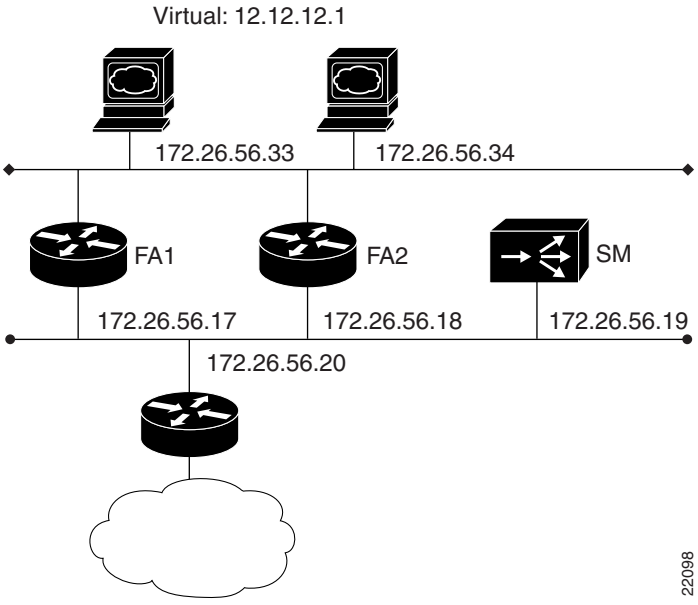
MNLB Forwarding Agent Examples

This section provides the following configuration examples:

- Forwarding Agent Configuration for FA2 Example
- Services Manager Configuration for SM Example

The network configured is shown in Figure 22.

Figure 22 MNLB Network Configuration



Forwarding Agent Configuration for FA2 Example

The following is a sample of a router configured as a Forwarding Agent. In this example all disabled interfaces have been omitted to simplify the display.

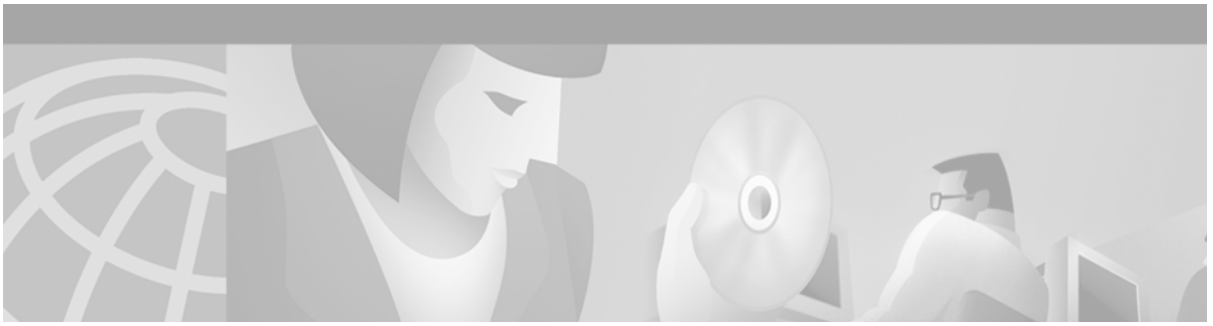
```
FA2# wr t
Building configuration...

Current configuration:
!
version 12.0
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
service udp-small-servers
```

```
service tcp-small-servers
!
hostname FA2
!
!
microcode CIP flash slot0:cip26-5
microcode reload
ip subnet-zero
no ip domain-lookup
!
ip cef distributed
ip casa 206.10.20.34 224.0.1.2
 forwarding-agent 1637
!
interface Ethernet0/0
 ip address 172.26.56.18 255.255.255.0
 no ip directed-broadcast
 ip route-cache flow
 ip igmp join-group 224.0.1.2
 no ip mroute-cache


!
interface Ethernet0/1
 ip address 172.26.56.37 255.255.255.0
 no ip directed-broadcast
!
!
!
router eigrp 777
 network 172.26.0.0
!

no ip classless
!
line con 0
 exec-timeout 0 0
 transport input none
line aux 0
line vty 0 4
 exec-timeout 0 0
login
!
end
```

Services Manager Configuration for SM Example

```
SM# wr t
Building configuration...
: Saved
: LocalDirector 420 Version 3.0.0.127
syslog output 20.3
no syslog console
enable password 00000000000000000000000000000000 encrypted
hostname SM
no shutdown ethernet 0
no shutdown ethernet 1
no shutdown ethernet 2
no shutdown ethernet 3
interface ethernet 0 auto
interface ethernet 1 auto
interface ethernet 2 auto
interface ethernet 3 auto
```

```
mtu 0 1500
mtu 1 1500
mtu 2 1500
mtu 3 1500
multiring all
no secure 0
no secure 1
no secure 2
no secure 3
ping-allow 0
ping-allow 1
ping-allow 2
ping-allow 3
ip address 172.26.56.19 255.255.255.248
route 172.26.10.249 255.255.255.255 172.26.56.20 1
route 206.10.20.33 255.255.255.255 172.26.56.17 1
route 206.10.20.34 255.255.255.255 172.26.56.18 1
no rip passive
failover ip address 0.0.0.0
failover
password cisco
telnet 161.0.0.0 255.0.0.0
no snmp-server contact
no snmp-server location
casa service-manager port 1638
casa service-manager multicast-ttl 60
tftp-server 172.26.10.249 /tftpboot/LD
virtual 172.26.56.13:0:0:tcp is
virtual 172.26.56.2:0:0:tcp is
redirection 172.26.56.13:0:0:tcp dispatched casa wildcard-ttl 60 fixed-ttl 60 igmp
224.0.1.2 port 1637
redirection 172.26.56.2:0:0:tcp dispatched casa wildcard-ttl 60 fixed-ttl 60 igmp
224.0.1.2 port 1637
real 172.26.56.34:0:0:tcp is
real 172.26.56.33:0:0:tcp is
real 172.26.56.6:0:0:tcp is
real 172.26.56.10:0:0:tcp is
bind 172.26.56.13:0:0:tcp 172.26.56.33:0:0:tcp
bind 172.26.56.13:0:0:tcp 172.26.56.34:0:0:tcp
bind 172.26.56.2:0:0:tcp 172.26.56.10:0:0:tcp
bind 172.26.56.2:0:0:tcp 172.26.56.6:0:0:tcp
: end
```



Configuring Server Load Balancing

This chapter describes how to configure the IOS Server Load Balancing (SLB) feature. For a complete description of the SLB commands in this chapter, refer to the "Server Load Balancing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services*. To locate documentation of other commands that appear in this chapter, use the command reference master index or search online.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

The SLB feature is a Cisco IOS-based solution that provides IP server load balancing. Using the IOS SLB feature, the network administrator defines a *virtual* server that represents a group of *real* servers in a cluster of network servers known as a *server farm*. In this environment the clients are configured to connect to the IP address of the virtual server. The virtual server IP address is configured as a loopback address, or secondary IP address, on each of the real servers. When a client initiates a connection to the virtual server, the IOS SLB function chooses a real server for the connection based on a configured load-balancing algorithm.

IOS SLB shares the same software code base as Cisco IOS software and has all the software features sets of Cisco IOS software. IOS SLB is recommended for customers desiring complete integration of SLB technology into traditional Cisco switches and routers.

On the Catalyst 6500 switch, IOS SLB takes advantage of hardware acceleration to forward data packets at very high speed when running in dispatched mode.

IOS SLB assures continuous, high availability of content and applications with proven techniques for actively managing servers and connections in a distributed environment. By distributing user requests across a cluster of servers, IOS SLB optimizes responsiveness and system capacity, and dramatically reduces the cost of providing Internet, database, and application services for large-scale sites as well as small- and medium-sized sites.

IOS SLB facilitates scalability, availability, and ease of maintenance as follows:

- The addition of new physical (real) servers, and the removal or failure of existing servers, can occur at any time, transparently, without affecting the availability of the virtual server.
- The slow start capability of IOS SLB allows a new server to increase its load gradually, preventing failures caused by assigning the server too many new connections too quickly.
- IOS SLB supports fragmented packets and packets with IP options, buffering your servers from client or network vagaries that are beyond your control.

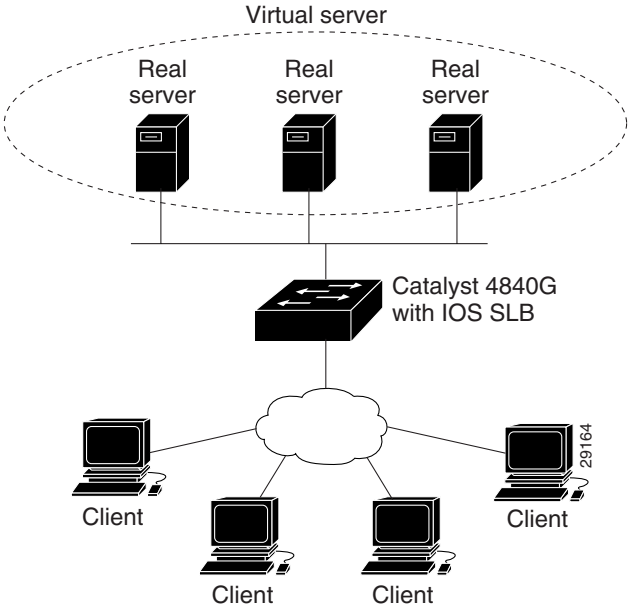
Administration of server applications is easier. Clients know only about virtual servers; no administration is required for real server changes.

Security of the real server is provided because its address is never announced to the external network. Users are familiar only with the virtual IP address. You can filter unwanted flows based on both IP address and TCP or UDP port numbers. Though it does not eliminate the need for a firewall, IOS SLB also can help protect against some denial-of-service attacks.

In a branch office, IOS SLB allows balancing of multiple sites and disaster recovery in the event of full-site failure, and distributes the work of load balancing.

Figure 23 illustrates a logical view of IOS SLB.

Figure 23 Logical View of IOS SLB



IOS SLB Functions and Capabilities

Functions and capabilities supported in IOS SLB are described in the following sections:

- Algorithms for Server Load Balancing
- Port-Bound Servers
- Client-Assigned Load Balancing
- Content Flow Monitor Support
- Sticky Connections
- Maximum Connections
- Delayed Removal of TCP Connection Context
- TCP Session Reassignment
- Automatic Server Failure Detection
- Automatic Unfail
- Slow Start

- SynGuard
- Dynamic Feedback Protocol for IOS SLB
- Alternate IP Addresses
- Transparent Web Cache Balancing
- NAT
- Redundancy Enhancement—Stateless Backup

Algorithms for Server Load Balancing

IOS SLB provides two load-balancing algorithms: weighted round robin and weighted least connections. You may specify either algorithm as the basis for choosing a real server for each new connection request that arrives at the virtual server.

Weighted Round Robin

The weighted round robin algorithm specifies that the real server used for a new connection to the virtual server is chosen from the server farm in a circular fashion. Each real server is assigned a weight, *n*, that represents its capacity to handle connections, as compared to the other real servers associated with the virtual server. That is, new connections are assigned to a given real server *n* times before the next real server in the server farm is chosen.

For example, assume a server farm comprises real server ServerA with $n = 3$, ServerB with $n = 1$, and ServerC with $n = 2$. The first three connections to the virtual server are assigned to ServerA, the fourth connection to ServerB, and the fifth and sixth connections to ServerC.

Note Assigning a weight of $n = 1$ to all of the servers in the server farm configures the IOS SLB switch to use a simple round robin algorithm.

Weighted Least Connections

The weighted least connections algorithm specifies that the next real server chosen from a server farm for a new connection to the virtual server is the server with the fewest number of active connections. Each real server is assigned a weight for this algorithm also. When weights are assigned, the server with the fewest number of connections is based on the number of active connections on each server, and on the relative capacity of each server. The capacity of a given real server is calculated as the assigned weight of that server divided by the sum of the assigned weights of all of the real servers associated with that virtual server, or $n_1/(n_1 + n_2 + n_3...)$.

For example, assume a server farm comprises real server ServerA with $n = 3$, ServerB with $n = 1$, and ServerC with $n = 2$. ServerA would have a calculated capacity of $3/(3 + 1 + 2)$, or half of all active connections on the virtual server, ServerB one-sixth of all active connections, and ServerC one-third of all active connections. At any point in time, the next connection to the virtual server would be assigned to the real server whose number of active connections is farthest below its calculated capacity.

Note Assigning a weight of $n = 1$ to all of the servers in the server farm configures the IOS SLB switch to use a simple least-connection algorithm.

Port-Bound Servers

When you define a virtual server, you must specify the TCP or UDP port handled by that virtual server. However, if you configure NAT on the server farm, you can also configure *port-bound servers*. Port-bound servers allow one virtual server IP address to represent one set of real servers for one service, such as HTTP, and a different set of real servers for another service, such as Telnet.

Packets destined for a virtual server address for a port that is not specified in the virtual server definition are not redirected.

IOS SLB supports both port-bound and nonport-bound servers, but port-bound servers are recommended.

Client-Assigned Load Balancing

Client-assigned load balancing allows you to limit access to a virtual server by specifying the list of client IP subnets that are permitted to use that virtual server. With this feature, you can assign a set of client IP subnets (such as internal subnets) connecting to a virtual IP address to one server farm, and assign another set of clients (such as external clients) to a different server farm.

Content Flow Monitor Support

IOS SLB supports the Cisco Content Flow Monitor (CFM), a Web-based status monitoring application within the CiscoWorks2000 product family. You can use CFM to manage Cisco server load-balancing devices. CFM runs on Windows NT and Solaris workstations, and is accessed using a Web browser.

Sticky Connections

When you use sticky connections, new connections from a client IP address or subnet are assigned to the same real server as were previous connections from that address or subnet.

IOS SLB creates sticky objects to track client assignments. The sticky objects remain in the IOS SLB database after the last sticky connection is deleted, for a period defined by a configurable *sticky timer*. If the timer is configured on a virtual server, new connections from a client are sent to the same real server that handled the previous client connection, provided one of the following conditions is true:

- A connection for the same client already exists.
- The amount of time between the end of a previous connection from the client and the start of the new connection is within the timer duration.

Sticky connections also permit the coupling of services that are handled by more than one virtual server. This allows connection requests for related services to use the same real server. For example, Web server (HTTP) typically uses TCP port 80, and HTTP over Secure Socket Layer (HTTPS) uses port 443. If HTTP virtual servers and HTTPS virtual servers are coupled, connections for ports 80 and 443 from the same client IP address or subnet are assigned to the same real server.

Maximum Connections

The maximum connections feature allows you to configure a limit on the number of active connections that a real server can handle.

Delayed Removal of TCP Connection Context

Because of IP packet ordering anomalies, IOS SLB might "see" the termination of a TCP connection (a finish [FIN] or reset [RST]) followed by other packets for the connection. This problem usually occurs when there are multiple paths that the TCP connection packets can follow. To correctly redirect the packets that arrive after the connection is terminated, IOS SLB retains the TCP connection information, or context, for a specified length of time. The length of time the context is retained after the connection is terminated is controlled by a configurable *delay timer*.

TCP Session Reassignment

IOS SLB tracks each TCP SYN sent to a real server by a client attempting to open a new connection. If several consecutive SYNs are not answered, or if a SYN is replied to with an RST, the TCP session is reassigned to a new real server. The number of SYN attempts is controlled by a configurable *reassign threshold*.

Automatic Server Failure Detection

IOS SLB automatically detects each failed TCP connection attempt to a real server, and increments a failure counter for that server. (The failure counter is not incremented if a failed TCP connection from the same client has already been counted.) If the failure counter of a server exceeds a configurable *failure threshold*, the server is considered *out of service* and is removed from the list of active real servers.

Automatic Unfail

When a real server fails and is removed from the list of active servers, it is assigned no new connections for a length of time specified by a configurable *retry timer*. After that timer expires, the server is again eligible for new virtual server connections and IOS SLB sends the server the next connection for which it qualifies. If the connection is successful, the failed server is again placed back on the list of active real servers. If the connection is unsuccessful, the server remains out of service and the retry timer is reset.

Slow Start

In an environment that uses weighted least connections load balancing, a real server that is placed in service initially has no connections, and could therefore be assigned so many new connections that it becomes overloaded. To prevent such an overload, the slow start feature controls the number of new connections that are directed to a real server that has just been placed in service.

SynGuard

The SynGuard feature limits the rate of TCP SYNs handled by a virtual server to prevent a type of network problem known as a *SYN flood denial-of-service attack*. A user might send a large number of SYNs to a server, which could overwhelm or crash the server, denying service to other users. SynGuard prevents such an attack from bringing down IOS SLB or a real server. SynGuard monitors the number of SYNs to a virtual server over a specific time interval and does not allow the number to exceed a configured *SYN threshold*. If the threshold is reached, any new SYNs are dropped.

Dynamic Feedback Protocol for IOS SLB

The IOS SLB Dynamic Feedback Protocol (DFP) is a mechanism that allows host agents in load-balanced environments to dynamically report the change in status of the host systems that provide a virtual service. The status reported is a relative weight that specifies the capacity of a host server to perform work.

Alternate IP Addresses

IOS SLB enables you to Telnet to the load-balancing device using an alternate IP address. To do so, use either of the following methods:

- Use any of the interface addresses to Telnet to the load-balancing device.
- Define a secondary IP address to Telnet to the load-balancing device.

This function is similar to that provided by the LocalDirector (LD) Alias command.

Transparent Web Cache Balancing

You can balance transparent Web caches if you know in advance the IP addresses they are serving. In IOS SLB, configure the IP addresses, or some common subset of them, as virtual servers.

Note A Web cache can start its own connections to real sites if pages are not available in its cache. Those connections cannot be load balanced back to the same set of caches. IOS SLB addresses this situation by allowing you to configure "client exclude" statements so that IOS SLB does not load balance connections initiated by the Web caches.

NAT

Cisco IOS Network Address Translation (NAT), RFC 1631, allows unregistered "private" IP addresses to connect to the Internet by translating them into globally registered IP addresses. Cisco IOS NAT also increases network privacy by hiding internal IP addresses from external networks.

IOS SLB can operate in one of two redirection modes:

- Directed mode—The virtual server can be assigned an IP address that is not known to any of the real servers. IOS SLB translates packets exchanged between a client and real server, translating the virtual server IP address to a real server address via NAT.
- Dispatched mode—The virtual server address is known to the real servers; you must configure the virtual server IP address as a loopback address, or secondary IP address, on each real server. IOS SLB redirects packets to the real servers at the media access control (MAC) layer. Because the virtual server IP address is not modified in dispatched mode, the real servers must be Layer 2 adjacent to IOS SLB, or intervening routers might not be able to route to the chosen real server.

The main advantage of dispatched mode is performance. In dispatched mode, the Layer 3 and Layer 4 addresses are not modified, which means IP header checksum adjustment occurs quickly, and checksum adjustment or recalculation for TCP or UDP is not required. Dispatched mode is also simpler than in directed mode because packets for applications with IP addresses in the packet need not be examined and modified.

The main disadvantage of dispatched mode is that the virtual server IP address is not modified, which means that the real servers must be Layer 2 adjacent with the load balancer or intervening routers may not be able to route to the chosen real server.

NAT (directed mode) is used to solve these dispatched mode problems.

IOS SLB currently supports only server NAT. By replacing the virtual server IP address with the real server IP address (and vice versa), servers can be many hops away from the load balancer and intervening routers can route to them without requiring tunneling. Additionally, loopback and secondary interfaces need no longer be on the real server.

Note On the Catalyst 6000 family switches and Cisco 7200 series routers, if an IP address is configured as a real IP address for a NAT virtual server, you cannot balance connection requests from that address to a different virtual server (whether NAT or dispatch) on the same load balancer.

The network designer must ensure that outbound packets travel through IOS SLB using one of the following methods:

- Direct wiring (all packets flow through a branch office IOS SLB device)
- Default gateways or policy-based routing
- IOS SLB NAT of client addresses, enabled as an outbound feature on server-side interfaces

A less common form of server NAT is server port translation, which involves replacement of a virtual server port. Server port translation does not require server IP address translation, but the two translations can be used together.

Redundancy Enhancement—Stateless Backup

An IOS SLB could represent a point of failure and the servers could lose their connections to the backbone if power fails, or if a link from a switch to the distribution-layer switch is disconnected. IOS SLB supports a stateless backup option you can use to reduce that risk. Stateless backup, based on the Hot Standby Router Protocol (HSRP), provides high network availability by routing IP flows from hosts on Ethernet networks without relying on the availability of a single Layer 3 switch.

HSRP is configured on Layer 3 switches that run IP over Ethernet. If a Layer 3 switch fails, HSRP automatically allows another Layer 3 switch to assume the function of the failing switch. HSRP is therefore particularly useful when you require continuous access to resources in the network.

HSRP is compatible with Internetwork Packet Exchange (IPX) from Novell and with AppleTalk.

Note To avoid any single point of failure in an IOS SLB network, use multiple Layer 2 switches to provide connectivity between the IOS SLB devices and the servers.

Restrictions

IOS SLB has the following restrictions:

- Operates in a standalone mode and currently does not operate as a MultiNode Load Balancing (MNLB) Services Manager. The presence of IOS SLB does not preclude the use of the existing MNLB Forwarding Agent with an external Services Manager in an MNLB environment.

- Does not support coordinating server load-balancing statistics among different IOS SLB instances for backup capability.
- Supports FTP only in dispatched mode.
- Does not support load balancing of flows between clients and real servers that are on the same LAN VLAN.
- Does not support IOS SLB and Cisco Applications and Services Architecture (CASA) configured with the same virtual IP address, even if they are for different services.
- Supports Cisco IOS NAT in directed mode with no hardware data packet acceleration. (Hardware data packet acceleration is performed by the Policy Feature Card (PFC), and in directed mode the data packets are handled by the Multilayer Switched Feature Card (MSFC), not the PFC.)

Catalyst 6000 family switch restrictions are as follows:

- Requires the MSFC and the PFC.
- Requires that the Multilayer Switching (MLS) flow mode be set to **full**. For more information about how to set the MLS flow, refer to the "Configuring IP Multilayer Switching" section in the *Catalyst 6000 Family MSFC (12.0) & PFC Configuration Guide, Release 5.4*.
- When IOS SLB is operating in dispatched mode, real servers must be Layer 2-adjacent to the IOS SLB switch (that is, not beyond an additional router), with hardware data packet acceleration performed by the PFC. All real servers that can be reached by a single IOS SLB device must be on the same VLAN. The loopback address must be configured in the real servers.
- When IOS SLB is operating in directed mode with server NAT, real servers need not be Layer 2-adjacent to the IOS SLB switch. This allows for more flexible network design, because servers can be placed several Layer 3 hops away from the IOS SLB switch.
- Requires that all real servers that can be reached by a single IOS SLB device must be on the same VLAN. The loopback address must be configured in the real servers.
  - Supports NativeIOS only and C6sup-is-mz images.

Cisco 7200 series restrictions are as follows:

- In dispatched mode, the servers must be Layer 2-adjacent or tag-switched. In directed mode, the servers can be one or more hops away.
- Supports Cisco IOS NAT in directed mode with no hardware data packet acceleration. Provides no hardware acceleration for the IOS SLB function for either dispatched mode or directed mode.
- Supports C7200-is-mz images.

IOS SLB Configuration Task List

Configuring IOS SLB involves identifying server farms, configuring groups of real servers in server farms, and configuring the virtual servers that represent the real servers to the clients. To configure the IOS SLB feature, perform the tasks described in the following sections in the order listed. Some tasks are required; others are optional.

- Specifying a Server Farm (Required)
- Specifying a Load-Balancing Algorithm (Optional)
- Specifying a Bind ID (Optional)
- Specifying a Real Server (Required)
- Configuring Real Server Attributes (Optional)

- Enabling the Real Server for Service (Required)
- Specifying a Virtual Server (Required)
- Associating a Virtual Server with a Server Farm (Required)
- Configuring Virtual Server Attributes (Required)
- Adjusting Virtual Server Values (Optional)
- Preventing Advertisement of Virtual Server Address (Optional)
- Enabling the Virtual Server for Service (Required)
- Configuring IOS SLB Dynamic Feedback Protocol (Optional)
- Configuring NAT (Optional)
- Implementing IOS SLB Stateless Backup (Optional)
- Verifying IOS SLB (Optional)
- Troubleshooting IOS SLB (Optional)

Specifying a Server Farm

Grouping real servers into server farms is an essential part of IOS SLB. Using server farms enables IOS SLB to assign new connections to the real servers based on their weighted capacities, and on the load-balancing algorithms used.

To configure a server farm, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip slb serverfarm` *serverfarm-name*	Adds a server farm definition to the IOS SLB configuration and initiates SLB server farm configuration mode.

Specifying a Load-Balancing Algorithm

To determine which real server to use for each new connection request, the IOS SLB feature uses one of two load-balancing algorithms: weighted round robin (the default) or weighted least connections. (See the "Weighted Round Robin" section or the "Weighted Least Connections" section for detailed descriptions of these algorithms.) To specify the load-balancing algorithm, use the following command in SLB server farm configuration mode:

Command	Purpose
`Router(config-slb-sfarm)# predictor [roundrobin | leastconns]`	Specifies whether the weighted round robin algorithm or the weighted least connections algorithm is to be used to determine how a real server is selected.

Specifying a Bind ID

To configure a bind ID on the server farm for use by DFP, use the following command in SLB server farm configuration mode:

Command	Purpose
`Router(config-slb-sfarm)# bindid [bind_id]`	Specifies a bind ID on the server farm for use by DFP.

Specifying a Real Server

A server farm comprises a number of real servers. The real servers are the physical devices that provide the load-balanced services.

To identify a real server in your network, use the following command inSLB server farm configuration mode:

Command	Purpose
`Router(config-slb-sfarm)# real ip-address`	Identifies a real server to the IOS SLB function and initiates real server configuration mode.

Configuring Real Server Attributes

To configure real server attributes, use the following commands in SLB real server configuration mode:

Command	Purpose
`Router(config-slb-real)# faildetect numconns number-conns [numclients number-clients]`	Specifies the number of consecutive connection failures and, optionally, the number of unique client connection failures, that constitute failure of the real server.
`Router(config-slb-real)# maxconns maximum-number`	Specifies the maximum number of active connections allowed on the real server at one time.
`Router(config-slb-real)# reassign threshold`	Specifies the number of consecutive unanswered SYNs that initiates assignment of the connection to a different real server.
`Router(config-slb-real)# retry retry-value`	Specifies the interval (in seconds) to wait between the detection of a server failure and the next attempt to connect to the failed server.
`Router(config-slb-real)# weight weighting-value`	Specifies the workload capacity of the real server relative to other servers in the server farm.

Enabling the Real Server for Service

To place the real server into service, use the following command in SLB real server configuration mode:

Command	Purpose
`Router(config-slb-real)# inservice`	Enables the real server for use by IOS SLB.

Specifying a Virtual Server

To specify a virtual server, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip slb vserver` *virtserver-name*	Identifies a virtual server and enters SLB virtual server configuration mode.

Associating a Virtual Server with a Server Farm

To associate the virtual server with a server farm, use the following command in SLB virtual server configuration mode:

Command	Purpose
`Router(config-slb-vserver)# serverfarm` *serverfarm-name*	Associates a real server farm with a virtual server.

Configuring Virtual Server Attributes

To configure virtual server attributes, use the following command in SLB virtual server configuration mode:

Command	Purpose
`Router(config-slb-vserver)# virtual` *ip-address* {**tcp** | **udp**} *port-number* [**service** *service-name*]	Specifies the virtual server IP address, type of connection, port number, and optional service coupling.

Adjusting Virtual Server Values

To change the default settings of the virtual server values, use the following commands in SLB virtual server configuration mode as needed:

Command	Purpose
`Router(config-slb-vserver)# client ip-address network-mask`	Specifies which clients are allowed to use the virtual server.
`Router(config-slb-vserver)# delay duration`	Specifies the amount of time IOS SLB maintains TCP connection context after a connection has terminated. The default value is 10 seconds.
`Router(config-slb-vserver)# idle duration`	Specifies the minimum amount of time IOS SLB maintains connection context in the absence of packet activity. The default value is 3600 seconds (1 hour).
`Router(config-slb-vserver)# sticky duration [group group-id]`	Specifies that connections from the same client use the same real server, as long as the interval between client connections does not exceed the specified duration.
`Router(config-slb-vserver)# synguard syn-count interval`	Specifies the rate of TCP SYNs handled by a virtual server in order to prevent a SYN flood denial-of -service attack.

Preventing Advertisement of Virtual Server Address

By default, virtual server addresses are *advertised*. That is, static routes to the Null0 interface are installed for the virtual server addresses. To advertise these static routes using the routing protocol, you must configure redistribution of static routes for the routing protocol. To prevent the installation of a static route, use the following command in SLB virtual server configuration mode:

Command	Purpose
`Router(config-slb-vserver)# no advertise`	Omits the virtual server IP address from the routing protocol updates.

Enabling the Virtual Server for Service

To place the virtual server into service, use the following command in SLB virtual server configuration mode:

Command	Purpose
`Router(config-slb-vserver)# inservice`	Enables the virtual server for use by IOS SLB.

Configuring IOS SLB Dynamic Feedback Protocol

To configure IOS SLB DFP, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip slb dfp [password password [timeout]]`	Configures DFP and, optionally, sets a password and initiates SLB DFP configuration mode.
Step 2	`Router(config-slb-dfp)# agent ip-address port [timeout [retry-count [retry-interval]]]`	Configures a DFP agent.

Configuring NAT

To configure IOS SLB NAT mode for a specific server farm, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip slb serverfarm serverfarm-name`	Adds a server farm definition to the IOS SLB configuration and initiates server farm configuration mode.
Step 2	`Router(config-slb-sfarm)# nat server`	Configures server NAT.
Step 3	`Router(config-slb-sfarm)# real ip-address`	Identifies a real server to the IOS SLB function and initiates real server configuration mode.

Implementing IOS SLB Stateless Backup

Stateless backup, based on the Hot Standby Router Protocol (HSRP), provides high network availability by routing IP flows from hosts on Ethernet networks without relying on the availability of any single Layer 3 switch. Stateless backup is particularly useful for hosts that do not support a router discovery protocol (such as the Intermediate System-to-Intermediate System [IS-IS] Interdomain Routing Protocol [IDRP]) and do not have the functionality to shift to a new Layer 3 switch when their selected Layer 3 switch reloads or loses power.

How IOS SLB Stateless Backup Works

A Layer 3 switch running HSRP detects a failure by sending and receiving multicast UDP hello packets. When the IOS SLB switch running HSRP detects that the designated active Layer 3 switch has failed, the selected backup Layer 3 switch assumes control of the HSRP group MAC and IP addresses. (You can also select a new standby Layer 3 switch at that time.) Both the primary and the backup Layer 3 switch must be on the same subnetwork.

The chosen MAC and IP addresses must be unique and must not conflict with any others on the same network segment. The MAC address is selected from a pool of Cisco MAC addresses. Configure the last byte of the MAC address by using the HSRP group number. When HSRP is running, it selects an active Layer 3 switch and instructs its device layer to listen on an additional (dummy) MAC address.

IOS SLB switching software supports HSRP over 10/100 Ethernet, Gigabit Ethernet, FEC, GEC, and Bridge Group Virtual Interface (BVI) connections.

HSRP uses a priority scheme to determine which HSRP-configured Layer 3 switch is to be the default active Layer 3 switch. To configure a Layer 3 switch as active, you assign it a priority higher than that of all other HSRP-configured Layer 3 switches. The default priority is 100, so if you configure just one Layer 3 switch to have a higher priority, that switch becomes the default active switch.

HSRP works by the exchange of multicast messages that advertise priority among HSRP-configured Layer 3 switches. When the active switch fails to send a hello message within a configurable period, the standby switch with the highest priority becomes the active switch. The transition of packet-forwarding functions between Layer 3 switches is completely transparent to all hosts accessing the network.

HSRP-configured Layer 3 switches exchange the following types of multicast messages:

- Hello—The hello message conveys the HSRP priority and state information of the switch. By default, an HSRP switch sends hello messages every 3 seconds.
- Coup—When a standby Layer 3 switch assumes the function of the active switch, it sends a coup message.
- Resign—The active Layer 3 switch sends a resign message when it is about to shut down or when a switch that has a higher priority sends a hello message.

At any time, HSRP-configured Layer 3 switches are in one of the following states:

- Active—The switch is performing packet-transfer functions.
- Standby—The switch is prepared to assume packet-transfer functions if the active router fails.
- Speaking and listening—The switch is sending and receiving hello messages.
- Listening—The switch is receiving hello messages.

Configuring IOS SLB Stateless Backup

To configure stateless backup, perform the following tasks. The first task is required; the second task is optional:

- Configure IOS SLB switches to run HSRP between interfaces on the server side
- Configure multiple IOS SLB switches that share a virtual IP address as long as the client ranges are exclusive and you use policy routing to forward the flows to the correct IOS SLB switch

To configure stateless backup over VLANs between IOS SLB switches, perform the following steps:

Step 1 Configure the server farms. See the “Specifying a Server Farm” section earlier in this chapter.

Step 2 Configure the real servers. See the “Specifying a Real Server” section earlier in this chapter.

Step 3 Configure the virtual servers. See the “Specifying a Virtual Server”section earlier in this chapter.

Note When you use the **inservice** (virtual service) command to configure the virtual server as “in-service” you must use the optional **standby** interface configuration command and configure an HSRP group name.

Step 4 Configure the IP routing protocol. See the “IP Routing Protocols” part of the *Cisco IOS IP Configuration Guide*.

Step 5 Configure the VLAN between the switches. See the “Virtual LANs” chapter of the *Cisco IOS Switching Services Configuration Guide*.

Step 6 Enable HSRP. See the “Enabling HSRP” section earlier in this chapter.

Step 7 Customize group attributes. See the "Customizing Group Attributes" section earlier in this chapter.

Step 8 Verify the IOS SLB HSRP configuration. See the "Verifying the IOS SLB Stateless Backup Configuration" section earlier in this chapter.

A sample stateless backup configuration is shown in the "IOS SLB Stateless Backup Configuration Example" section.

Enabling HSRP

To enable HSRP on an IOS SLB interface, enable the protocol, then customize it for the interface. Use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# standby [group-number] ip [ip-address [secondary]]`	Enables HSRP.

Customizing Group Attributes

To customize Hot Standby group attributes, use the following commands in interface configuration mode as needed:

Command	Purpose
`Router(config-if)# standby [group-number] authentication string`	Selects an authentication string to be carried in all HSRP messages.
`Router(config-if)# standby [group-number] name group-name`	Specifies an HSRP group name with which to associate an IOS SLB interface.
`Router(config-if)# standby [group-number] preempt`	Specifies that if the local router has priority over the current active router, the local router should attempt to take its place as the active router.
`Router(config-if)# standby [group-number] priority priority`	Sets the Hot Standby priority used to choose the active router.
`Router(config-if)# standby [group-number] timers hellotime holdtime`	Configures the time between hello packets and the hold time before other routers declare the active router to be down.
`Router(config-if)# standby [group-number] track type-number [interface-priority]`	Configures the interface to track other interfaces, so that if one of the other interfaces goes down the Hot Standby priority for the device is lowered.

Verifying the IOS SLB Stateless Backup Configuration

To verify that stateless backup has been configured and is operating correctly, use the following **show ip slb vservers** EXEC commands to display information about the IOS SLB virtual server status:

```
Router# show ip slb vservers

slb vservers      prot  virtual              state         conns
--------------------------------------------------------------------
```

```
VS1              TCP   10.10.10.12:23        INSERVICE     2
VS2              TCP   10.10.10.18:23        INSERVICE     2

Router# show ip slb vservers detail

VS1, state = INSERVICE, v_index = 10
  virtual = 10.10.10.12:23, TCP, service = NONE, advertise = TRUE
  server farm = SERVERGROUP1, delay = 10, idle = 3600
  sticky timer = 0, sticky subnet = 255.255.255.255
  sticky group id = 0
  synguard counter = 0, synguard period = 0
  conns = 0, total conns = 0, syns = 0, syn drops = 0
  standby group = None
VS2, state = INOFSERVICE, v_index = 11
  virtual = 10.10.10.18:23, TCP, service = NONE, advertise = TRUE
  server farm = SERVERGROUP2, delay = 10, idle = 3600
  sticky timer = 0, sticky subnet = 255.255.255.255
  sticky group id = 0
  synguard counter = 0, synguard period = 0
  conns = 0, total conns = 0, syns = 0, syn drops = 0
  standby group = None
```

Verifying IOS SLB

The following sections describe how to verify the following different aspects of the IOS SLB feature:

- Verifying IOS SLB Installation
- Verifying Server Failure Detection

Verifying IOS SLB Installation

To verify that the IOS SLB is installed and working properly, perform the following steps:

Step 1 Telnet to the IOS SLB device.

Step 2 Ping from that device to each of the clients and real servers. If it is not precluded by firewalls or network configuration, ping from the client side to each of the real servers.

Step 3 From the client side, ping the virtual server. Pings are answered by IOS SLB even if no real servers are in service, so this ensures that the IOS SLB device is reachable.

Step 4 For the selected protocol, start a client connection to the virtual server.

Step 5 If you want sticky connections, perform the following steps:

a. Configure the sticky connections.

b. Start a client connection.

c. Enter the **show ip slb reals detail** and **show ip slb conns** EXEC commands.

d. Examine the real server connection counts. The real server whose count increased is the one to which the client connection is assigned.

e. Enter the **show ip slb sticky** EXEC command to display the sticky relationships that IOS SLB stored.

f. End the connection.

g. Ensure that the connection count of the real server decreased.

h. Restart the connection, after waiting no longer than the sticky timeout value.

i. Enter the **show ip slb conns** EXEC command again.

j. Examine the real server connection counts again, and verify that the sticky connection is assigned to the same real server as before.

Step 6 Start additional client connections.

Step 7 Enter the **show ip slb reals detail** EXEC command.

Step 8 Verify that the the connection counts are increasing.

Verifying Server Failure Detection

To verify that server failures are detected correctly, perform the following steps:

Step 1 Use a large client population. If the number of clients is very small, tune the **numclients** keyword on the **faildetect** SLB real server configuration command so that the servers are not displayed as **failed**.

Step 2 Enter the **show ip slb reals detail** EXEC command to show the status of the real servers.

Step 3 Examine the status and connection counts of the real servers:

- Servers that failed show a status of **failed**, **testing**, or **ready_to_test**, based on whether IOS SLB is checking that the server came back up when the command was sent.
- When a real server fails, connections that are assigned but not established (no SYN or ACK is received) are reassigned to another real server on the first inbound SYN after the **reassign** threshold is met. However, any connections that were already established are forwarded to the same real server because, although it may not be accepting new connections, it may be servicing existing ones.
- For weighted least connections, a real server that has just been placed in service starts slowly so that it is not overloaded with new connections. (See the "Slow Start" section for more information on this feature.) Therefore, the connection counts displayed for a new real server show connections going to other real servers (despite the lower count of the new real server). The connection counts also show "dummy connections" to the new real server, which IOS SLB uses to artificially inflate the connection counts for the real server during the slow start period.

Troubleshooting IOS SLB

Table 6 lists questions and answers that can help you troubleshoot IOS SLB.

Table 6 IOS SLB Troubleshooting Guidelines

Question	Answer
Why can I connect to real servers directly, but not to the virtual server?	Make sure that the virtual IP address is configured as a loopback in each of the real servers (if you are running in dispatched mode).
Why is IOS SLB not marking my real server as failed when I disconnect it from the network?	Tune the values for the **numclients**, **numconns**, and **delay** keywords. If you have a very small client population (for example, in a test environment), the **numclients** keyword could be causing the problem. This parameter prevents IOS SLB from mistaking the failure of a small number of clients for the failure of a real server.
Why is IOS SLB not marking my connections as **established** even though I am transferring data?	If you are using dispatched mode, make sure there are no alternate paths that allow outbound flows to bypass IOS SLB. Also, make sure that the clients and real servers are not on the same IP subnet.
Why does IOS SLB show my real server as **inservice** even though I have taken it down or physically disconnected it?	The **inservice** and **outofservice** states indicate whether the network administrator *intends* for that real server to be used when it is operational. A real server that was **inservice** but was removed from the selection list dynamically by IOS SLB as a result of automatic failure detection, is marked as **failed**. Use the **show ip slb reals detail** EXEC command to display these real server states. Beginning with Cisco IOS Release 12.1(1)E, the **inservice** keyword is changed to **operational**, to better reflect actual condition.

Why is IOS SLB not balancing correctly? I am using dispatched mode, the servers are leaving sockets open, and I am seeing RSTs in response to a number of SYNs. Curiously, sometimes things work fine.	Enter the **show mls flow** command:
	`Router# show mls flow`
	
	`current ip flowmask for unicast: full flow`
	`current ipx flowmask for unicast: destination only`
	
	The current IP flowmask must be **full flow**. If it is not, correct the problem using the **mls flow ip full** global configuration command:
	`Router# configure terminal`
	`Enter configuration commands, one per line.`
	`End with CNTL/Z.`
	`Router(config)# mls flow ip full`
	`Router(config)#`

Monitoring and Maintaining IOS SLB

To obtain and display run-time information about IOS SLB, use the following commands in EXEC mode as needed:

Command	Purpose
Router# **show ip slb conns** [**vservers** *virtserver-name*] [**client** *ip-address*] [**detail**]	Displays all connections handled by IOS SLB, or, optionally, only those connections associated with a particular virtual server or client.
Router# **show ip slb dfp** [**agent** *ip-address port-number*] [**detail**] [**weights**]	Displays information about DFP and DFP agents, and about the weights assigned to real servers.
Router# **show ip slb reals** [**vservers** *virtserver-name*] [**detail**]	Displays information about the real servers defined to IOS SLB.
Router# **show ip slb serverfarms** [**name** *serverfarm-name*] [**detail**]	Displays information about the server farms defined to IOS SLB.
Router# **show ip slb stats**	Displays IOS SLB statistics.
Router# **show ip slb sticky** [**client** *ip-address*]	Displays information about the sticky connections defined to IOS SLB.
Router# **show ip slb vservers** [**name** *virtserver-name*] [**detail**]	Displays information about the virtual servers defined to IOS SLB.

Configuration Examples

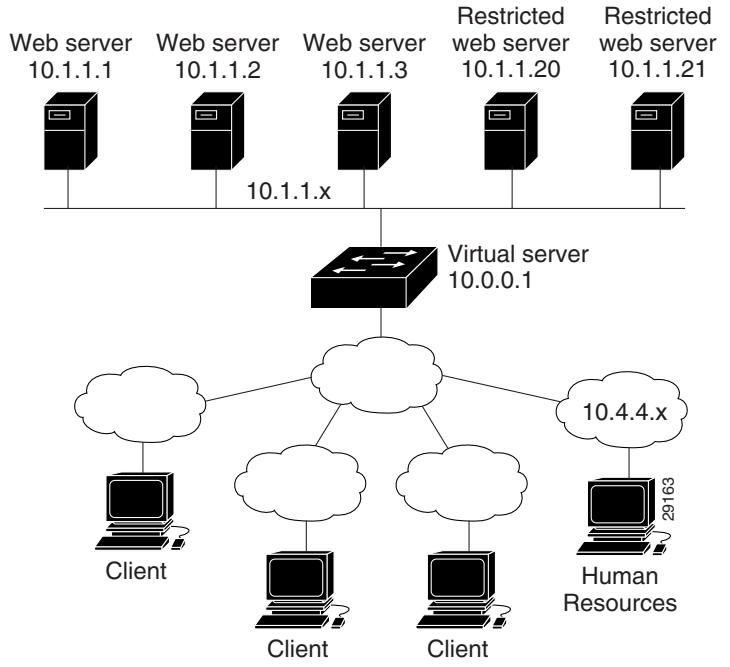
This section provides the following IOS SLB configuration examples:

- IOS SLB Network Configuration Example
- NAT Configuration Example
- HSRP Configuration Example
- IOS SLB Stateless Backup Configuration Example

IOS SLB Network Configuration Example

This section provides a configuration example based on the network layout shown in Figure 24.

Figure 24 IOS SLB Network Configuration



As shown in the following sample code, the example topology has three public Web servers and two restricted Web servers for privileged clients in subnet 10.4.4.x. The public Web servers are weighted according to their capacity, with server 10.1.1.2 having the lowest capacity and having a connection limit imposed on it. The restricted Web servers are configured as members of the same sticky group, so that HTTP connections and Secure Socket Layer (SSL) connections from the same client use the same real server.

This configuration is coded as follows:

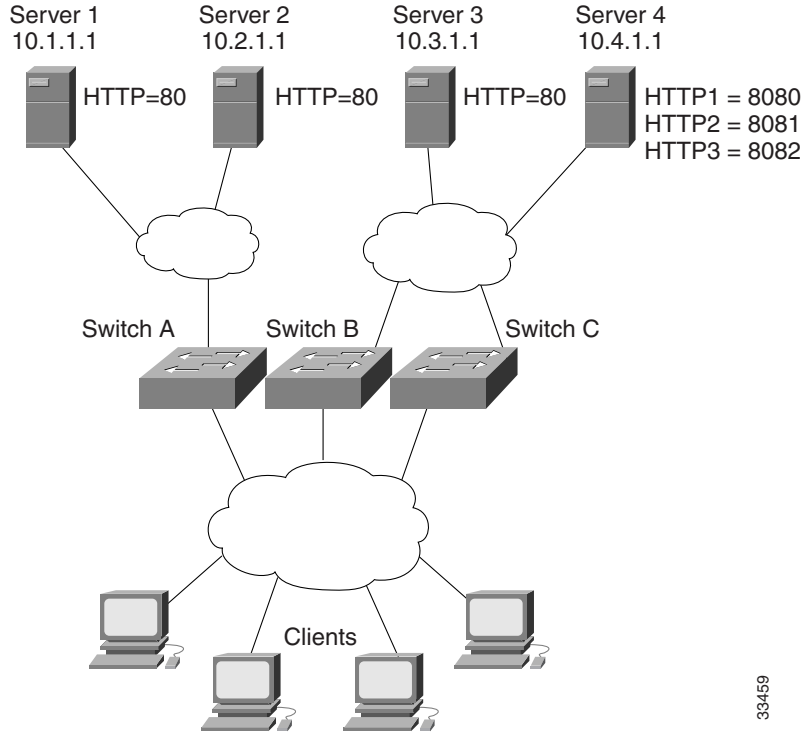
```
ip slb serverfarm PUBLIC                    Unrestricted Web server farm
  predictor leastconns                      Use weighted least connections algorithm
  real 10.1.1.1                             First real server
    weight 16
    inservice
  real 10.1.1.2                             Second real server
    weight 4
    maxconns 1000                           Restrict maximum number of connections
    inservice
  real 10.1.1.3                             Third real server
    weight 24
    inservice


ip slb serverfarm RESTRICTED                Restricted Web server farm
  predictor leastconns                      Use weighted least connections algorithm
  real 10.1.1.20                            First real server
    in-service
  real 10.1.1.21                            Second real server
    in-service
```

```
ip slb vservers PUBLIC_HTTP                 Unrestricted Web virtual server
  virtual 10.0.0.1 tcp www                 Handle HTTP requests
  serverfarm PUBLIC                        Use public Web server farm
  inservice

ip slb vservers RESTRICTED_HTTP             Restricted HTTP virtual server
  virtual 10.0.0.1 tcp www                 Handle HTTP requests
  serverfarm RESTRICTED                    Use restricted Web server farm
  client 10.4.4.0 255.255.255.0            Only allow clients from 10.4.4.x
  sticky 60 idle 120 group 1               Couple connections with RESTRICTED_SSL
  inservice

ip slb vservers RESTRICTED_SSL              Restricted SSL virtual server
  virtual 10.0.0.1 tcp https               Handle SSL requests
  serverfarm RESTRICTED                    Use restricted Web server farm
  client 10.4.4.0 255.255.255.0            Only allow clients from 10.4.4.x
  sticky 60 idle 120 group 1               Couple connections with RESTRICTED_HTTP
  inservice
```

NAT Configuration Example

This section provides a configuration example based on the network layout shown in Figure 25.

Figure 25 IOS SLB NAT Topology



The topology in Figure 25 has four Web servers, configured as follows:

- Servers 1, 2, and 3 are running single HTTP server applications listening on port 80.

- Server 4 has multiple HTTP server applications listening on ports 8080, 8081, and 8082.

Servers 1 and 2 are load balanced using Switch A, which is performing server address translation.

Servers 3 and 4 are load balanced using Switches B and C. These two switches are performing server address translation. These switches also perform server port translation for HTTP packets to and from Server 4.

The configuration statements for Switch A are as follows:

```
ip slb serverfarm FARM1
! Translate server addresses
  nat server
! Server 1 port 80
  real 10.1.1.1
    inservice
! Server 2 port 80
  real 10.2.1.1
    inservice
!
ip slb vservers HTTP1
! Handle HTTP (port 80) requests
  virtual 128.1.0.1 tcp www
  serverfarm FARM1
  inservice
```

The configuration statements for Switch B are as follows:

```
ip slb serverfarm FARM2
! Translate server addresses
  nat server
! Server 3 port 80
  real 10.3.1.1
    inservice
! Server 4 port 8080
  real 10.4.1.1 port 8080
    inservice
! Server 4 port 8081
  real 10.4.1.1 port 8081
    inservice
! Server 4 port 8082
  real 10.4.1.1 port 8082
    inservice
!
ip slb vservers HTTP2
! Handle HTTP (port 80) requests
  virtual 128.2.0.1 tcp www
  serverfarm FARM2
  inservice
```

The configuration statements for Switch C are as follows:

```
ip slb serverfarm FARM2
! Translate server addresses
  nat server
! Server 3 port 80
  real 10.3.1.1
    inservice
! Server 4 port 8080
  real 10.4.1.1 port 8080
    inservice
! Server 4 port 8081
  real 10.4.1.1 port 8081
    inservice
! Server 4 port 8082
```

```
  real 10.4.1.1 port 8082
    inservice
!
ip slb vservers HTTP2
! Handle HTTP (port 80) requests
  virtual 128.4.0.1 tcp www
  serverfarm FARM2
  inservice
```

HSRP Configuration Example

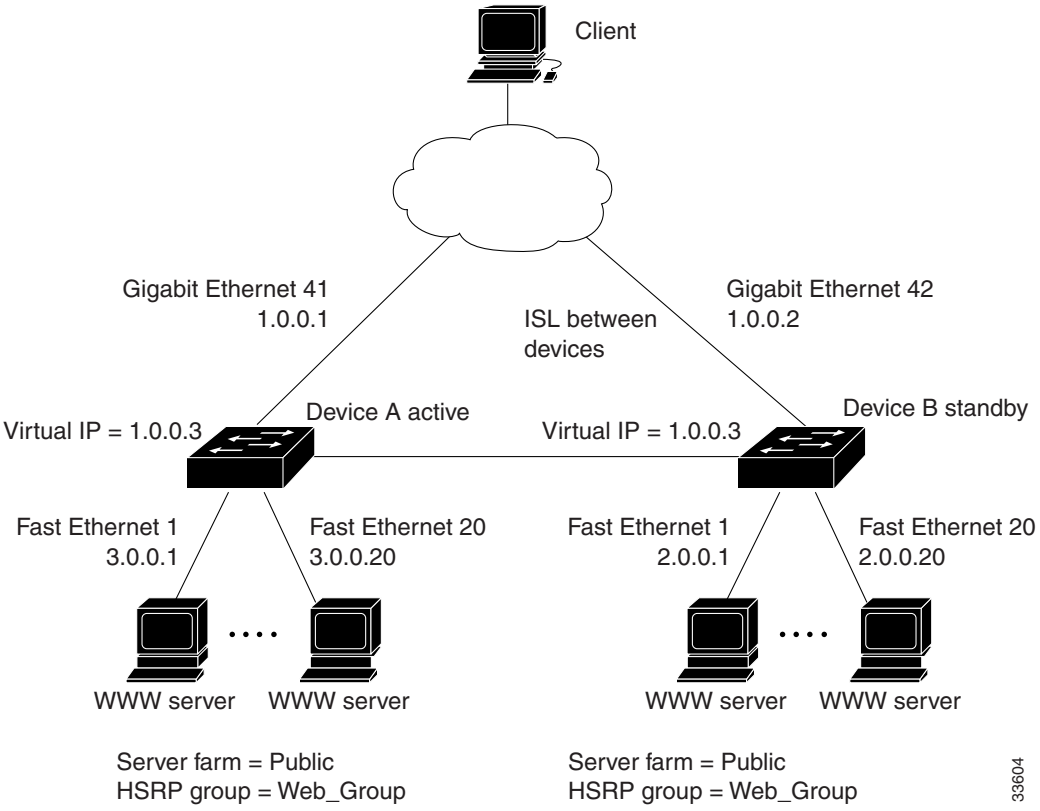
Figure 26 shows the topology of an IP network with two Layer 3 switches configured for HSRP. The following conditions exist in this network:

- Device A is the active HSRP Layer 3 switch and handles packets to the real servers with IP addresses 3.0.01 through 3.0.020.
- Device B handles packets to real servers with IP addresses 2.0.0.1 through 2.0.0.20.
- All hosts accessing the network use the IP address of the virtual router (in this case, 1.0.0.3).
- The configuration shown uses the Enhanced Interior Gateway Routing Protocol (Enhanced IGRP), but HSRP can be used with any other routing protocol supported by the Cisco IOS software, such as Open Shortest Path First (OSPF).

Note Some configurations that use HSRP still require a routing protocol for convergence when a topology change occurs. The standby Layer 3 switch becomes active, but connectivity does not occur until convergence occurs.

If the connection between Device A and the client accessing virtual IP 1.0.0.3 fails, fast-converging routing protocols (such as Enhanced IGRP and OSPF) can respond within seconds, ensuring that Device B is prepared to transfer packets that would have gone through Device A.

Figure 26 HSRP Example Network Topology



The configuration for Device A is as follows:

```
hostname Device A

interface GigabitEthernet 41
ip address 1.0.0.1 255.0.0.0
standby 1 ip 1.0.0.3
standby 1 preempt
standby 1 priority 110
standby 1 authentication denmark
standby 1 timers 5 15
standby 1 name Web-Group

interface FastEthernet 1
ip address 3.0.0.1 255.0.0.0

router eigrp 1
network 1.0.0.0
network 3.0.0.0
```

The configuration for Device B is as follows:

```
hostname Device B

interface GigabitEthernet 41
ip address 1.0.0.2 255.0.0.0
standby 1 ip 1.0.0.3
standby 1 preempt
standby 1 authentication denmark
```

```
standby 1 timers 5 15
standby 1 name Web-Group

interface FastEthernet 41
ip address 2.0.0.1 255.0.0.0

router eigrp 1
network 1.0.0.0
network 2.0.0.0
```

The **standby ip** interface configuration command enables HSRP and establishes 1.0.0.3 as the IP address of the virtual router. The configurations of both Layer 3 switches include this command so that both switches share the same virtual IP address. The number 1 establishes Hot Standby group 1. (If you do not specify a group number, the default is group 0.) The configuration for at least one of the Layer 3 switches in the Hot Standby group must specify the IP address of the virtual router; specifying the IP address of the virtual router is optional for other routers in the same Hot Standby group.

The **standby preempt** interface configuration command allows the Layer 3 switch to become the active switch when its priority is higher than all other HSRP-configured switches in this Hot Standby group. The configurations of both switches include this command so that each can be the standby Layer 3 switch for the other switch. The number 1 indicates that this command applies to Hot Standby group 1. If you do not use the **standby preempt** command in the configuration for a Layer 3 switch, that switch cannot become the active Layer 3 switch.

The **standby priority** interface configuration command sets the HSRP priority of the Layer 3 switch to 110, which is higher than the default priority of 100. Only the configuration of Device A includes this command, which makes Device A the default active Layer 3 switch. The number 1 indicates that this command applies to Hot Standby group 1.

The **standby authentication** interface configuration command establishes an authentication string whose value is an unencrypted eight-character string that is incorporated in each HSRP multicast message. This command is optional. If you choose to use it, each HSRP-configured Layer 3 switch in the group should use the same string so that each switch can authenticate the source of the HSRP messages that it receives. The number 1 indicates that this command applies to Hot Standby group 1.

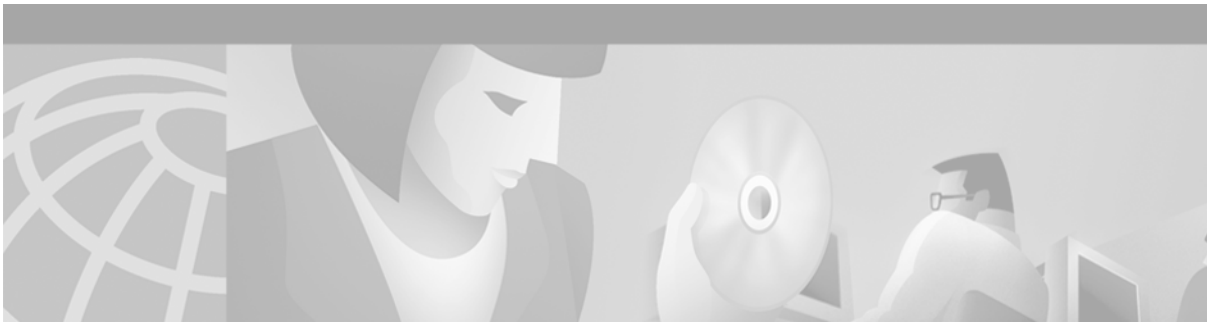
The **standby timers** interface configuration command sets the interval (in seconds) between hello messages (called the *hello time*) to 5 seconds, and sets the interval (in seconds) that a Layer 3 switch waits before it declares the active Layer 3 switch to be down (called the *hold time*) to 8 seconds. (The defaults are 3 and 10 seconds, respectively.) To modify the default values, you must configure each Layer 3 switch to use the same hello time and hold time. The number 1 indicates that this command applies to Hot Standby group 1.

The **standby name** interface configuration command associates the IOS SLB interface with an HSRP group name (in this case, Web-Group), previously specified on an **inservice (virtual server)** command. The number 1 indicates that this command applies to Hot Standby group 1.

IOS SLB Stateless Backup Configuration Example

The following commands enable the HSRP standby group 100 IP address, priority, preempt, and timers; and configures a name and authentication for Device A in Figure 26:

```
standby 100 ip 172.20.100.10
standby 100 priority 110
standby 100 preempt
standby 100 timers 5 15
standby 100 name Web_group1
standby 100 authentication Secret
exit
```



Configuring Mobile IP

This chapter describes how to configure Mobile IP. For a complete description of the Mobile IP commands in this chapter, refer to the "Mobile IP Commands" chapter of the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services*. To locate documentation of other commands that appear in this chapter, use the command reference master index or search online.

Mobile IP Overview

If an IP node, for example, a personal digital assistant (PDA), moves from one link to another, the network prefix of its IP address no longer equals the network prefix assigned to its current link. As a result, packets are not delivered to the current location of the PDA.

Mobile IP enables an IP node to retain the same IP address and maintain existing communications while traveling from one link to another.

Mobile IP is an IETF standards based solution for mobility at the network layer, which is Layer 3. Mobile IP supports the following RFCs:

- RFC 2002, *IP Mobility Support*
- RFC 2003, *IP Encapsulation within IP*
- RFC 2005, *Applicability Statement for Mobile IP*
- RFC 2006, *The Definitions of Managed Objects for IP Mobility Support*

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

Why is Mobile IP Needed?

New devices and business practices, such as PDAs and the next-generation of data-ready cellular phones and services, are driving interest in the ability of a user to roam while maintaining network connectivity. The requirement for data connectivity solutions for this group of users is very different than it is for the fixed dialup user or the stationary wired LAN user. Solutions need to accommodate the challenge of movement during a data session or conversation.

IP routing decisions are based on the network prefix of the IP address to be scalable for the Internet. All nodes on the same link share a common network prefix. If a node moves to another link, the network prefix does not equal the network prefix on the new link. Consequently, IP routing would fail to route the packets to the node after movement to the new link.

An alternative to network-prefix routing is host-specific routing. Host-specific routing is not a problem in small networks. However, considering there are billions of hosts on the Internet, this solution is not feasible for Internet connections. Routers would need enough memory to store tens of millions of routing table entries and would spend most of their computing resources updating routing tables.

DHCP (Dynamic Host Configuration Protocol) is commonly used in corporate environments and allows a server to dynamically assign IP addresses and deliver configuration parameters to nodes. The DHCP Server verifies the identity of the node, "leases" it the IP address from a pool of addresses for a predetermined period of time, and reclaims the address for reassignment when the lease expires. The node can terminate existing communication sessions, move to a new point-of-attachment to the network, reconnect to the network, and receive a new IP address from DHCP. This arrangement conserves IP addresses and reduces Internet access costs. However, if users are mobile and need continuous communications and accessibility without any interruptions in their sessions, DHCP is not an adequate solution. DHCP won't allow applications to maintain connections across subnet/network boundaries.

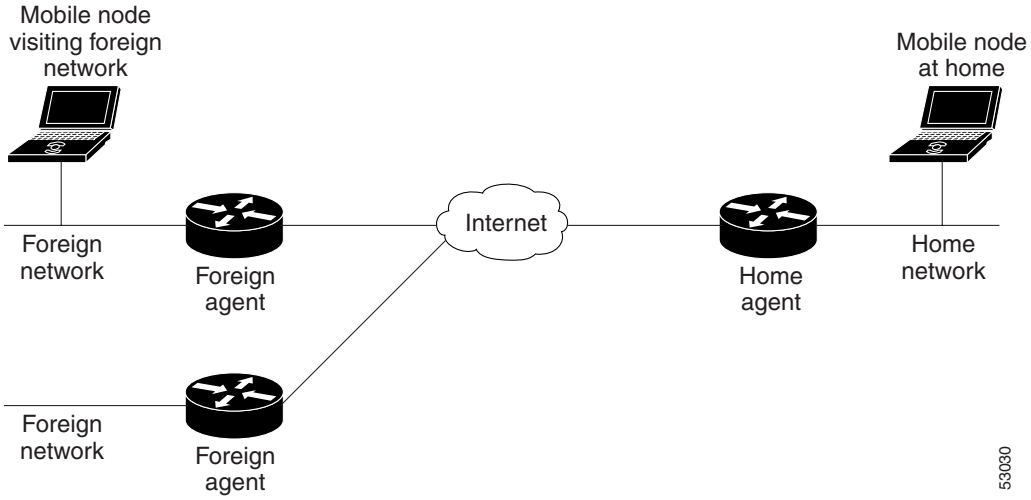
Mobile IP is scalable for the Internet because it is based on IP—any media that supports IP can support Mobile IP. Mobile IP does not drop the network prefix of the IP address of the node, which is critical to the proper routing of packets throughout the Internet. Also, certain network services, such as software licenses and access privileges, are based on IP addresses. Changing these IP addresses could compromise the network services. Certain applications, such as remote login, remote printing, and file transfers are examples of applications where it is undesirable to interrupt communications while a mobile node moves from one link to another. Thus, Mobile IP provides the solution for continuous connectivity that is scalable for the Internet.

Mobile IP Components

Mobile IP is comprised of the following three components, as shown in Figure 27:

- Mobile node (MN)
- Home agent (HA)
- Foreign agent (FA)

Figure 27 Mobile IP Components and Relationships



An MN is a node, for example, a PDA, a laptop computer, or a data-ready cellular phone, that can change its point of attachment from one network or subnet to another. This node can maintain ongoing communications while using only its home IP address.

An HA is a router on the home network of the MN that maintains an association between the home IP address of the MN and its *care-of address*, which is the current location of the MN on a foreign or visited network. The HA redirects packets by tunneling them to the MN while it is away from home.

An FA is a router on a foreign network that assists the MN in informing its HA of its current care-of address. The FA detunnels and delivers packets to the MN that were tunneled by the HA. The FA also acts as the default router for packets generated by the MN while it is connected to the foreign network.

It is recommended that HA and FA functionality be designed with interfaces with line protocol states that are normally up.

How Mobile IP Works

This section explains how Mobile IP works. The Mobile IP process includes three main phases, which are discussed in the following sections:

- Agent Discovery
- Registration
- Routing

Agent Discovery

During the agent discovery phase, HAs and FAs advertise their presence on their attached links by periodically multicasting or broadcasting messages called *agent advertisements*. MNs listen to these advertisements and determine if they are connected to their home link or a foreign link. Rather than waiting for agent advertisements, an MN can also send an *agent solicitation.* This solicitation forces any agents on the link to immediately send an agent advertisement.

If an MN determines that it is connected to a foreign link, it acquires a care-of address. Two types of care-of addresses exist:

- FA care-of address
- Collocated care-of address

An FA care-of address is a temporary, loaned IP address that the MN acquires from the FA agent advertisement. This type of care-of address is the exit point of the tunnel from the HA to the FA. A collocated care-of address is an address temporarily assigned to an MN interface. This address is assigned by DHCP or by manual configuration.

Registration

After receiving a care-of address, the MN registers this address with its HA through an exchange of messages. The HA creates a *mobility binding table* that maps the home IP address of the MN to the current care-of address of the MN. An entry in this table is called a *mobility binding*. The main purpose of registration is to create, modify, or delete the mobility binding of an MN at its HA.

During registration, the MN also asks for service from the FA.

The HA advertises reachability to the home IP address of the MN, thereby attracting packets that are destined for that address. When a device on the Internet, called a *corresponding node* (CN), sends a packet to the MN, the packet is routed to the home network of the MN. The HA intercepts the packet and tunnels it to the registered care-of address of the MN. At the care-of address, the FA extracts the packet from the tunnel and delivers it to the MN.

If the MN is sending registration requests through a FA, the FA keeps track of all visiting MNs by keeping a visitor list. The FA relays the registration request directly to the HA without the need for tunneling. The FA serves as the router for all packets sent by the visiting MN.

When the MN powers down or determines that it is reconnected to its home link, it deregisters by sending a deregistration request to the HA. The HA then reclaims the MN.

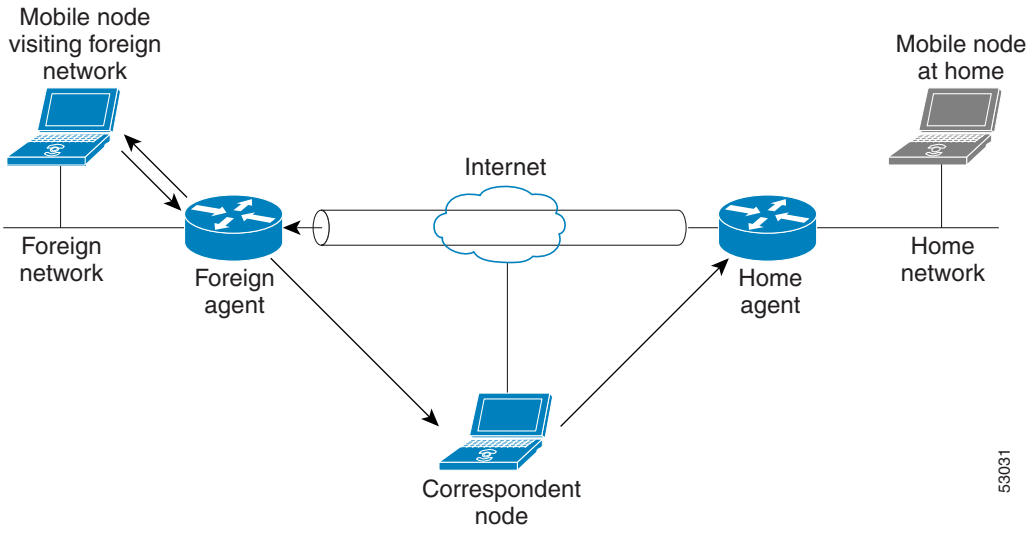
Routing

Because the major function of a Layer 3 protocol is routing, the major features of Mobile IP deal with how to route packets to users who are mobile.

Mobile IP is a tunneling-based solution that takes advantage of the Cisco-created generic routing encapsulation (GRE) tunneling technology and simpler IP-in-IP tunneling protocol. The traffic destined for the MN is forwarded in a triangular manner. When the CN (a device on the Internet) sends a packet to the MN, the HA redirects the packet by tunneling to the care-of address (current location) of the MN on the foreign network. The FA receives the packet from the HA and forwards it locally to the MN. However, packets sent by the MN are routed directly to the CN.

See Figure 28 for a diagram of typical packet forwarding in Mobile IP.

Figure 28 Mobile IP Typical Packet Forwarding



Mobile IP Security

Mobile IP provides the following guidelines on security between its components:

- Communication between MN and HA must be authenticated.
- Communication between MN and FA can optionally be authenticated.
- Communication between FA and HA can optionally be authenticated.

Also, communication between an active HA and a standby HA, as implemented when using the HA redundancy feature, must be authenticated. For more information on this feature, see the "Home Agent Redundancy" section later in this chapter.

MN-HA

In particular, the Mobile IP registration process is vulnerable to security attacks, because it informs the HA where to tunnel packets to a traveling MN. An illegitimate node could send a bogus registration request to an HA and cause all packets to be tunneled to the illegitimate node instead of the MN. This type of attack, called a *denial-of-service attack*, prevents the MN from receiving and sending any packets. To prevent denial-of-service attacks, Mobile IP requires that all registration messages between an MN and an HA be authenticated.

Cisco IOS software supports the Mobile-Home Authentication Extension (MHAE). All registration messages between an MN and an HA include a mandatory authentication extension.

Message Digest 5 (MD5) is an algorithm that takes the registration message and a key to compute the smaller chunk of data, called a *message digest*, plus a secret key. The MN and HA both have a copy of the key, called a *symmetric key*, and authenticate each other by comparing the results of the computation.

The time stamp is an identifier in the message that ensures the origination of the registration request and the time it was sent, thereby preventing *replay attacks*. A replay attack occurs when an individual records an authentic message that was previously transmitted and replays it at a later time. The time stamp is also protected by MD5.

This authentication process begins when a MN sends the registration request. The MN adds the time stamp, computes the message digest, and appends the MHAE to the registration request. The HA receives the request, checks that the time stamp is valid, computes the message digest using the same key, and compares the message digest results. If the results match, the request is successfully authenticated. For the registration reply, the HA adds the time stamp, computes the message digest, and appends the MHAE to the registration reply. The MN authenticates the registration reply upon arrival from the HA.

MN-FA

Mobile IP does not require that communication between an MN and an FA be authenticated. Cisco IOS software supports the optional Mobile-Foreign Authentication Extension (MFAE). MFAE protects the communication between the MN and FA by keeping a shared key between them.

FA-HA

Mobile IP does not require that communication between an FA and an HA be authenticated. Cisco IOS software supports the optional Foreign-Home Authentication Extension (FHAE). FHAE protects the communication between the FA and HA by keeping a shared key between them.

HA-HA

Communication between an active HA and a standby HA in an HA redundancy topology must be authenticated. The authentication process works in the same manner as described in the previous "MN-HA" section. However, HA-HA authentication is an added Cisco-proprietary authentication extension needed to secure communication between peer HAs for HA redundancy. (Active HAs and standby HAs are peers to each other.)

Use the **ip mobile secure home-agent** global configuration command to configure the security associations between all peer HAs within a standby group for each of the other HAs within the standby group. The configuration is necessary because any HA within the standby group can become active HA or standby HA at any time. See the "Mobile IP HA Redundancy Configuration Task List" section later in this chapter for more information on HA-HA authentication.

Storing Security Associations

As discussed in the "Mobile IP Security" section earlier in this chapter, authentication between the MN and the HA involves keys. You can store the keys or *security associations* (SAs) on one of the following locations:

- NVRAM of an HA
- Authentication, authorization, and accounting (AAA) server that can be accessed using either TACACS+ or RADIUS

Because the NVRAM of an HA is typically limited, you should store the SAs on the HA only if your organization has a small number of MNs. If your organization has a large number of MNs, you should store the SAs on a AAA server.

Storing SAs on AAA

A AAA server can store a large number of SAs and scale well for future SA storage. It can accommodate not only the SAs for MN-HA authorization, but SAs for authorization between other Mobile IP components as well. Storing all SAs in a centralized location can streamline administrative and maintenance tasks related to the SAs.

Caching SAs on HA

When an MN is registering with an HA, keys are needed for the MN-HA authorization process, which requires AAA authorization for Mobile IP. If SAs are stored on a AAA server, the HA must retrieve the appropriate SA from the server. The SA is downloaded to the HA, and the HA caches the SA and reuses it when necessary rather than retrieving it from the AAA server again.

Home Agent Redundancy

During the Mobile IP registration process, an HA creates a mobility binding table that maps the home IP address of an MN to the current care-of address of the MN. If the HA fails, the mobility binding table will be lost and all MNs registered with the HA will lose their connectivity. To reduce the impact of an HA failure, Cisco IOS software supports the HA redundancy feature.

The functionality of HA redundancy runs on top of the Hot Standby Router Protocol (HSRP). HSRP is a protocol developed by Cisco that provides network redundancy in a way that ensures that user traffic will immediately and transparently recover from failures.

HSRP Groups

Before configuring HA redundancy, you must understand the concept of HSRP groups.

An *HSRP group* is composed of two or more routers that share an IP address and a MAC (Layer 2) address and act as a single virtual router. For example, your Mobile IP topology can include one active HA and one or more standby HAs that the rest of the topology view as a single virtual HA.

You must define certain HSRP group attributes on the interfaces of the HAs so that Mobile IP can implement the redundancy. You can use the groups to provide redundancy for MNs with a home link on either the interface of the group (a *physical network*) or on virtual networks. *Virtual networks* are logical circuits that are programmed and share a common physical infrastructure.

How HA Redundancy Works

The HA redundancy feature enables you to configure an active HA and one or more standby HAs.

HA functionality is a service provided by the router and is not interface specific. Therefore, the HA and the MN must agree on which HA interface the MN should send its registration requests, and conversely, on which HA interface the HA should receive the registration requests. This agreement must factor in the following two scenarios:

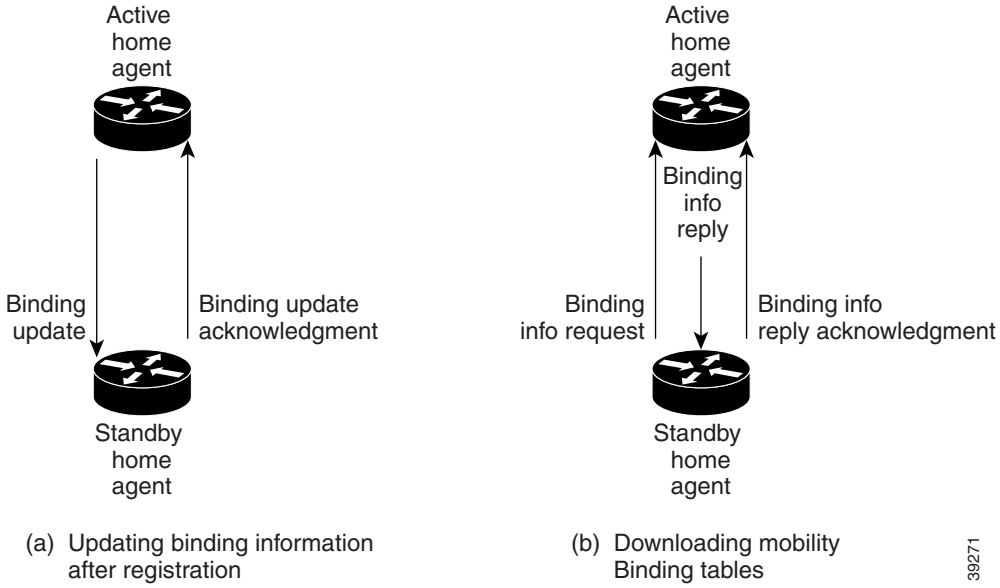
- An MN that has an HA interface (HA IP address) that is not on the same subnet as the MN
- An MN that requires the HA interface to be on the same subnet as the MN, that is, the HA and the MN must be on the same home network

For MNs on physical networks, an active HA accepts registration requests from the MN and sends binding updates to the standby HA. This process keeps the mobility binding table on the active and standby HAs synchronized. See (a) in Figure 29 for an example of this process.

For MNs on virtual networks, the active and standby HAs are peers—either HA can handle registration requests from the MN and update the mobility binding table on the peer HA.

When a standby HA comes up, it must request all mobility binding information from the active HA. The active HA responds by downloading the mobility binding table to the standby HA. The standby HA acknowledges that it has received the requested binding information. See (b) in Figure 29 for an example of an active HA downloading the mobility bindings to a standby HA. A main concern in this stage of the process is which HA IP interface the standby HA should use to retrieve the appropriate mobility binding table and on which interface of the standby HA the binding request should be sent.

Figure 29 Mobility Binding Process



Managing Mobility Binding Tables

When a binding is cleared on an active home agent, it will not be cleared on the standby/peer home agent. If you want to clear the binding on the standby/peer home agent, you must manually clear it using the **clear ip mobile binding** command. This design ensures that binding information will not be accidentally lost.

It is possible that binding tables of two home agents in a redundancy group might be out of synchronization because of a network problem. You can force the synchronization of the binding tables by using the **clear ip mobile binding all load** *standby-group-name* command.

Prerequisites

To configure home agent functionality on your router, you need to determine IP addresses or subnets for which you want to allow roaming service. If you intend to support roaming on virtual networks, you need to identify the subnets for which you will allow this service and place these virtual networks appropriately on the home agent. It is possible to enable home agent functionality for a physical or virtual subnet. In the case of virtual subnets, you must define the virtual networks on the router using the **ip mobile virtual-network** global configuration command. Mobile IP home agent and foreign agent services can be configured on the same router or on separate routers to enable Mobile IP service to users.

Because Mobile IP requires support on the host device, each mobile node must be appropriately configured for the desired Mobile IP service with client software. Please refer to the manual entries in your mobile aware IP stack vendor documentation for details.

Mobile IP Configuration Task List

To enable Mobile IP services on your network, you need to determine not only which home agents will facilitate the tunneling for selected IP address, but also where these devices or hosts will be allowed to roam. The areas, or subnets, into which the hosts will be allowed to roam will determine where foreign agent services need to be set up.

To configure Mobile IP, perform the tasks described in the following sections as related to the functions you intend to support. The tasks in the first two sections are required; the tasks in the remaining sections are optional.

- Enabling Home Agent Services (Required)
- Enabling Foreign Agent Services (Required)
- Configuring AAA in the Mobile IP Environment (Optional)
- Configuring RADIUS in the Mobile IP Environment (Optional)
- Configuring TACACS+ in the Mobile IP Environment (Optional)
- Verifying Setup (Optional)
- Monitoring and Maintaining Mobile IP (Optional)
- Shutting Down Mobile IP (Optional)

Enabling Home Agent Services

Home agent functionality is useful within an enterprise network to allow users to retain an IP address while they move their laptop PCs from their desktops into conference rooms or labs or common areas. It is especially beneficial in environments where wireless LANs are used because the tunneling of datagrams hides the movement of the host and thus allows seamless transition between base stations. To support the mobility of users beyond the bounds of the enterprise network, home agent functionality can be enabled for virtual subnets on the DMZ or periphery of the network to communicate with external foreign agents.

To enable home agent service for users having homed or virtually homed IP addresses on the router, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router mobile`	Enables Mobile IP on the router.
Step 2	`Router(config-router)# exit`	Returns to global configuration mode.
Step 3	`Router(config)# ip mobile home-agent`	Enables home agent service.
Step 4	`Router(config)# ip mobile virtual-network` *net mask* [**address** *address*]	Adds virtual network to routing table. If not using a virtual network, go to step 6.
Step 5	`Router(config)# router` *protocol*	Configures a routing protocol.
Step 6	`Router(config)# redistribute mobile`	Enables redistribution of a virtual network into routing protocols.

	Command	Purpose
Step 7	`Router(config)# ip mobile host lower [upper] virtual-network net mask [aaa [load-sa]]`	Specifies mobile nodes (on a virtual network) and where their security associations are stored.[1]
Step 8	`Router(config)# ip mobile host lower [upper] {interface name}`	Specifies mobile nodes on an interface and where their security associations are stored. Omit this step if no mobile nodes are on the interface.
Step 9	`Router(config)# ip mobile secure host lower-address [upper-address]{inbound-spi spi-in outbound-spi spi-out | spi spi} key hex string`	Sets up mobile host security associations. Omit this step if using AAA.
Step 10	`Router(config)# ip mobile secure foreign-agent address {inbound-spi spi-in outbound-spi spi-out | spi spi} key hex string`	(Optional) Sets up foreign agent security associations. Omit this step unless you have security associations with remote foreign agents.

1. By default, security associations are expected to be configured locally; however, the security association configuration can be offloaded to an AAA server.

Enabling Foreign Agent Services

Foreign agent services need to be enabled on a router attached to any subnet into which a mobile node may be roaming. Therefore, you need to configure foreign agent functionality on routers connected to conference room or lab subnets, for example. For administrators that want to utilize roaming between wireless LANs, foreign agent functionality would be configured on routers connected to each base station. In this case it is conceivable that both home agent and foreign agent functionality will be enabled on some of the routers connected to these wireless LANs.

To start a foreign agent providing default services, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router mobile`	Enables Mobile IP on the router.
Step 2	`Router(config-router)# exit`	Returns to global configuration mode.
Step 3	`Router(config)# ip mobile foreign-agent care-of interface`	Sets up care-of addresses advertised to all foreign agent-enabled interfaces.
Step 4	`Router(config-if)# ip mobile foreign-service`	Enables foreign agent service on the interface.
Step 5	`Router(config)# ip mobile secure home-agent address {inbound-spi spi-in outbound-spi spi-out | spi spi} key hex string`	(Optional) Sets up home agent security association. Omit steps 4 and 5 unless you have security association with remote home agents or visitors.
Step 6	`Router(config)# ip mobile secure visitor address {inbound-spi spi-in outbound-spi spi-out | spi spi} key hex string [replay timestamp]`	(Optional) Sets up visitor security association.

Configuring AAA in the Mobile IP Environment

To configure AAA in the Mobile IP environment, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# aaa new-model`	Enables the AAA access control model.
Step 2	`Router(config)# aaa authorization ipmobile {tacacs+ | radius}`	Authorizes Mobile IP to retrieve security associations from the AAA server using TACACS+ or RADIUS.

Configuring RADIUS in the Mobile IP Environment

Remote Authentication Dial-in User Service (RADIUS) is a method for defining the exchange of AAA information in the network. In the Cisco implementation, RADIUS clients run on Cisco routers and send authentication requests to a RADIUS server that contains all user authentication and network server access information. For detailed information about RADIUS configuration options, refer to the "Configuring RADIUS" chapter in the *Cisco IOS Security Configuration Guide*.

To configure RADIUS in the Mobile IP environment, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# radius-server host`	Specifies a RADIUS server host.
Step 2	`Router(config)# radius-server key`	Sets the authentication and encryption key for all RADIUS communications between the router and the RADIUS daemon.

Configuring TACACS+ in the Mobile IP Environment

Terminal Access Controller Access Control System Plus (TACACS+) is an authentication protocol that provides remote access authentication and related services, such as event logging. For detailed information about TACACS+ configuration options, refer to the "Configuring TACACS+" chapter in the *Cisco IOS Security Configuration Guide*.

To configure TACACS+ in the Mobile IP environment, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# tacacs-server host`	Specifies a TACACS+ server host.
Step 2	`Router(config)# tacacs-server key`	Sets the authentication encryption key used for all TACACS+ communications between the access server and the TACACS+ daemon.

Verifying Setup

To make sure Mobile IP is set up correctly, use the following commands in EXEC mode as needed:

Command	Purpose
`Router# show ip mobile globals`	Displays home agent and foreign agent global settings.
`Router# show ip mobile host group`	Displays mobile node groups.
`Router# show ip mobile secure {host | visitor | foreign-agent | home-agent | summary} address`	Displays security associations.
`Router# show ip mobile interface`	Displays advertisements on interfaces.

Monitoring and Maintaining Mobile IP

To monitor and maintain Mobile IP, use any of the following EXEC commands:

Command	Purpose
`Router# show ip mobile host`	Displays mobile node counters (home agent only).
`Router# show ip mobile binding`	Displays mobility bindings (home agent only).
`Router# show ip mobile tunnel`	Displays active tunnels.
`Router# show ip mobile visitor`	Displays visitor bindings (foreign agent only).
`Router# show ip route mobile`	Displays Mobile IP routes.
`Router# show ip mobile traffic`	Displays protocol statistics.
`Router# clear ip mobile traffic`	Clears counters.
`Router# show ip mobile violation`	Displays information about security violations.
`Router# debug ip mobile advertise`	Displays advertisement information.[1]
`Router# debug ip mobile host`	Displays mobility events.

1. Make sure IRDP is running on the interface.

Shutting Down Mobile IP

To shut down Mobile IP, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# no ip mobile home-agent`	Disables home agent services.
Step 2	`Router(config)# no ip mobile foreign-agent`	Disables foreign agent services.
Step 3	`Router(config)# no router mobile`	Disables Mobile IP process.

Mobile IP HA Redundancy Configuration Task List

To configure your routers for Mobile IP HA redundancy, perform the required tasks described in the following sections:

- Enabling Mobile IP (Required)

- Enabling HSRP (Required)
- Enabling HA Redundancy for a Physical Network (Required)

Depending on your network configuration, perform one of the optional tasks described in the following sections:

- Enabling HA Redundancy for a Physical Network (Optional)
- Enabling HA Redundancy for a Virtual Network Using One Physical Network (Optional)
- Enabling HA Redundancy for a Virtual Network Using Multiple Physical Networks (Optional)
- Enabling HA Redundancy for Multiple Virtual Networks Using One Physical Network (Optional)
- Enabling HA Redundancy for Multiple Virtual Networks Using Multiple Physical Networks (Optional)
- Verifying HA Redundancy (Optional)

Enabling Mobile IP

To enable Mobile IP on the router, use the following command in global configuration mode:

Command	Purpose
`Router(config)# router mobile`	Enables Mobile IP on the router.

Enabling HSRP

To enable HSRP on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router (config-if)# standby [group-number] ip ip-address`	Enables HSRP.

Configuring HSRP Group Attributes

To configure HSRP group attributes that affect how the local router participates in HSRP, use either of the following commands in interface configuration mode:

Command	Purpose

`Router(config-if)# standby [group-number] priority priority [preempt [delay [minimum | sync] delay]]`
 	
or
 	
`Router(config-if)# standby [group-number] [priority priority] preempt [delay [minimum | sync] delay]`
	Sets the Hot Standby priority used in choosing the active router. By default, the router that comes up later becomes standby. When one router is designated as an active HA, the priority is set highest in the HSRP group and the preemption is set. Configure the **preempt delay sync** command so that all bindings will be downloaded to the router before it takes the active role. The router becomes active when all bindings are downloaded or when the timer expires, whichever comes first.

Enabling HA Redundancy for a Physical Network

To enable HA redundancy for a physical network, use following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router (config-if)# standby [group-number] ip ip-address`	Enables HSRP.
Step 2	`Router(config-if)# standby name hsrp-group-name`	Sets the name of the standby group.
Step 3	`Router(config)# ip mobile home-agent standby hsrp-group-name`	Configures the home agent for redundancy using the HSRP group name.
Step 4	`Router(config)# ip mobile secure home-agent address spi spi key hex string`	Sets up the home agent security association between peer routers. If configured on the active HA, the IP address *address* argument is that of the standby HA. If configured on the standby HA, the IP address *address* argument is that of the active router. Note that a security association needs to be set up between all HAs in the standby group.

Enabling HA Redundancy for a Virtual Network Using One Physical Network

To enable HA redundancy for a virtual network and a physical network, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router (config-if)# standby [group-number] ip ip-address`	Enables HSRP.
Step 2	`Router(config-if)# standby name hsrp-group-name`	Sets the name of the standby group.
Step 3	`Router(config)# ip mobile home-agent address address`	Defines a global home agent address. In this configuration, the address is the HSRP group address. Enter this command if the mobile node and home agent are on different subnets.
	or	or
	`Router(config)# ip mobile home-agent`	Enables and controls home agent services to the router. Enter this command if the mobile node and home agent are on the same subnet.
Step 4	`Router(config)# ip mobile virtual-network net mask [address address]`	Defines the virtual network. If the mobile node and home agent are on the same subnet, use the [**address** *address*] option.

	Command	Purpose
Step 5	`Router(config)# ip mobile home-agent standby hsrp-group-name [[virtual-network] address address]`	Configures the home agent for redundancy using the HSRP group to support virtual networks.
Step 6	`Router(config)# ip mobile secure home-agent address spi spi key hex string`	Sets up the home agent security association between peer routers. If configured on the active HA, the IP address *address* argument is that of the standby HA. If configured on the standby HA, the IP address *address* argument is that of the active router. Note that a security association needs to be set up between all HAs in the standby group.

Enabling HA Redundancy for a Virtual Network Using Multiple Physical Networks

To enable HA redundancy for a virtual network using multiple physical networks, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# standby [group-number] ip ip-address`	Enables HSRP.
Step 2	`Router(config-if)# standby name hsrp-group-name1`	Sets the name of the standby HSRP group 1.
Step 3	`Router(config-if)# standby name hsrp-group-name2`	Sets the name of the standby HSRP group 2.
Step 4	`Router(config)# ip mobile home-agent address address`	Defines the global home agent address for virtual networks. In this configuration, the address is the loopback interface address. Enter this command if the mobile node and home agent are on different subnets.
	or	or
	`Router(config)# ip mobile home-agent`	Enables and controls home agent services to the router. Enter this command if the mobile node and home agent are on the same subnet.
Step 5	`Router(config)# ip mobile virtual-network net mask [address address]`	Defines the virtual network. If the mobile node and home agent are on the same subnet, use the [**address** *address*] option.
Step 6	`Router(config)# ip mobile home-agent standby hsrp-group-name1 [[virtual-network] address address]`	Configures the home agent for redundancy using the HSRP group 1 to support virtual networks.
Step 7	`Router(config)# ip mobile home-agent standby hsrp-group-name2 [[virtual-network] address address]`	Configures the home agent for redundancy using the HSRP group 2 to support virtual networks.
Step 8	`Router(config)# ip mobile secure home-agent address spi spi key hex string`	Sets up the home agent security association between peer routers. If configured on the active HA, the IP address *address* argument is that of the standby HA. If configured on the standby HA, the IP address *address* argument is that of the active router. Note that a security association needs to be set up between all HAs in the standby group.

Enabling HA Redundancy for Multiple Virtual Networks Using One Physical Network

To enable HA redundancy for multiple virtual networks using one physical network, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# standby [group-number] ip ip-address`	Enables the HSRP.
Step 2	`Router(config-if)# standby name hsrp-group-name`	Sets the name of the standby group.
Step 3	`Router(config)# ip mobile home-agent address address`	Defines a global home agent address. In this configuration, the address is the HSRP group address. Enter this command if the mobile node and home agent are on different subnets.
	or	or
	`Router(config)# ip mobile home-agent`	Enables and controls home agent services to the router. Enter this command if the mobile node and home agent are on the same subnet.
Step 4	`Router(config)# ip mobile virtual-network net mask [address address]`	Defines the virtual networks. Repeat this step for each virtual network. If the mobile node and home agent are on the same subnet, use the [**address** *address*] option.
Step 5	`Router(config)# ip mobile home-agent standby hsrp-group-name [[virtual-network] address address]`	Configures the home agent for redundancy using the HSRP group to support virtual networks.
Step 6	`Router(config)# ip mobile secure home-agent address spi spi key hex string`	Sets up the home agent security association between peer routers. If configured on the active HA, the IP address *address* argument is that of the standby HA. If configured on the standby HA, the IP address *address* argument is that of the active router. Note that a security association needs to be set up between all HAs in the standby group.

Enabling HA Redundancy for Multiple Virtual Networks Using Multiple Physical Networks

To enable HA redundancy for multiple virtual networks using multiple physical networks, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router (config-if)# standby [group-number] ip ip-address`	Enables the HSRP.
Step 2	`Router(config-if)# standby name hsrp-group-name1`	Sets the name of the standby HSRP group 1.
Step 3	`Router(config-if)# standby name hsrp-group-name2`	Sets the name of the standby HSRP group 2.

	Command	Purpose
Step 4	`Router(config)# ip mobile home-agent address address`	Defines the global home agent address for virtual networks. In this configuration, the address is the loopback interface address. Enter this command if the mobile node and home agent are on different subnets.
	or	or
	`Router(config)# ip mobile home-agent`	Enables and controls home agent services to the router. Enter this command if the mobile node and home agent are on the same subnet.
Step 5	`Router(config)# ip mobile virtual-network net mask [address address]`	Defines the virtual networks. Repeat this step for each virtual network. If the mobile node and home agent are on the same subnet, use the [**address** *address*] option.
Step 6	`Router(config)# ip mobile home-agent standby hsrp-group-name1 [[virtual-network] address address]`	Configures the home agent for redundancy using the HSRP group 1 to support virtual networks.
Step 7	`Router(config)# ip mobile home-agent standby hsrp-group-name2 [[virtual-network] address address]`	Configures the home agent for redundancy using the HSRP group 2 to support virtual networks.
Step 8	`Router(config)# ip mobile secure home-agent address spi spi key hex string`	Sets up the home agent security association between peer routers. If configured on the active HA, the IP address *address* argument is that of the standby HA. If configured on the standby HA, the IP address *address* argument is that of the active router. Note that a security association needs to be set up between all HAs in the standby group.

Verifying HA Redundancy

To verify that the Mobile IP Home Agent Redundancy feature is configured correctly on the router, perform the following steps:

Step 1 Enter the **show ip mobile globals** EXEC command.

Step 2 Examine global information for mobile agents.

Step 3 Enter the **show ip mobile binding** [**home-agent** *address* | **summary**] EXEC command.

Step 4 Examine the mobility bindings associated with a home agent address.

Step 5 Enter the **show standby** EXEC command.

Step 6 Examine information associated with the HSRP group.

Monitoring and Maintaining HA Redundancy

To monitor and maintain HA redundancy, use the following commands in EXEC mode, as needed:

Command	Purpose
`Router# debug ip mobile standby`	Displays debug messages for Mobile IP redundancy activities.
`Router# show ip mobile globals`	Displays the global home address if configured. For each Mobile IP standby group, displays the home agent address supported.
`Router# show ip mobile binding [home-agent address | summary]`	Displays mobility bindings with specific home agent address.

Mobile IP Configuration Examples

This section provides the following Mobile IP configuration examples:

- Home Agent Configuration Example
- Home Agent Using AAA Server Example
- Foreign Agent Configuration Example
- Mobile IP HA Redundancy Configuration Examples
  - HA Redundancy for Physical Networks Example
  - HA Redundancy for a Virtual Network Using One Physical Network Example
  - HA Redundancy for a Virtual Network Using Multiple Physical Networks Example
  - HA Redundancy for Multiple Virtual Networks Using One Physical Network Example
  - HA Redundancy for Multiple Virtual Networks Using Multiple Physical Networks Example

Home Agent Configuration Example

In the following example, the home agent has five mobile hosts on interface Ethernet1 (network 11.0.0.0) and ten on virtual network 10.0.0.0. There are two mobile node groups. Each mobile host has one security association. The home agent has an access list to disable roaming capability by mobile host 11.0.0.5. The 11.0.0.0 group has a lifetime of 1 hour (3600 seconds). The 10.0.0.0 group cannot roam in areas where the network is 13.0.0.0.

```
router mobile
!
! Define which hosts are permitted to roam
ip mobile home-agent broadcast roam-access 1
!
! Define a virtual network
ip mobile virtual-network 10.0.0.0 255.0.0.0
!
! Define which hosts are on the virtual network, and the care-of access list
ip mobile host 10.0.0.1 10.0.0.10 virtual-network 10.0.0.0 255.0.0.0 care-of-access 2
!
! Define which hosts are on Ethernet 1, with lifetime of one hour
ip mobile host 11.0.0.1 11.0.0.5 interface Ethernet1 lifetime 3600
```

```
!
! The next ten lines specify security associations for mobile hosts
! on virtual network 10.0.0.0
!
ip mobile secure host 10.0.0.1 spi 100 key hex 12345678123456781234567812345678
ip mobile secure host 10.0.0.2 spi 200 key hex 87654321876543218765432187654321
ip mobile secure host 10.0.0.3 spi 300 key hex 31323334353637383930313233343536
ip mobile secure host 10.0.0.4 spi 100 key hex 45678332353637383930313233343536
ip mobile secure host 10.0.0.5 spi 200 key hex 33343536313233343536373839303132
ip mobile secure host 10.0.0.6 spi 300 key hex 73839303313233343536313233343536
ip mobile secure host 10.0.0.7 spi 100 key hex 83930313233343536313233343536373
ip mobile secure host 10.0.0.8 spi 200 key hex 43536373839313233330313233343536
ip mobile secure host 10.0.0.9 spi 300 key hex 23334353631323334353637383930313
ip mobile secure host 10.0.0.10 spi 100 key hex 637383931323334353303132333435 36
!
! The next five lines specify security associations for mobile hosts
! on Ethernet1
!
ip mobile secure host 11.0.0.1 spi 100 key hex 73839303313233343536313233343536
ip mobile secure host 11.0.0.2 spi 200 key hex 83930313233343536313233343536373
ip mobile secure host 11.0.0.3 spi 300 key hex 43536373839313233330313233343536
ip mobile secure host 11.0.0.4 spi 100 key hex 23334353631323334353637383930313
ip mobile secure host 11.0.0.5 spi 200 key hex 63738393132333435330313233343536
!
! Deny access for this host
access-list 1 deny   11.0.0.5
!
! Deny access to anyone on network 13.0.0.0 trying to register
access-list 2 deny   13.0.0.0
```

Home Agent Using AAA Server Example

In the following AAA server configuration, the home agent can use a AAA server for storing security associations. Mobile IP has been authorized using a RADIUS server to retrieve the security association information, which is used by the home agent to authenticate registrations. This format can be imported into a CiscoSecure server.

```
user = 20.0.0.1 {
    service = mobileip {
        set spi#0 = "spi 100 key hex 123456781234567812345678123456 78"
    }
}

user = 20.0.0.2 {
    service = mobileip {
        set spi#0 = "spi 100 key hex 123456781234567812345678123456 78"
    }
}

user = 20.0.0.3 {
    service = mobileip {
        set spi#0 = "spi 100 key hex 123456781234567812345678123456 78"
    }
}
```

In the example above, the user is the mobile node's IP address. The syntax for the security association is **spi#***num* **= "***string***"**, where *string* is the rest of the **ip mobile secure** {**host** | **visitor** | **home-agent** | **foreign-agent**} **key hex** *string* command.

The following example shows how the home agent is configured to use the AAA server:

```
aaa new-model
aaa authorization ipmobile radius
!
ip mobile home-agent
ip mobile virtual-network 20.0.0.0 255.0.0.0
ip mobile host 20.0.0.1 20.0.0.3 virtual-network 20.0.0.0 255.0.0.0 aaa load-sa
!
radius-server host 1.2.3.4
radius-server key cisco
```

Foreign Agent Configuration Example

In the following example, the foreign agent is providing service on Ethernet1 interface, advertising care-of address 68.0.0.31 and a lifetime of 1 hour:

```
interface Ethernet0
 ip address 68.0.0.31 255.0.0.0
interface Ethernet1
ip address 67.0.0.31 255.0.0.0
 ip irdp
 ip irdp maxadvertinterval 10
 ip irdp minadvertinterval 7
 ip mobile foreign-service
 ip mobile registration-lifetime 3600
!
router mobile
!
ip mobile foreign-agent care-of Ethernet0
```

Mobile IP HA Redundancy Configuration Examples

Table 7 summarizes the Mobile IP HA redundancy configuration required to support mobile nodes on physical and virtual home networks. Refer to this table for clarification as you read the examples in this section.

Table 7 Mobile IP HA Redundancy Configuration Overview

Mobile Node Home Network	Physical Connections	Home Agent Address	Configuration
Mobile Nodes with Home Agents on Different Subnets			
Physical network	Single	HSRP group address	**ip mobile home-agent standby** *hsrp-group-name*
Virtual network	Single	**ip mobile home-agent address** *address* In this configuration, *address* is the HSRP group address.	**ip mobile home-agent standby** *hsrp-group-name* **virtual-network**

Table 7 Mobile IP HA Redundancy Configuration Overview (continued)

Mobile Node Home Network	Physical Connections	Home Agent Address	Configuration
Virtual network	Multiple	**ip mobile home-agent address** *address* In this configuration, *address* is the loopback interface address.	**ip mobile home-agent standby** *hsrp-group-name1* **virtual-network** **ip mobile home-agent standby** *hsrp-group-name2* **virtual-network** Repeat this command for each HSRP group associated with the physical connection.
Multiple virtual networks	Single	**ip mobile home-agent address** *address* In this configuration, *address* is the HSRP group address.	**ip mobile home-agent standby** *hsrp-group-name* **virtual-network**
Multiple virtual networks	Multiple	**ip mobile home-agent address** *address* In this configuration, *address* is the loopback interface address.	**ip mobile home-agent standby** *hsrp-group-name1* **virtual-network** **ip mobile home-agent standby** *hsrp-group-name2* **virtual-network** Repeat this command for each HSRP group associated with the physical connection.
Mobile Nodes with Home Agents on the Same Subnet			
Physical network	Single	HSRP group address	**ip mobile home-agent standby** *hsrp-group-name*
Virtual network	Single	**ip mobile virtual-network** *net mask* **address** *address* In this configuration, *address* is the loopback interface address.	**ip mobile home-agent standby** *hsrp-group-name* **virtual-network**
Virtual network	Multiple	**ip mobile virtual-network** *net mask* **address** *address* In this configuration, *address* is the loopback interface address.	**ip mobile home-agent standby** *hsrp-group-name1* **virtual-network** **ip mobile home-agent standby** *hsrp-group-name2* **virtual-network** Repeat this command for each HSRP group associated with the physical connection.

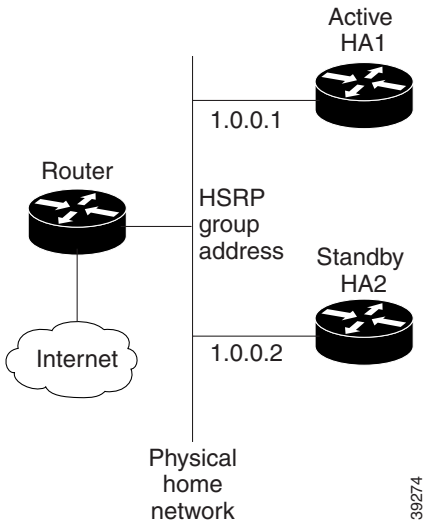
Table 7 Mobile IP HA Redundancy Configuration Overview (continued)

Mobile Node Home Network	Physical Connections	Home Agent Address	Configuration
Multiple virtual networks	Single	**ip mobile virtual-network** *net mask* **address** *address* Repeat this command for each virtual network. The *address* argument is an address configured on the loopback interface to be on the same subnet. Specify the **ip address** *address mask* **secondary** interface configuration command to support multiple IP addresses configured on the same interface.	**ip mobile home-agent standby** *hsrp-group-name* **virtual-network**
Multiple virtual networks	Multiple	**ip mobile virtual-network** *net mask* **address** *address* Repeat this command for each virtual network. The *address* argument is an address configured on the loopback interface to be on the same subnet. Specify the **ip address** *address mask* **secondary** interface configuration command to support multiple IP addresses configured on the same interface.	**ip mobile home-agent standby** *hsrp-group-name1* **virtual-network** **ip mobile home-agent standby** *hsrp-group-name2* **virtual-network** Repeat this command for each HSRP group associated with the physical connection.

HA Redundancy for Physical Networks Example

Figure 30 shows an example network topology for physical networks. The configuration example supports home agents that are on the same or a different physical network as the mobile node.

Figure 30 Topology Showing HA Redundancy on a Physical Network



HA1 is favored to provide home agent service for mobile nodes on physical network e0 because the priority is set to 110, which is above the default of 100. HA1 will preempt any active home agent when it comes up. During preemption, it does not become the active home agent until it retrieves the mobility binding table from the current active home agent or until 100 seconds expire for home agent synchronization.

Note If the **standby preempt** command is used, the preempt synchronization delay must be set or mobility bindings cannot be retrieved before the home agent preempts to become active.

The standby HSRP group name is SanJoseHA and the HSRP group address is 1.0.0.10. The standby HA uses this HSRP group address to retrieve mobility bindings for mobile nodes on the physical network. Mobile IP is configured to use the SanJoseHA standby group to provide home agent redundancy.

Mobile nodes are configured with HA address 1.0.0.10. When registrations come in, only the active home agent processes them. The active home agent sends a mobility binding update to the standby home agent, which also sets up a tunnel with the same source and destination endpoints. Updates and table retrievals are authenticated using the security associations configured on the home agent for its peer home agent. When packets destined for mobile nodes are received, either of the home agents tunnel them. If HA1 goes down, HA2 becomes active through HSRP and will process packets sent to home agent address 1.0.0.10.

HA1 Configuration

```
interface ethernet0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA
 standby preempt delay sync 100
 standby priority 110

 ip mobile home-agent standby SanJoseHA
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

 ip mobile home-agent standby SanJoseHA
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

HA Redundancy for a Virtual Network Using One Physical Network Example

This section presents two configuration examples:

- The mobile node and home agent are on different subnets.
- The mobile node and home agent are on the same subnet.

Mobile Node and Home Agent on Different Subnets

HA1 and HA2 share responsibility for providing home agent service for mobile nodes on virtual network 20.0.0.0. The home agents are connected on only one physical network.

The standby group name is SanJoseHA and the HSRP group address is 1.0.0.10. Mobile IP is configured to use the SanJoseHA standby group to provide home agent redundancy. Thus, HSRP allows the home agent to receive packets destined to 1.0.0.10.

This configuration differs from the physical network example in that a global HA address must be specified to support virtual networks. This address is returned in registration replies to the mobile node.

HA1 Configuration

```
interface ethernet0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

! specifies global HA address=HSRP group address to be used by all mobile nodes
 ip mobile home-agent address 1.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
! used to map to the HSRP group SanJoseHA
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

! specifies global HA address=HSRP group address to be used by all mobile nodes
 ip mobile home-agent address 1.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
! used to map to the HSRP group SanJoseHA
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

Mobile Node and Home Agent on Same Subnet

In this example, a loopback address is configured on the HA to be on the same subnet as the virtual network. A mobile node on a virtual network uses the HA IP address=loopback address configured for the virtual network. When a standby HA comes up, it uses this HA IP address to retrieve mobility bindings for mobile nodes on the virtual network.

HA1 Configuration

```
interface ethernet0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

! loopback to receive registration from MN on virtual-network
interface loopback0
 ip address 20.0.0.1 255.255.255.255

ip mobile home-agent
! address used by Standby HA for redundancy (update and download)
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

! loopback to receive registration from MN on virtual-network
 interface loopback0
 ip address 20.0.0.1 255.255.255.255

 ip mobile home-agent
! address used by Standby HA for redundancy (update and download)
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

HA Redundancy for a Virtual Network Using Multiple Physical Networks Example

This section presents two configuration examples:

- The mobile node and home agent are on different subnets.
- The mobile node and home agent are on the same subnet.

Mobile Node and Home Agent on Different Subnets

HA1 and HA2 share responsibility in providing home agent service for mobile nodes on virtual network 20.0.0.0. Both home agents are configured with a global home agent address of 10.0.0.10, which is the address of their loopback interface. This configuration allows home agents to receive registration requests and packets destined to 10.0.0.10.

The loopback address is used as the global HA address instead of the HSRP group addresses 1.0.0.10 and 2.0.0.10 to allow the HAs to continue serving the virtual network even if either physical network goes down.

Mobile nodes are configured with a home agent address 10.0.0.10. When registrations come in, either home agent processes them (depending on routing protocols) and updates the peer home agent. The home agent that receives the registration finds the first HSRP group that is mapped to 10.0.0.10 with a peer in the group and sends the update out that interface. If there is a network problem (for example, the home agent network adapter fails or cable disconnects), HSRP notices the absence of the peer. The home agent does not use that HSRP group and finds another HSRP group to use.

Note All routers must have identical loopback interface addresses, which will be used as the global HA address. However, do not use this address as the router ID for routing protocols.

When the peer home agent receives the registration update, both home agents tunnel the packets to the mobile nodes.

HA1 Configuration

```
interface ethernet0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHANet1

interface ethernet1
 ip add 2.0.0.1 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

interface loopback0
 ip address 10.0.0.10 255.255.255.255

!Specifies global HA address=loopback address to be used by all mobile nodes
 ip mobile home-agent address 10.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
! Used to map to the HSRP group SanJoseHANet1
 ip mobile home-agent standby SanJoseHANet1 virtual-network
! Used to map to the HSRP group SanJoseHANet2
 ip mobile home-agent standby SanJoseHANet2 virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHANet1

interface ethernet1
 ip address 2.0.0.2 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

interface loopback0
 ip address 10.0.0.10 255.255.255.255

!Specifies global HA address=loopback address to be used by all mobile nodes
 ip mobile home-agent address 10.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
! Used to map to the HSRP group SanJoseHANet1
 ip mobile home-agent standby SanJoseHANet1 virtual-network
! Used to map to the HSRP group SanJoseHANet2
 ip mobile home-agent standby SanJoseHANet2 virtual-network
```

```
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

Mobile Node and Home Agent on Same Subnet

In this example, a loopback address is configured on the HA to be on the same subnet as the virtual networks. A mobile node on a virtual network uses the HA IP address=loopback address configured for the virtual network. When a standby HA comes up, it uses this HA IP address to retrieve mobility bindings for mobile nodes on the virtual networks.

HA1 Configuration

```
interface ethernet0
 ip addr 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHANet1

interface ethernet1
 ip addr 2.0.0.1 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

! loopback to receive registration from MN on virtual-network
interface loopback0
 ip address 20.0.0.1 255.255.255.255

 ip mobile home-agent
! address used by Standby HA for redundancy (update and download)
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
 ip mobile home-agent standby SanJoseHANet1 virtual-network
 ip mobile home-agent standby SanJoseHANet2 virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

interface ethernet1
 ip address 2.0.0.2 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

! loopback to receive registration from MN on virtual-network
interface loopback0
 ip address 20.0.0.1 255.255.255.255

 ip mobile home-agent
! address used by Standby HA for redundancy (update and download)
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
 ip mobile home-agent standby SanJoseHANet1 virtual-network
 ip mobile home-agent standby SanJoseHANet2 virtual-network
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

HA Redundancy for Multiple Virtual Networks Using One Physical Network Example

This section presents two configuration examples:

- The mobile node and home agent are on different subnets.
- The mobile node and home agent are on the same subnet.

Figure 31 shows an example network topology for the first scenario. Figure 32 shows an example network topology for the second scenario.

Figure 31 Topology Showing HA Redundancy on Multiple Virtual Networks Using One Physical Network (Different Subnets)

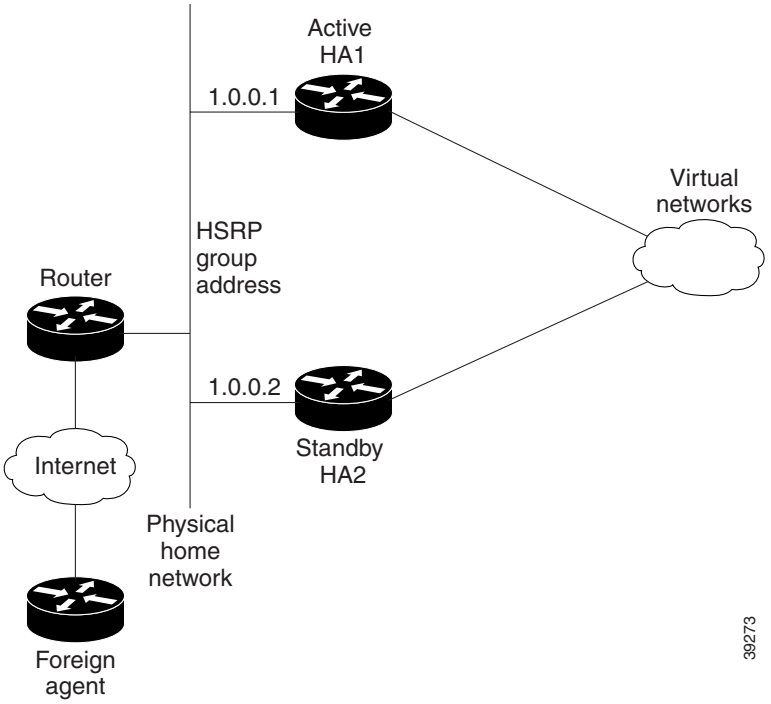
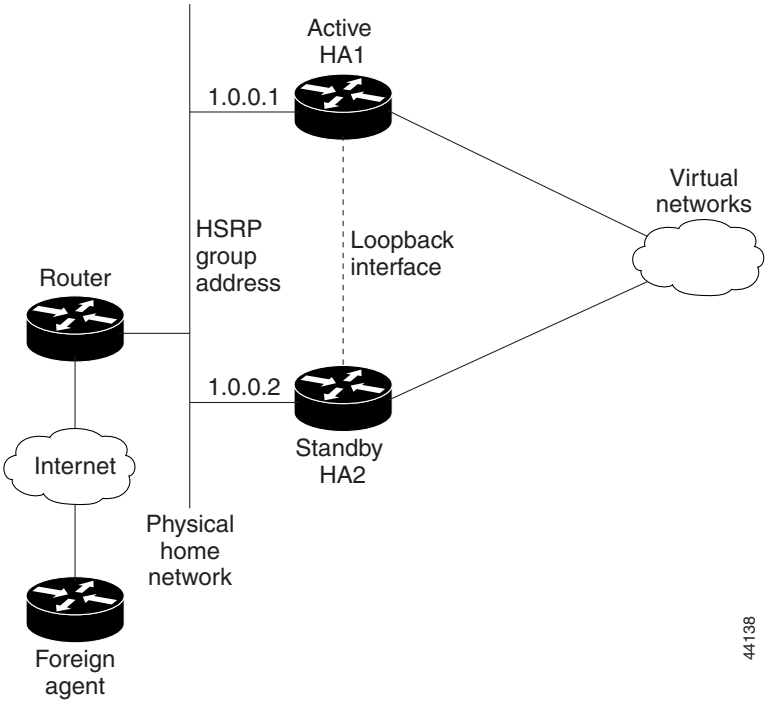


Figure 32 Topology Showing HA Redundancy on Multiple Virtual Networks Using One Physical Network (Same Subnet)



Mobile Node and Home Agent on Different Subnets

HA1 and HA2 share responsibility for providing home agent service for mobile nodes on virtual networks 20.0.0.0 and 30.0.0.0. The home agents are connected on only one physical network.

The standby group name is SanJoseHA and the HSRP group address is 1.0.0.10. Mobile IP is configured to use the SanJoseHA standby group to provide home agent redundancy. Thus, HSRP allows the home agent to receive packets destined to 1.0.0.10.

This configuration differs from the physical network example in that a global HA address must be specified to support virtual networks. This address is returned in registration replies to the mobile node.

HA1 Configuration

```
interface ethernet0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

! specifies global HA address=HSRP group address to be used by all mobile nodes
 ip mobile home-agent address 1.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
 ip mobile virtual-network 30.0.0.0 255.0.0.0
! used to map to the HSRP group SanJoseHA
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
```

```
 standby ip 1.0.0.10
 standby name SanJoseHA

! specifies global HA address=HSRP group address to be used by all mobile nodes
 ip mobile home-agent address 1.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
 ip mobile virtual-network 30.0.0.0 255.0.0.0
! used to map to the HSRP group SanJoseHA
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

Mobile Node and Home Agent on Same Subnet

For each virtual network, a loopback address is configured on the HA to be on the same subnet as the virtual network. It is only necessary to configure one loopback interface and to assign different IP addresses to the loopback interface for each virtual network using the **ip address** *ip-address mask* [**secondary**] interface configuration command. A mobile node on a particular virtual network uses the HA IP address =loopback address configured for that virtual network. When a standby HA comes up, it also uses this HA IP address to retrieve mobility bindings for mobile nodes on a particular virtual network.

HA1 Configuration

```
interface ethernet0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

! loopback to receive registration from MN on each virtual-network
interface loopback0
 ip address 20.0.0.1 255.255.255.255
 ip address 30.0.0.1 255.255.255.255 secondary

 ip mobile home-agent
! address used by Standby HA for redundancy (update and download) for
! each virtual-network
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
 ip mobile virtual-network 30.0.0.0 255.0.0.0 address 30.0.0.1
! used to map to the HSRP group SanJoseHA
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface e0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

! loopback to receive registration from MN on each virtual-network
interface loopback0
 ip address 20.0.0.1 255.255.255.255
 ip address 30.0.0.1 255.255.255.255 secondary

ip mobile home-agent
! address used by Standby HA for redundancy (update and download) for
! each virtual-network
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
 ip mobile virtual-network 30.0.0.0 255.0.0.0 address 30.0.0.1
! used to map to the HSRP group SanJoseHA
 ip mobile home-agent standby SanJoseHA virtual-network
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

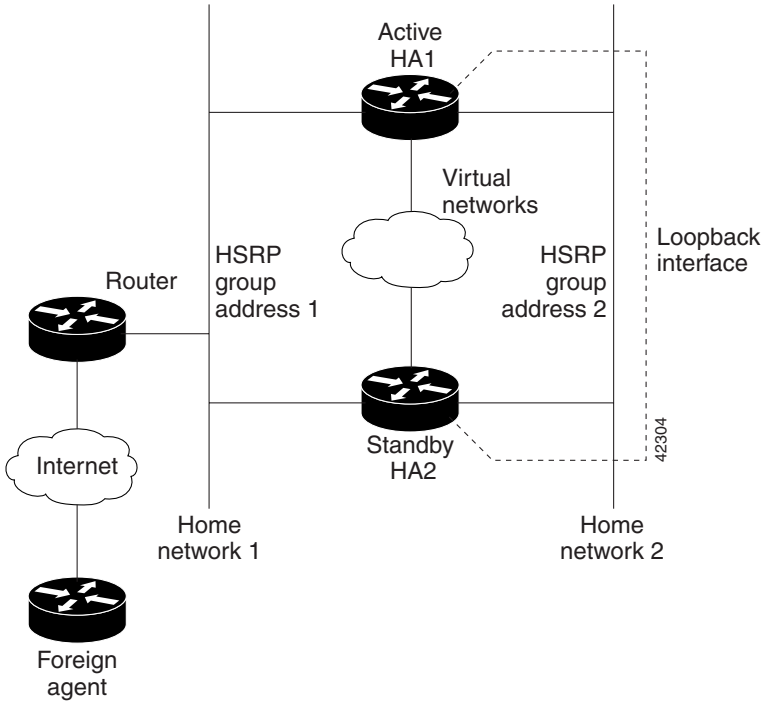
HA Redundancy for Multiple Virtual Networks Using Multiple Physical Networks Example

This section presents two configuration examples:

- The mobile node and home agent are on different subnets.
- The mobile node and home agent are on the same subnet.

Figure 33 shows an example network topology for this configuration type.

Figure 33 Topology Showing HA Redundancy on Virtual Networks Using Multiple Physical Networks



Mobile Node and Home Agent on Different Subnets

HA1 and HA2 share responsibility in providing home agent service for mobile nodes on virtual networks 20.0.0.0, 30.0.0.0, and 40.0.0.0. Both home agents are configured with a global home agent address of 10.0.0.10, which is the address of their loopback interface. This configuration allows home agents to receive registration requests and packets destined to 10.0.0.10.

The loopback address is used as the global HA address instead of the HSRP group addresses 1.0.0.10 and 2.0.0.10 to allow the HAs to continue serving the virtual networks even if either physical network goes down.

Mobile nodes are configured with home agent address 10.0.0.10. When registrations come in, either home agent processes them (depending on routing protocols) and updates the peer home agent. The home agent that receives the registration finds the first HSRP group that is mapped to 10.0.0.10 with a peer in the group and sends the update out that interface. If there is a network problem (for example, the home agent network adapter fails or cable disconnects), HSRP notices the absence of the peer. The home agent does not use that HSRP group and finds another HSRP group to use.

Note All routers must have identical loopback interface addresses, which will be used as the global HA address. However, do not use this address as the router ID for routing protocols.

When the peer home agent receives the registration update, both home agents tunnel the packets to the mobile nodes.

HA1 Configuration

```
interface ethernet0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHANet1

interface ethernet1
 ip address 2.0.0.1 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

interface loopback0
 ip address 10.0.0.10 255.255.255.255

!Specifies global HA address=loopback address to be used by all mobile nodes
 ip mobile home-agent address 10.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
 ip mobile virtual-network 30.0.0.0 255.0.0.0
 ip mobile virtual-network 40.0.0.0 255.0.0.0
! Used to map to the HSRP group SanJoseHANet1
 ip mobile home-agent standby SanJoseHANet1 virtual-network
! Used to map to the HSRP group SanJoseHANet2
 ip mobile home-agent standby SanJoseHANet2 virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHANet1

interface ethernet1
 ip address 2.0.0.2 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

interface loopback0
 ip address 10.0.0.10 255.255.255.255

!Specifies global HA address=loopback address to be used by all mobile nodes
 ip mobile home-agent address 10.0.0.10
 ip mobile virtual-network 20.0.0.0 255.0.0.0
 ip mobile virtual-network 30.0.0.0 255.0.0.0
 ip mobile virtual-network 40.0.0.0 255.0.0.0
! Used to map to the HSRP group SanJoseHANet1
 ip mobile home-agent standby SanJoseHANet1 virtual-network
! Used to map to the HSRP group SanJoseHANet2
 ip mobile home-agent standby SanJoseHANet2 virtual-network
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

Mobile Node and Home Agent on Same Subnet

For each virtual network, a loopback address is configured on the HA to be on the same subnet as the virtual network. It is only necessary to configure one loopback interface and assign different IP addresses to the loopback interface for each virtual network, that is, using the **ip address** *ip-address mask* [**secondary**] interface configuration command. A mobile node on a particular virtual network uses the HA IP address =loopback address configured for that virtual network. When a standby HA comes up, it also uses this HA IP address to retrieve mobility bindings for mobile nodes on a particular virtual network.

HA1 Configuration

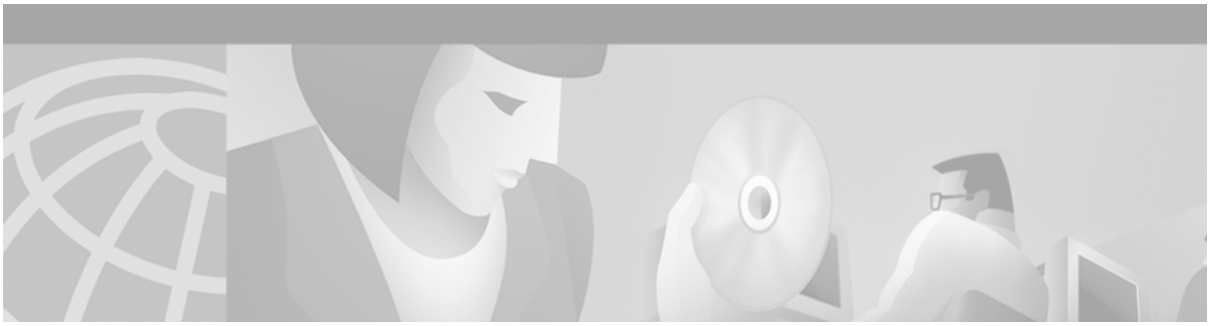
```
interface e0
 ip address 1.0.0.1 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHANet1

interface ethernet1
 ip address 2.0.0.1 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

! loopback to receive registration from MN on each virtual-network
interface loopback0
 ip address 20.0.0.1 255.255.255.255
 ip address 30.0.0.1 255.255.255.255 secondary
 ip address 40.0.0.1 255.255.255.255 secondary

ip mobile home-agent
! address used by Standby HA for redundancy (update and download) for
! each virtual-network
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
 ip mobile virtual-network 30.0.0.0 255.0.0.0 address 30.0.0.1
 ip mobile virtual-network 40.0.0.0 255.0.0.0 address 40.0.0.1
! used to map to the HSRP groups SanJoseHANet1 and SanJoseHANet2
 ip mobile home-agent standby SanJoseHANet1 virtual-network
 ip mobile home-agent standby SanJoseHANet2 virtual-network
 ip mobile secure home-agent 1.0.0.2 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.2 spi 100 key hex 00112233445566778899001122334455
```

HA2 Configuration

```
interface ethernet0
 ip address 1.0.0.2 255.0.0.0
 standby ip 1.0.0.10
 standby name SanJoseHA

interface ethernet1
 ip address 2.0.0.2 255.0.0.0
 standby ip 2.0.0.10
 standby name SanJoseHANet2

! loopback to receive registration from MN on each virtual-network
interface loopback0
 ip address 20.0.0.1 255.255.255.255
 ip address 30.0.0.1 255.255.255.255 secondary
 ip address 40.0.0.1 255.255.255.255 secondary

ip mobile home-agent
! address used by Standby HA for redundancy (update and download) for
! each virtual-network
 ip mobile virtual-network 20.0.0.0 255.0.0.0 address 20.0.0.1
```

```
 ip mobile virtual-network 30.0.0.0 255.0.0.0 address 30.0.0.1
 ip mobile virtual-network 40.0.0.0 255.0.0.0 address 40.0.0.1
! used to map to the HSRP groups SanJoseHANet1 and SanJoseHANet2
 ip mobile home-agent standby SanJoseHANet1 virtual-network
 ip mobile home-agent standby SanJoseHANet2 virtual-network
 ip mobile secure home-agent 1.0.0.1 spi 100 key hex 00112233445566778899001122334455
 ip mobile secure home-agent 2.0.0.1 spi 100 key hex 00112233445566778899001122334455
```

IP Routing Protocols



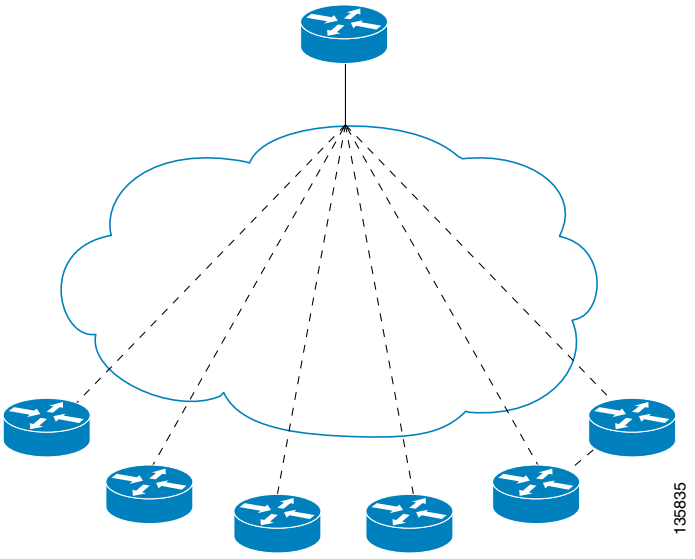
Configuring On-Demand Routing

This chapter describes how to configure On-Demand Routing (ODR). For a complete description of the ODR commands in this chapter, refer to the "On-Demand Routing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* publication. To locate documentation of other commands in this chapter, use the command reference master index or search online.

ODR is a feature that provides IP routing for stub sites, with minimum overhead. The overhead of a general, dynamic routing protocol is avoided without incurring the configuration and management overhead of static routing.

A *stub router* can be thought of as a spoke router in a hub-and-spoke network topology—as shown in Figure 34—where the only router to which the spoke is adjacent is the hub router. In such a network topology, the IP routing information required to represent this topology is fairly simple. These stub routers commonly have a WAN connection to the hub router, and a small number of LAN network segments (*stub networks*) are directly connected to the stub router.

Figure 34 Hub-And-Spoke Network Topology Example



These stub networks might consist only of end systems and the stub router, and thus do not require the stub router to learn any dynamic IP routing information.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

On-Demand Routing Configuration Task List

To configure ODR, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional:

- Enabling ODR (Required)
- Filtering ODR Information (Optional)
- Redistributing ODR Information into the Dynamic Routing Protocol of the Hub (Optional)
- Reconfiguring CDP or ODR Timers (Optional)
- Using ODR with Dialer Mappings (Optional)

Enabling ODR

ODR allows you to easily install IP stub networks where the hubs dynamically maintain routes to the stub networks. This installation is accomplished without requiring the configuration of an IP routing protocol on the stubs.

On stub routers that support the ODR feature, the stub router advertises IP prefixes corresponding to the IP networks configured on all directly connected interfaces. If the interface has multiple logical IP networks configured, only the primary IP network is advertised through ODR. Because ODR advertises IP prefixes and not simply IP network numbers, ODR is able to carry variable-length subnet mask (VSLM) information.

To enable ODR, use the following command in global configuration mode:

Command	Purpose
`Router(config)# router odr`	Enables ODR on the hub router.

Once ODR is enabled on a hub router, the hub router begins installing stub network routes in the IP forwarding table. The hub router also can be configured to redistribute these routes into any configured dynamic IP routing protocols.

On the stub router, no IP routing protocol must be configured. In fact, from the standpoint of ODR, a router is automatically considered to be a stub when no IP routing protocols have been configured.

ODR uses the Cisco Discovery Protocol (CDP) to carry minimal routing information between the hub and stub routers. The stub routers send IP prefixes to the hub router. The hub router provides default route information to the stub routers, thereby eliminating the need to configure a default route on each stub router.

Using the **no cdp run** global configuration command disables the propagation of ODR stub routing information entirely. Using the **no cdp enable** interface configuration command disables the propagation of ODR information on a particular interface.

Filtering ODR Information

The hub router will attempt to populate the IP routing table with ODR routes as they are learned dynamically from stub routers. The IP next hop for these routes is the IP address of the neighboring router as advertised through CDP.

Use IP filtering to limit the network prefixes that the hub router will permit to be learned dynamically through ODR.

To filter ODR information, use the following command in router configuration mode:

Command	Purpose
Router(config-router)# **distribute-list** *access-list-number* | *access-list-name* | **prefix** *list-name* {**in** | **out**} [*interface-type interface-number*]	Filters ODR information on the hub router.

For example, the following configuration causes the hub router to only accept advertisements for IP prefixes about (or subnets of) the Class C network 1982.168.1.0:

```
Router(config)# access-list 101 permit ip any 192.168.1.0 0.0.0.255
Router(config)# !
Router(config)# router odr
Router(config)# distribute-list 101 in
Router(config)# end
```

Redistributing ODR Information into the Dynamic Routing Protocol of the Hub

This task may be performed by using the **redistribute** router configuration command. The exact syntax depends upon the routing protocol into which ODR is being redistributed.

See the "Redistribute Routing Information" section in the "Configuring IP Routing Protocol-Independent Features" chapter.

Reconfiguring CDP or ODR Timers

By default, CDP sends updates every 60 seconds. This update interval may not be frequent enough to provide speedy reconvergence of IP routes on the hub router side of the network. A faster reconvergence rate may be necessary if the stub connects to one of several hub routers via asynchronous interfaces such as modem lines.

ODR expects to receive periodic CDP updates containing IP prefix information. When ODR fails to receive such updates for routes that it has installed in the routing table, these ODR routes are first marked invalid and eventually removed from the routing table. (By default, ODR routes are marked invalid after 180 seconds and are removed from the routing table after 240 seconds.) These defaults are based on the default CDP update interval. Configuration changes made to either the CDP or ODR timers should be reflected through changes made to both.

To configure CDP or ODR timers, use the following commands beginning in global configuration mode:

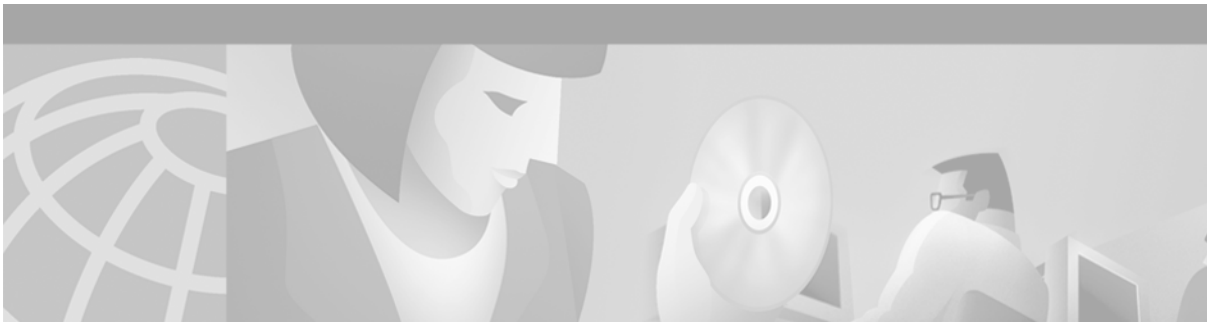
	Command	Purpose
Step 1	`Router(config)# cdp timer seconds`	Changes the rate at which CDP updates are sent.
Step 2	`Router(config)# router odr`	Enables ODR.
Step 3	`Router(config-router)# timers basic update invalid holddown flush [sleeptime]`	Changes the rate at which ODR routes are expired from the routing table.

Other CDP features are described in the *Cisco IOS Configuration Fundamentals Configuration Guide*, in the "Monitoring the Router and Network" chapter.

Using ODR with Dialer Mappings

For interfaces that specify dialer mappings, CDP packets will make use of dialer map configuration statements that pertain to the IP protocol. Because CDP packets are always broadcast packets, these dialer map statements must handle broadcast packets, typically through use of the dialer map **broadcast** keyword. The **dialer string** interface configuration command may also be used.

On DDR interfaces, certain kinds of packets can be classified as interesting. These interesting packets can cause a DDR connection to be made or cause the idle timer of a DDR interface to be reset. For the purposes of DDR classification, CDP packets are considered uninteresting. This classification occurs even while CDP is making use of dialer map statements for IP, where IP packets are classified as interesting.



Configuring Routing Information Protocol

This chapter describes how to configure Routing Information Protocol (RIP). For a complete description of the RIP commands that appear in this chapter, refer to the "RIP Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols*. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

RIP is a relatively old but still commonly used interior gateway protocol created for use in small, homogeneous networks. It is a classical distance-vector routing protocol. RIP is documented in RFC 1058.

RIP uses broadcast User Datagram Protocol (UDP) data packets to exchange routing information. Cisco IOS software sends routing information updates every 30 seconds, which is termed *advertising.* If a router does not receive an update from another router for 180 seconds or more, it marks the routes served by the nonupdating router as being unusable. If there is still no update after 240 seconds, the router removes all routing table entries for the nonupdating router.

The metric that RIP uses to rate the value of different routes is *hop count.* The hop count is the number of routers that can be traversed in a route. A directly connected network has a metric of zero; an unreachable network has a metric of 16. This small range of metrics makes RIP an unsuitable routing protocol for large networks.

A router that is running RIP can receive a default network via an update from another router that is running RIP, or the router can source (generate) the default network itself with RIP. In both cases, the default network is advertised through RIP to other RIP neighbors.

Cisco IOS software will source the default network with RIP if one of the following conditions is met:

- The **ip default-network** command is configured.
- The **default-information originate** command is configured.
- The default route is learned via another routing protocol or static route and then redistributed into RIP.

RIP sends updates to the interfaces in the specified networks. If the network of an interface network is not specified, it will not be advertised in any RIP update.

The Cisco implementation of RIP Version 2 supports plain text and Message Digest 5 (MD5) authentication, route summarization, classless interdomain routing (CIDR), and variable-length subnet masks (VLSMs).

For protocol-independent features, which also apply to RIP, see the chapter "Configuring IP Routing Protocol-Independent Features" in this book.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

RIP Configuration Task List

To configure RIP, perform the tasks described in the following sections. The tasks in the first two sections are required; the tasks in the remaining sections are optional.

- Enabling RIP (Required)
- Allowing Unicast Updates for RIP (Required)
- Applying Offsets to Routing Metrics (Optional)
- Adjusting Timers (Optional)
- Specifying a RIP Version (Optional)
- Enabling RIP Authentication (Optional)
- Configuring Route Summarization on an Interface (Optional)
- Verifying IP Route Summarization (Optional)
- Disabling Automatic Route Summarization (Optional)
- Running IGRP and RIP Concurrently (Optional)
- Disabling the Validation of Source IP Addresses (Optional)
- Enabling or Disabling Split Horizon (Optional)
- Configuring Interpacket Delay (Optional)
- Connecting RIP to a WAN (Optional)

For information about the following topics, see the "Configuring IP Routing Protocol-Independent Features" chapter:

- Filtering RIP information
- Key management (available in RIP Version 2)
- VLSM

Enabling RIP

To enable RIP, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router rip`	Enables a RIP routing process, which places you in router configuration mode.
Step 2	`Router(config-router)# network ip-address`	Associates a network with a RIP routing process.

Allowing Unicast Updates for RIP

Because RIP is normally a broadcast protocol, in order for RIP routing updates to reach nonbroadcast networks, you must configure the Cisco IOS software to permit this exchange of routing information. To do so, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor ip-address`	Defines a neighboring router with which to exchange routing information.

To control the set of interfaces with which you want to exchange routing updates, you can disable the sending of routing updates on specified interfaces by configuring the **passive-interface** router configuration command. See the discussion on filtering in the "Filter Routing Information" section in the "Configuring IP Routing Protocol-Independent Features" chapter.

Applying Offsets to Routing Metrics

An offset list is the mechanism for increasing incoming and outgoing metrics to routes learned via RIP. Optionally, you can limit the offset list with either an access list or an interface. To increase the value of routing metrics, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# offset-list [access-list-number | access-list-name] {in | out} offset [interface-type interface-number]`	Applies an offset to routing metrics.

Adjusting Timers

Routing protocols use several timers that determine such variables as the frequency of routing updates, the length of time before a route becomes invalid, and other parameters. You can adjust these timers to tune routing protocol performance to better suit your internetwork needs. You can make the following timer adjustments:

- The rate (time in seconds between updates) at which routing updates are sent
- The interval of time (in seconds) after which a route is declared invalid
- The interval (in seconds) during which routing information regarding better paths is suppressed
- The amount of time (in seconds) that must pass before a route is removed from the routing table
- The amount of time for which routing updates will be postponed

It also is possible to tune the IP routing support in the software to enable faster convergence of the various IP routing algorithms, and, hence, quicker fallback to redundant routers. The total effect is to minimize disruptions to end users of the network in situations where quick recovery is essential.

In addition, an address family can have explicitly specified timers that apply to that address-family (or VRF) only. The **timers basic** command must be specified for an address family or the system defaults for the **timers basic** command are used regardless of what is configured for RIP routing. The VRF does not inherit the timer values from the base RIP configuration. The VRF will always use the system default timers unless explicitly changed using the **timers basic** command.

To adjust the timers, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# timers basic update invalid holddown flush [sleeptime]`	Adjusts routing protocol timers.

See the "Address Family Timers Example" section at the end of this chapter for examples of adjusting timers for an address family (VRF).

Specifying a RIP Version

The Cisco implementation of RIP Version 2 supports authentication, key management, route summarization, CIDR, and VLSMs. Key management and VLSM are described in the chapter "Configuring IP Routing Protocol-Independent Features."

By default, the software receives RIP Version 1 and Version 2 packets, but sends only Version 1 packets. You can configure the software to receive and send only Version 1 packets. Alternatively, you can configure the software to receive and send only Version 2 packets. To configure the software to send and receive packets from only one version, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# version {1 | 2}`	Configures the software to receive and send only RIP Version 1 or only RIP Version 2 packets.

The preceding task controls the default behavior of RIP. You can override that behavior by configuring a particular interface to behave differently. To control which RIP version an interface sends, use the following commands in interface configuration mode, as needed:

:

Command	Purpose
`Router(config-if)# ip rip send version 1`	Configures an interface to send only RIP Version 1 packets.
`Router(config-if)# ip rip send version 2`	Configures an interface to send only RIP Version 2 packets.
`Router(config-if)# ip rip send version 1 2`	Configures an interface to send RIP Version 1 and Version 2 packets.

Similarly, to control how packets received from an interface are processed, use the following commands in interface configuration mode, as needed:

Command	Purpose
`Router(config-if)# ip rip receive version 1`	Configures an interface to accept only RIP Version 1 packets.
`Router(config-if)# ip rip receive version 2`	Configures an interface to accept only RIP Version 2 packets.
`Router(config-if)# ip rip receive version 1 2`	Configures an interface to accept either RIP Version 1 or 2 packets.

Enabling RIP Authentication

RIP Version 1 does not support authentication. If you are sending and receiving RIP Version 2 packets, you can enable RIP authentication on an interface.

The key chain determines the set of keys that can be used on the interface. If a key chain is not configured, no authentication is performed on that interface, not even the default authentication. Therefore, you must also perform the tasks in the section "Managing Authentication Keys" in the "Configuring IP Routing Protocol-Independent Features" chapter.

We support two modes of authentication on an interface for which RIP authentication is enabled: plain text authentication and MD5 authentication. The default authentication in every RIP Version 2 packet is plain text authentication.

Note Do not use plain text authentication in RIP packets for security purposes, because the unencrypted authentication key is sent in every RIP Version 2 packet. Use plain text authentication when security is not an issue, for example, to ensure that misconfigured hosts do not participate in routing.

To configure RIP authentication, use the following commands in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# ip rip authentication key-chain` *name-of-chain*	Enables RIP authentication.
Step 2	`Router(config-if)# ip rip authentication mode {text | md5}`	Configures the interface to use MD5 digest authentication (or let it default to plain text authentication).

See the "Key Management Examples" section of the "Configuring IP Routing Protocol-Independent Features" chapter for key management information and examples.

RIP Route Summarization

Summarizing routes in RIP Version 2 improves scalability and efficiency in large networks. Summarizing IP addresses means that there is no entry for child routes (routes that are created for any combination of the individual IP addresses contained within a summary address) in the RIP routing table, reducing the size of the table and allowing the router to handle more routes.

Summary IP address functions more efficiently than multiple individually advertised IP routes for the following reasons:

- The summarized routes in the RIP database are processed first.
- Any associated child routes that are included in a summarized route are skipped as RIP looks through the routing database, reducing the processing time required.

Cisco routers can summarize routes in two ways:

- Automatically, by summarizing subprefixes to the classful network boundary when crossing classful network boundaries (automatic summary).

Note You need not configure anything for automatic summary to be enabled. To disable automatic summary, use the Router (config-router)# **no auto-summary** router configuration command.

- As specifically configured, advertising a summarized local IP address pool on the specified interface (on a network access server) so that the address pool can be provided to dialup clients.

Automatic summary addressing always summarizes to the classful address boundary, while the **ip summary-address** router configuration command summarizes addresses on a specified interface. If automatic summary addressing is enabled, automatic summarization is the default behavior for interfaces on the router not associated with dial-in clients (the "backbone"), with *or* without the **ip summary-address rip** interface command present.

For example, if a local IP address pool of 10.1.1.1 to 10.1.1.254 is configured on the network access server, you could configure the **ip summary-address rip 10.1.1.0 255.255.255.0** command on the network access server port that provides addresses to dialup clients to cause the router to advertise 10.1.1.0/24 routes to dialup clients. Because a summary route is advertised, advertisement of the /32 host routes (installed when the dialup client connects) is suppressed so that the router does not advertise these routes to the network access server interface.

Automatic summary will override the configured summary address feature on a given interface except when *both* of the following conditions are true:

- The configured interface summary address and the IP address of the configured interface share the same major network (the classful, nonsubnetted portion of the IP address).
- Split horizon is not enabled on the interface.

Note If split horizon is enabled, neither an automatic summary address nor the interface summary address is advertised.

In the following example configuration, the major network is 10.0.0.0. The 10 in the address defines a Class A address space, allowing space for 0.*x.x.x* unique hosts where *x* defines unique bit positions in the addresses for these hosts. The summary of the major net defines the prefix as implied by the class (A, B, or C) of the address, without any network mask. The summary address 10.2.0.0 overrides the automatic summary address of 10.0.0.0, 10.2.0.0 is advertised out interface E1, and 10.0.0.0 is not advertised.

```
interface Ethernet1
 ip address 10.1.1.1 255.255.255.0
 ip summary-address rip 10.2.0.0 255.255.0.0
 no ip split-horizon

router rip
 network 10.0.0.0
```

When RIP determines that a summary address is required in the RIP database, a summary entry is created in the RIP routing database. As long as there are child routes for a summary address, the address remains in the routing database. When the last child route is removed, the summary entry also is removed from the database. This method of handling database entries reduces the number of entries in the database because each child route is not listed in an entry, and the aggregate entry itself is removed when there are no longer any valid child routes for it.

RIP Version 2 route summarization requires that the lowest metric of the "best route" of an aggregated entry, or the lowest metric of all current child routes, be advertised. The best metric for aggregated summarized routes is calculated at route initialization or when there are metric modifications of specific routes at advertisement time, and not at the time the aggregated routes are advertised.

Restrictions to RIP Route Summarization

Supernet advertisement (advertising any network prefix less than its classful major network) is not allowed in RIP route summarization, other than advertising a supernet learned in the routing tables. Supernets learned on any interface that is subject to configuration are still learned. For example, the following summarization is invalid:

```
interface E1
.
.
.
ip summary-address rip 10.0.0.0 252.0.0.0 (invalid supernet summarization)
```

Each route summarization on an interface must have a unique major net, even if the subnet mask is unique. For example, the following is not permitted:

```
interface Ethernet1
.
.
.
ip summary-address rip 10.1.0.0 255.255.0.0
ip summary-address rip 10.2.0.0 255.255.0.0 (or different mask)
```

Note The **ip summary-address eigrp** router configuration command uses other options that are not applicable to RIP. Do not confuse Enhanced IGRP (EIGRP) summary address with the new RIP command, **ip summary-address rip**.

Configuring Route Summarization on an Interface

The **ip summary-address rip** router configuration command causes the router to summarize a given set of routes learned via RIP Version 2 or redistributed into RIP Version 2. Host routes are especially applicable for summarization. To configure IP summary addressing, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface ethernet1`	Enters interface configuration mode for the ethernet 1 port.
Step 2	`Router(config-if)# ip summary-address rip` *ip_address ip_network_mask*	Specifies the IP address and network mask that identify the routes to be summarized.

See the "Route Summarization Examples" section at the end of this chapter for examples of using split horizon.

Verifying IP Route Summarization

You can verify which routes are summarized for an interface using the **show ip protocols** EXEC command. The following example shows potential summarizations and the associated interface summary address and network mask for Ethernet interface 2:

```
router# show ip protocols

 Routing Protocol is "rip"
   Sending updates every 30 seconds, next due in 8 seconds
```

```
  Invalid after 180 seconds, hold down 180, flushed after 240
  Outgoing update filter list for all interfaces is
  Incoming update filter list for all interfaces is
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface        Send  Recv  Triggered RIP  Key-chain
    Ethernet2        2     2
    Ethernet3        2     2
    Ethernet4        2     2
    Ethernet5        2     2
  Automatic network summarization is not in effect
  Address Summarization:
    10.11.0.0/16 for Ethernet2
```

You can check summary address entries in the RIP database. These entries will appear in the database only if relevant child routes are being summarized. When the last child route for a summary address becomes invalid, the summary address is also removed from the routing table. The following example shows a summary address entry for route 10.11.0.0/16, with three child routes active:

```
router# show ip rip database

 10.0.0.0/8    auto-summary
 10.11.11.0/24    directly connected, Ethernet2
 10.1.0.0/8    auto-summary
 10.11.0.0/16    int-summary
 ^^^^^^^^^^^^^^^^^^^^^^^^^^
 10.11.10.0/24    directly connected, Ethernet3
 10.11.11.0/24    directly connected, Ethernet4
 10.11.12.0/24    directly connected, Ethernet5
```

Disabling Automatic Route Summarization

RIP Version 2 supports automatic route summarization by default. The software summarizes subprefixes to the classful network boundary when crossing classful network boundaries.

If you have disconnected subnets, disable automatic route summarization to advertise the subnets. When route summarization is disabled, the software sends subnet and host routing information across classful network boundaries. To disable automatic summarization, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no auto-summary`	Disables automatic summarization.

Running IGRP and RIP Concurrently

It is possible to run Interior Gateway Routing Protocol (IGRP) and RIP concurrently. The IGRP information will override the RIP information by default because of the administrative distance of IGRP.

However, running IGRP and RIP concurrently does not work well when the network topology changes. Because IGRP and RIP have different update timers, and because they require different amounts of time to propagate routing updates, one part of the network will accept and use IGRP routes and another part will accept and use RIP routes. Running IGRP and RIP concurrently will result in routing loops. Even though these loops do not exist for very long, the time-to-live (TTL) value will quickly reach zero, and Internet Control Message Protocol (ICMP) will send a “TTL exceeded” message. This message will cause most applications to stop attempting network connections.

Disabling the Validation of Source IP Addresses

By default, the software validates the source IP address of incoming RIP routing updates. If that source address is not valid, the software discards the routing update.

You might want to disable this feature if you have a router that is "off network" and you want to receive its updates. However, disabling this feature is not recommended under normal circumstances. To disable the default function that validates the source IP addresses of incoming routing updates, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no validate-update-source`	Disables the validation of the source IP address of incoming RIP routing updates.

Enabling or Disabling Split Horizon

Normally, routers that are connected to broadcast-type IP networks and that use distance-vector routing protocols employ the *split horizon* mechanism to reduce the possibility of routing loops. Split horizon blocks information about routes from being advertised by a router out of any interface from which that information originated. This behavior usually optimizes communications among multiple routers, particularly when links are broken. However, with nonbroadcast networks (such as Frame Relay and Switched Multimegabit Digital System [SMDS]), situations can arise for which this behavior is less than ideal. For these situations, you might want to disable split horizon with IGRP and RIP.

If an interface is configured with secondary IP addresses and split horizon is enabled, updates might not be sourced by every secondary address. One routing update is sourced per network number unless split horizon is disabled.

To enable or disable split horizon, use the following commands in interface configuration mode, as needed:

Command	Purposes
`Router(config-if)# ip split-horizon`	Enables split horizon.
`Router(config-if)# no ip split-horizon`	Disables split horizon.

Split horizon for Frame Relay and SMDS encapsulation is disabled by default. Split horizon is not disabled by default for interfaces using any of the X.25 encapsulations. For all other encapsulations, split horizon is enabled by default.

See the "Split Horizon Examples" section at the end of this chapter for examples of using split horizon.

Note In general, changing the state of the default is not recommended unless you are certain that your application requires making a change in order to advertise routes properly. Remember that if split horizon is disabled on a serial interface (and that interface is attached to a packet-switched network), you *must* disable split horizon for all routers in any relevant multicast groups on that network.

Configuring Interpacket Delay

By default, the software adds no delay between packets in a multiple-packet RIP update being sent. If you have a high-end router sending to a low-speed router, you might want to add such interpacket delay to RIP updates, in the range of 8 to 50 milliseconds. To do so, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# output-delay delay`	Adds interpacket delay for RIP updates sent.

Connecting RIP to a WAN

Routers are used on connection-oriented networks to allow potential connectivity to many remote destinations. Circuits on the WAN are established on demand and are relinquished when the traffic subsides. Depending on the application, the connection between any two sites for user data could be short and relatively infrequent.

There are two problems using RIP to connect to a WAN:

- Periodic broadcasting by RIP generally prevents WAN circuits from being closed.
- Even on fixed, point-to-point links, the overhead of periodic RIP transmissions could seriously interrupt normal data transfer because of the quantity of information that passes through the line every 30 seconds.

To overcome these limitations, triggered extensions to RIP cause RIP to send information on the WAN only when there has been an update to the routing database. Periodic update packets are suppressed over the interface on which this feature is enabled. RIP routing traffic is reduced on point-to-point, serial interfaces. Therefore, you can save money on an on-demand circuit for which you are charged for usage. Triggered extensions to RIP partially support RFC 2091, *Triggered Extensions to RIP to Support Demand Circuits*.

To enable triggered extensions to RIP, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface serial controller-number`	Configures a serial interface.
Step 2	`Router(config-if)# ip rip triggered`	Enables triggered extensions to RIP.

To display the contents of the RIP private database, use the following command in EXEC mode:

Command	Purpose
`Router# show ip rip database [prefix mask]`	Displays the contents of the RIP private database.

RIP Configuration Examples

The following section provides RIP configuration examples:

- Route Summarization Examples, page 209
- Split Horizon Examples, page 210
- Address Family Timers Example, page 212

Route Summarization Examples

A correct and an incorrect configuration example of route summarization are provided.

Example 1: Correct Configuration

The following example shows how the **ip summary-address rip** router configuration command works with automatic summary addressing in RIP, starting in global configuration mode. In the example, the major network is 10.0.0.0. The summary address 10.2.0.0 overrides the automatic summary address of 10.0.0.0, so that 10.2.0.0 is advertised out Ethernet interface 1 and 10.0.0.0 is not advertised.

Note If split horizon is enabled, neither automatic summary nor interface summary addresses (those configured with the **ip summary-address rip** router configuration command) are advertised.

```
Router(config)# router rip
Router(config-router)# network 10.0.0.0
Router(config-router)# exit
Router(config)# interface ethernet1
Router(config-if)# ip address 10.1.1.1 255.255.255.0
Router(config-if)# ip summary-address rip 10.2.0.0 255.255.0.0
Router(config-if)# no ip split-horizon
Router(config-if)# exit
```

Example 2: Incorrect Configuration

The following example shows an illegal use of the **ip summary-address rip** router configuration command, because both addresses to be summarized have the same major network. Each route summarization on an interface must have a unique major network, whether or not the addresses have unique address masks.

```
Router(config)# interface ethernet1
.
.
.
Router(config-if)# ip summary-address rip 10.1.0.0 255.255.0.0
Rotuer(config-if)# ip summary-address rip 10.2.0.0 255.255.255.0
```

Split Horizon Examples

Two examples of configuring split horizon are provided.

Example 1

The following configuration shows a simple example of disabling split horizon on a serial link. In this example, the serial link is connected to an X.25 network.

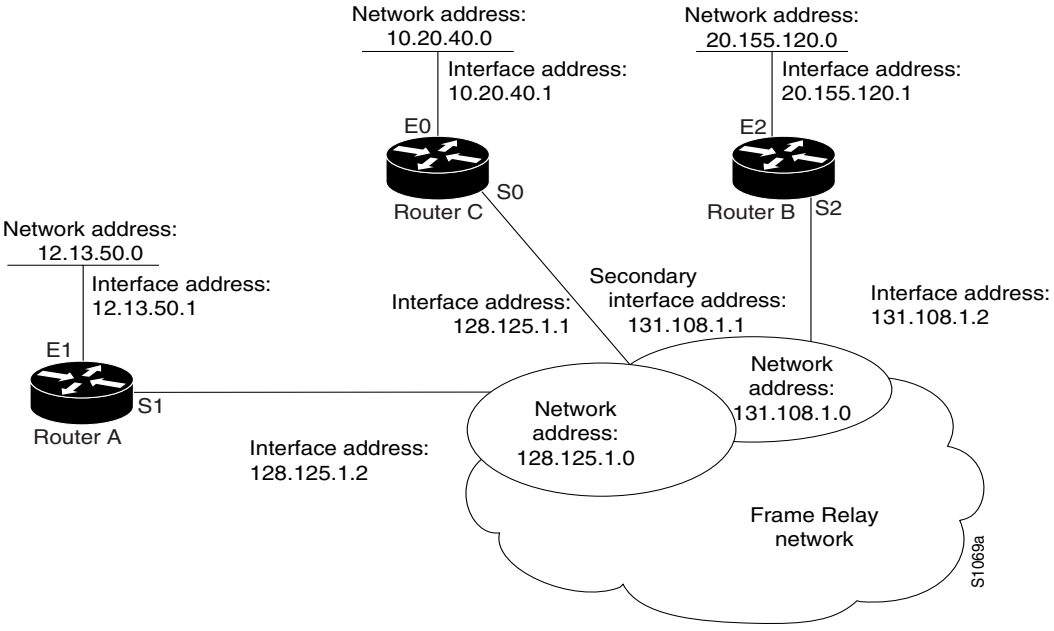
```
interface serial 0
 encapsulation x25
 no ip split-horizon
```

Example 2

In the next example, Figure 35 illustrates a typical situation in which the **no ip split-horizon** interface configuration command would be useful. This figure depicts two IP subnets that are both accessible via a serial interface on Router C (connected to Frame Relay network). In this example, the serial interface on Router C accommodates one of the subnets via the assignment of a secondary IP address.

The Ethernet interfaces for Router A, Router B, and Router C (connected to IP networks 12.13.50.0, 10.20.40.0, and 20.155.120.0, respectively, all have split horizon *enabled* by default, while the serial interfaces connected to networks 128.125.1.0 and 131.108.1.0 all have split horizon *disabled* with the **no ip split-horizon** command. Figure 35 shows the topology and interfaces.

Figure 35 Disabled Split Horizon Example for Frame Relay Network



In this example, split horizon is disabled on all serial interfaces. However, split horizon must be disabled on Router C in order for network 128.125.0.0 to be advertised into network 131.108.0.0, and vice versa. These subnets overlap at Router C, interface S0. If split horizon were enabled on serial interface S0, it would not advertise a route back into the Frame Relay network for either of these networks.

Configuration for Router A

```
interface ethernet 1
 ip address 12.13.50.1
!
interface serial 1
 ip address 128.125.1.2
 encapsulation frame-relay
 no ip split-horizon
```

Configuration for Router B

```
interface ethernet 2
 ip address 20.155.120.1
!
interface serial 2
 ip address 131.108.1.2
 encapsulation frame-relay
 no ip split-horizon
```

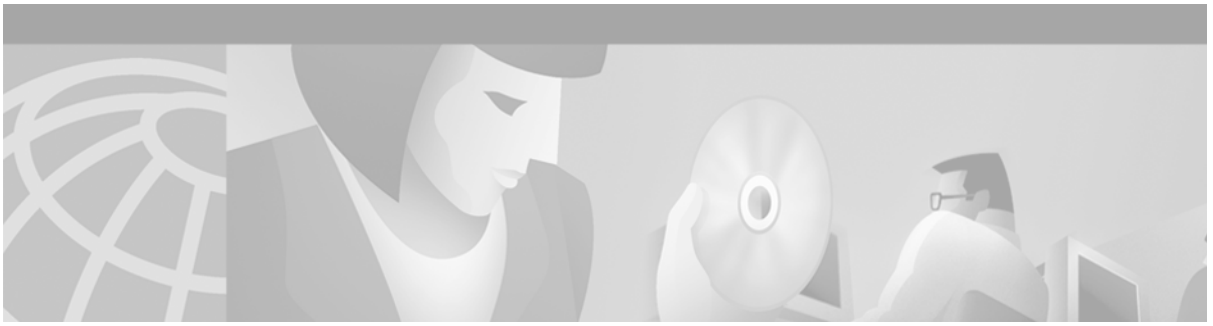
Configuration for Router C

```
interface ethernet 0
 ip address 10.20.40.1
!
interface serial 0
 ip address 128.125.1.1
 ip address 131.108.1.1 secondary
 encapsulation frame-relay
 no ip split-horizon
```

Address Family Timers Example

The following example shows how to adjust individual address family timers.
Note that the address family "notusingtimers" will use the system defaults of 30, 180, 180, and 240 even though timer values of 5, 10, 15, and 20 are used under the general RIP configuration. Address family timers are not inherited from the general RIP configuration.

```
Router(config)#router rip
Router(config-router)# version 2
Router(config-router)# timers basic 5 10 15 20
Router(config-router)# redistribute connected
Router(config-router)# network 5.0.0.0
Router(config-router)# default-metric 10
Router(config-router)# no auto-summary
Router(config-router)#!
Router(config-router)# address-family ipv4 vrf foo
Router(config-router-af)# timers basic 10 20 20 20
Router(config-router-af)# redistribute connected
Router(config-router-af)# network 10.0.0.0
Router(config-router-af)# default-metric 5
Router(config-router-af)# no auto-summary
Router(config-router-af)# version 2
Router(config-router-af)# exit-address-family
Router(config-router)#!
Router(config-router)# address-family ipv4 vrf bar
Router(config-router-af)# timers basic 20 40 60 80
Router(config-router-af)# redistribute connected
Router(config-router-af)# network 20.0.0.0
Router(config-router-af)# default-metric 2
Router(config-router-af)# no auto-summary
Router(config-router-af)# version 2
Router(config-router-af)# exit-address-family
Router(config-router)#!
Router(config-router)# address-family ipv4 vrf notusingtimers
Router(config-router-af)# redistribute connected
Router(config-router-af)# network 20.0.0.0
Router(config-router-af)# default-metric 2
Router(config-router-af)# no auto-summary
Router(config-router-af)# version 2
Router(config-router-af)# exit-address-family
Router(config-router)#!
```



Configuring IGRP

This chapter describes how to configure the Interior Gateway Routing Protocol (IGRP). For a complete description of the IGRP commands in this chapter, refer to the "IGRP Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols*. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

IGRP is a dynamic distance-vector routing protocol designed by Cisco in the mid-1980s for routing in an autonomous system that contains large, arbitrarily complex networks with diverse bandwidth and delay characteristics.

For protocol-independent features, see the chapter "Configuring IP Routing Protocol-Independent Features" in this book.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

The Cisco IGRP Implementation

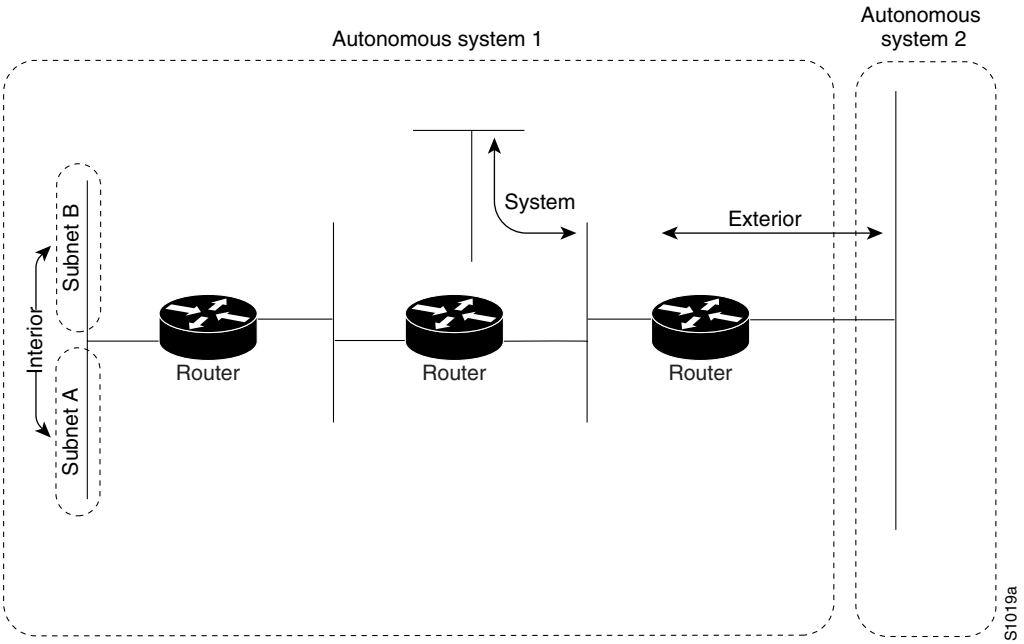
IGRP uses a combination of user-configurable metrics, including internetwork delay, bandwidth, reliability, and load.

IGRP also advertises three types of routes: interior, system, and exterior, as shown in Figure 36. *Interior routes* are routes between subnets in the network attached to a router interface. If the network attached to a router is not subnetted, IGRP does not advertise interior routes.

System routes are routes to networks within an autonomous system. The Cisco IOS software derives system routes from directly connected network interfaces and system route information provided by other IGRP-speaking routers or access servers. System routes do not include subnet information.

Exterior routes are routes to networks outside the autonomous system that are considered when identifying a *gateway of last resort*. The Cisco IOS software chooses a gateway of last resort from the list of exterior routes that IGRP provides. The software uses the gateway (router) of last resort if it does not have a better route for a packet and the destination is not a connected network. If the autonomous system has more than one connection to an external network, different routers can choose different exterior routers as the gateway of last resort.

Figure 36 Interior, System, and Exterior Routes



IGRP Updates

By default, a router running IGRP sends an update broadcast every 90 seconds. It declares a route inaccessible if it does not receive an update from the first router in the route within three update periods (270 seconds). After seven update periods (630 seconds), the Cisco IOS software removes the route from the routing table.

IGRP uses *flash update* and *poison reverse updates* to speed up the convergence of the routing algorithm. Flash update is the sending of an update sooner than the standard periodic update interval of notifying other routers of a metric change. Poison reverse updates are intended to defeat larger routing loops caused by increases in routing metrics. The poison reverse updates are sent to remove a route and place it in *holddown*, which keeps new routing information from being used for a certain period of time.

IGRP Configuration Task List

To configure IGRP, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional:

- Creating the IGRP Routing Process (Required)
- Applying Offsets to Routing Metrics (Optional)
- Allowing Unicast Updates for IGRP (Optional)
- Defining Unequal-Cost Load Balancing (Optional)
- Controlling Traffic Distribution (Optional)
- Adjusting the IGRP Metric Weights (Optional)
- Adjusting Timers (Optional)

- Disabling Holddown (Optional)
- Enforcing a Maximum Network Diameter (Optional)
- Validating Source IP Addresses (Optional)
- Enabling or Disabling Split Horizon (Optional)

Also see the examples in the "IGRP Configuration Examples" section at the end of this chapter.

Creating the IGRP Routing Process

To create the IGRP routing process, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router igrp as-number`	Enables an IGRP routing process, which places you in router configuration mode.
Step 2	`Router(config-router)# network network-number`	Associates networks with an IGRP routing process.

IGRP sends updates to the interfaces in the specified networks. If the network of an interface is not specified, the interface will not be advertised in any IGRP update.

It is not necessary to have a registered autonomous system number to use IGRP. If you do not have a registered number, you are free to create your own. We recommend that if you do have a registered number, you use it to identify the IGRP process.

Applying Offsets to Routing Metrics

An offset list is the mechanism for increasing incoming and outgoing metrics to routes learned via IGRP. Applying an offset limit is done to provide a local mechanism for increasing the value of routing metrics. Optionally, you can limit the offset list with either an access list or an interface. To increase the value of routing metrics, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# offset-list [access-list-number | access-list-name] {in | out} offset [interface-type | interface-number]`	Applies an offset to routing metrics.

Allowing Unicast Updates for IGRP

Because IGRP is normally a broadcast protocol, in order for IGRP routing updates to reach nonbroadcast networks, you must configure the Cisco IOS software to permit this exchange of routing information.

To permit information exchange, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor ip-address`	Defines a neighboring router with which to exchange routing information.

To control the set of interfaces with which you want to exchange routing updates, you can disable the sending of routing updates on specified interfaces by configuring the **passive-interface** router configuration command. See the discussion on filtering in the "Filter Routing Information" section in the "Configuring IP Routing Protocol-Independent Features" chapter.

Defining Unequal-Cost Load Balancing

IGRP can simultaneously use an asymmetric set of paths for a given destination. This feature is known as *unequal-cost load balancing*. Unequal-cost load balancing allows traffic to be distributed among multiple (up to four) unequal-cost paths to provide greater overall throughput and reliability. Alternate *path variance* (that is, the difference in desirability between the primary and alternate paths) is used to determine the *feasibility* of a potential route. An alternate route is *feasible* if the next router in the path is *closer* to the destination (has a lower metric value) than the current router and if the metric for the entire alternate path is *within* the variance. Only paths that are feasible can be used for load balancing and included in the routing table. These conditions limit the number of cases in which load balancing can occur, but ensure that the dynamics of the network will remain stable.

The following general rules apply to IGRP unequal-cost load balancing:

- IGRP will accept up to four paths for a given destination network.
- The local best metric must be greater than the metric learned from the next router; that is, the next hop router must be closer (have a smaller metric value) to the destination than the local best metric.
- The alternative path metric must be within the specified *variance* of the local best metric. The multiplier times the local best metric for the destination must be greater than or equal to the metric through the next router.

If these conditions are met, the route is deemed feasible and can be added to the routing table.

By default, the amount of variance is set to one (equal-cost load balancing). To define how much worse an alternate path can be before that path is disallowed, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)#` **`variance`** *`multiplier`*	Defines the variance associated with a particular path.

Note By using the variance feature, the Cisco IOS software can balance traffic across all feasible paths and can immediately converge to a new path if one of the paths should fail.

See the "IGRP Feasible Successor Relationship Example" section at the end of this chapter.

Controlling Traffic Distribution

If variance is configured as described in the preceding section, "Defining Unequal-Cost Load Balancing," IGRP or Enhanced IGRP (EIGRP) will distribute traffic among multiple routes of unequal cost to the same destination. If you want to have faster convergence to alternate routes, but you do not want to send traffic across inferior routes in the normal case, you might prefer to have no traffic flow along routes with higher metrics.

To control how traffic is distributed among multiple routes of unequal cost, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# traffic-share balanced`	Distribute traffic proportionately to the ratios of metrics.

Adjusting the IGRP Metric Weights

You have the option of altering the default behavior of IGRP routing and metric computations. For example, you can tune system behavior to allow for transmissions via satellite. Although IGRP metric defaults were carefully selected to provide excellent operation in most networks, you can adjust the IGRP metric. Adjusting IGRP metric weights can dramatically affect network performance, however, so ensure that you make all metric adjustments carefully.

To adjust the IGRP metric weights, use the following command in router configuration mode. Because of the complexity of this command, we recommend that you only use it with guidance from an experienced system designer.

Command	Purpose
`Router(config-router)# metric weights tos k1 k2 k3 k4 k5`	Adjusts the IGRP metric.

By default, the IGRP composite metric is a 24-bit quantity that is a sum of the segment delays and the lowest segment bandwidth (scaled and inverted) for a given route. For a network of homogeneous media, this metric reduces to a hop count. For a network of mixed media (Ethernet, FDDI, and serial lines running from 9600 bits per second to T1 rates), the route with the lowest metric reflects the most desirable path to a destination.

Adjusting Timers

Routing protocols use several timers that determine such variables as the frequency of routing updates, the length of time before a route becomes invalid, and other parameters. You can adjust these timers to tune routing protocol performance to better suit your internetwork needs. You can make the following timer adjustments:

- The rate (time in seconds between updates) at which routing updates are sent
- The interval of time (in seconds) after which a route is declared invalid
- The interval (in seconds) during which routing information regarding better paths is suppressed
- The amount of time (in seconds) that must pass before a route is removed from the routing table
- The amount of time for which routing updates will be postponed

It also is possible to tune the IP routing support in the software to enable faster convergence of the various IP routing algorithms, and, hence, quicker fallback to redundant routers. The total effect is to minimize disruptions to end users of the network in situations where quick recovery is essential.

To adjust the timers, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# timers basic update invalid holddown flush [sleeptime]`	Adjusts routing protocol timers.

Disabling Holddown

When the Cisco IOS software learns that a network is at a greater distance than was previously known, or it learns the network is down, the route to that network is placed in holddown. During the holddown period, the route is advertised, but incoming advertisements about that network from any router other than the one that originally advertised the new metric of the network will be ignored. This mechanism is often used to help avoid routing loops in the network, but has the effect of increasing the topology convergence time.

To disable holddowns with IGRP, use the following command in router configuration mode. All devices in an IGRP autonomous system must be consistent in their use of holddowns.

Command	Purpose
`Router(config-router)# no metric holddown`	Disables the IGRP holddown period.

Enforcing a Maximum Network Diameter

The Cisco IOS software enforces a maximum diameter to the IGRP network. Routes whose hop counts exceed this diameter are not advertised. The default maximum diameter is 100 hops. The maximum diameter is 255 hops.

To configure the maximum diameter, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# metric maximum-hops hops`	Configures the maximum network diameter.

Validating Source IP Addresses

By default, the system validates the source IP addresses of incoming IGRP routing updates. To disable this function, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no validate-update-source`	Disables the checking and validation of the source IP address of incoming routing updates.

Enabling or Disabling Split Horizon

Normally, routers that are connected to broadcast-type IP networks and that use distance-vector routing protocols employ the *split horizon* mechanism to reduce the possibility of routing loops. Split horizon blocks information about routes from being advertised by a router out of any interface from which that information originated. This behavior usually optimizes communications among multiple routers, particularly when links are broken. However, with nonbroadcast networks (such as Frame Relay and Switched Multimegabit Data Service [SMDS]), situations can arise for which this behavior is less than ideal. For these situations, you might want to disable split horizon.

If an interface is configured with secondary IP addresses and split horizon is enabled, updates might not be sourced by every secondary address. One routing update is sourced per network number unless split horizon is disabled.

To enable or disable split horizon, use the following commands in interface configuration mode as needed:

Command	Purpose
`Router(config-if)#` **`ip split-horizon`**	Enables split horizon.
`Router(config-if)#` **`no ip split-horizon`**	Disables split horizon.

Split horizon for Frame Relay and SMDS encapsulation is disabled by default. Split horizon is not disabled by default for interfaces using any of the X.25 encapsulations. For all other encapsulations, split horizon is enabled by default.

See the "Split Horizon Examples" section at the end of this chapter for examples of using split horizon.

Note In general, changing the state of the default is not recommended unless you are certain that your application requires making a change in order to advertise routes properly. Remember that if split horizon is disabled on a serial interface (and that interface is attached to a packet-switched network), you *must* disable split horizon for all routers in any relevant multicast groups on that network.

IGRP Configuration Examples

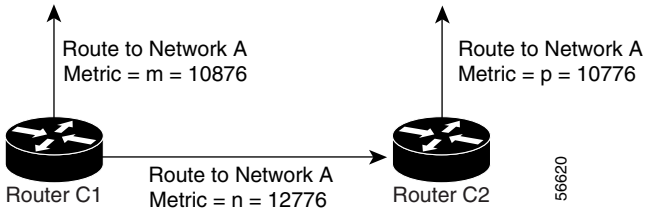
This section contains the following IGRP configuration examples:

- IGRP Feasible Successor Relationship Example
- Split Horizon Examples

IGRP Feasible Successor Relationship Example

In Figure 37, the assigned metrics meet the conditions required for a feasible successor relationship, so the paths in this example can be included in routing tables and be used for load balancing.

Figure 37 Assigning Metrics for IGRP Path Feasibility



The feasibility test would work as follows:

- Assume that Router C1 already has a route to Network A with metric *m* and has just received an update about Network A from Router C2. The best metric at Router C2 is *p*. The metric that Router C1 would use through Router C2 is *n*.
- If both of the following two conditions are met, the route to Network A through Router C2 will be included in the routing table of Router C1:
  - If *m* is greater than *p*.
  - If the *multiplier* (value specified by the **variance** router configuration command) times *m* is greater than or equal to *n*.
- The configuration for Router C1 would be as follows:

```
router igrp 109
 variance 10
```

A maximum of four paths can be in the routing table for a single destination. If there are more than four feasible paths, the four best feasible paths are used.

Split Horizon Examples

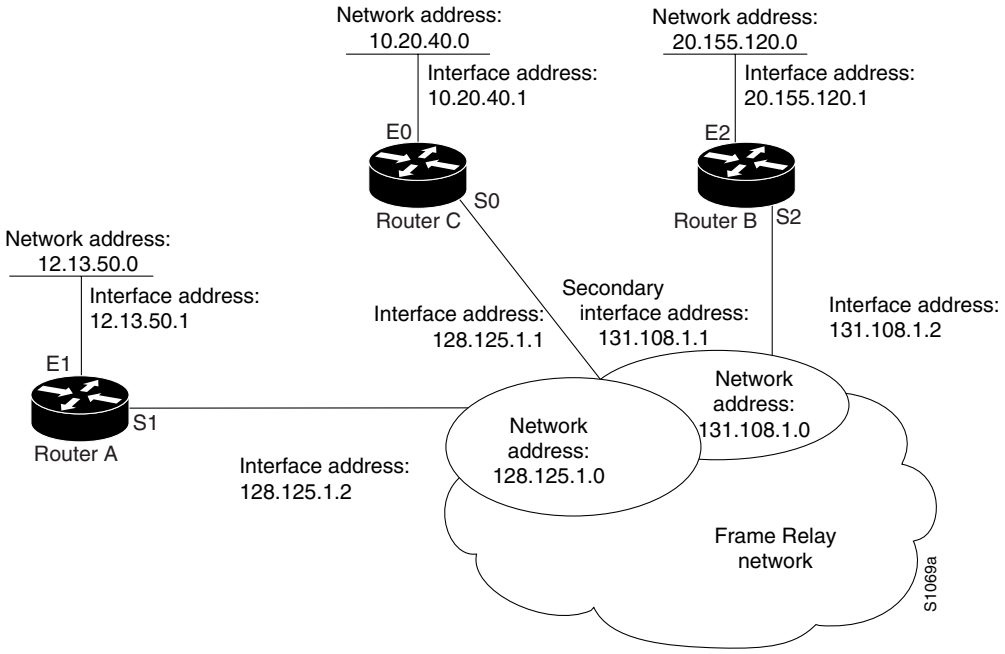
The following configuration shows a simple example of disabling split horizon on a serial link. In this example, the serial link is connected to an X.25 network.

```
interface serial 0
 encapsulation x25
 no ip split-horizon
```

In the next example, Figure 38 illustrates a typical situation in which the **no ip split-horizon** interface configuration command would be useful. This figure depicts two IP subnets that are both accessible via a serial interface on Router C (connected to Frame Relay network). In this example, the serial interface on Router C accommodates one of the subnets via the assignment of a secondary IP address.

The Ethernet interfaces for Router A, Router B, and Router C (connected to IP networks 12.13.50.0, 10.20.40.0, and 20.155.120.0, respectively) all have split horizon *enabled* by default, while the serial interfaces connected to networks 128.125.1.0 and 131.108.1.0 all have split horizon *disabled* by default. The partial interface configuration specifications for each router that follow Figure 38 illustrate that the **ip split-horizon** interface configuration command is *not* explicitly configured under normal conditions for any of the interfaces.

Figure 38 Disabled Split Horizon Example



In this example, split horizon must be disabled in order for network 128.125.0.0 to be advertised into network 131.108.0.0, and vice versa. These subnets overlap at Router C, serial interface 0. If split horizon were enabled on serial interface 0, it would not advertise a route back into the Frame Relay network for either of these networks.

The configurations for routers A, B, and C follow.

Router Configuration A

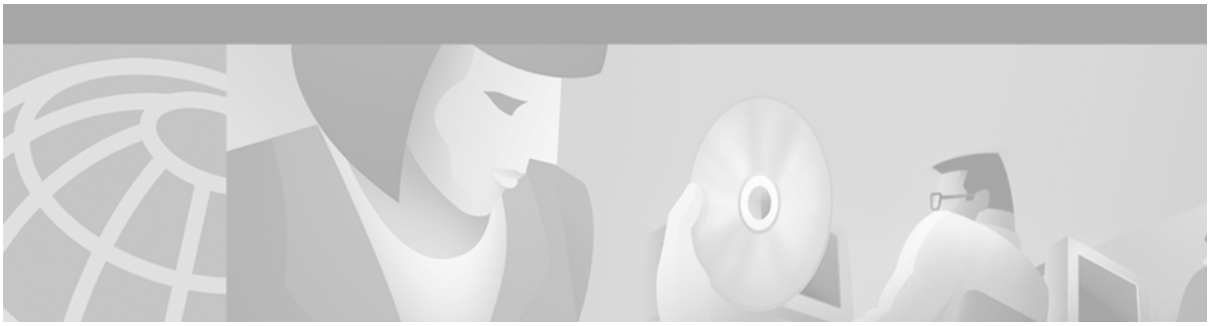
```
interface ethernet 1
 ip address 12.13.50.1
!
interface serial 1
 ip address 128.125.1.2
 encapsulation frame-relay
```

Router Configuration B

```
interface ethernet 2
 ip address 20.155.120.1
!
interface serial 2
 ip address 131.108.1.2
 encapsulation frame-relay
```

Router Configuration C

```
interface ethernet 0
 ip address 10.20.40.1
!
interface serial 0
 ip address 128.124.1.1
 ip address 131.108.1.1 secondary
 encapsulation frame-relay
```



Configuring OSPF

This chapter describes how to configure Open Shortest Path First (OSPF). For a complete description of the OSPF commands in this chapter, refer to the "OSPF Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* publication. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

OSPF is an Interior Gateway Protocol (IGP) developed by the OSPF working group of the Internet Engineering Task Force (IETF). Designed expressly for IP networks, OSPF supports IP subnetting and tagging of externally derived routing information. OSPF also allows packet authentication and uses IP multicast when sending and receiving packets.

We support RFC 1253, *Open Shortest Path First (OSPF) MIB*, August 1991. The OSPF MIB defines an IP routing protocol that provides management information related to OSPF and is supported by Cisco routers.

For protocol-independent features that include OSPF, see the chapter "Configuring IP Routing Protocol-Independent Features" in this book.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

The Cisco OSPF Implementation

The Cisco implementation conforms to the OSPF Version 2 specifications detailed in the Internet RFC 2328. The list that follows outlines key features supported in the Cisco OSPF implementation:

- Stub areas—Definition of stub areas is supported.
- Route redistribution—Routes learned via any IP routing protocol can be redistributed into any other IP routing protocol. At the intradomain level, OSPF can import routes learned via Interior Gateway Routing Protocol (IGRP), Routing Information Protocol (RIP), and Intermediate System-to-Intermediate System (IS-IS). OSPF routes can also be exported into IGRP, RIP, and IS-IS. At the interdomain level, OSPF can import routes learned via Exterior Gateway Protocol (EGP) and Border Gateway Protocol (BGP). OSPF routes can be exported into BGP and EGP.
- Authentication—Plain text and Message Digest 5 (MD5) authentication among neighboring routers within an area is supported.
- Routing interface parameters—Configurable parameters supported include interface output cost, retransmission interval, interface transmit delay, router priority, router "dead" and hello intervals, and authentication key.

- Virtual links—Virtual links are supported.
- Not so stubby area (NSSA)—RFC 1587.
- OSPF over demand circuit—RFC 1793.

OSPF Configuration Task List

OSPF typically requires coordination among many internal routers: Area Border Routers (ABRs), which are routers connected to multiple areas, and Autonomous System Boundary Routers (ASBRs). At a minimum, OSPF-based routers or access servers can be configured with all default parameter values, no authentication, and interfaces assigned to areas. If you intend to customize your environment, you must ensure coordinated configurations of all routers.

To configure OSPF, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional, but might be required for your application.

- Enabling OSPF (Required)
- Configuring OSPF Interface Parameters (Optional)
- Configuring OSPF over Different Physical Networks (Optional)
- Configuring OSPF Area Parameters (Optional)
- Configuring OSPF NSSA (Optional)
- Configuring Route Summarization Between OSPF Areas (Optional)
- Configuring Route Summarization When Redistributing Routes into OSPF (Optional)
- Creating Virtual Links (Optional)
- Generating a Default Route (Optional)
- Configuring Lookup of DNS Names (Optional)
- Forcing the Router ID Choice with a Loopback Interface (Optional)
- Controlling Default Metrics (Optional)
- Changing the OSPF Administrative Distances (Optional)
- Configuring OSPF on Simplex Ethernet Interfaces (Optional)
- Configuring Route Calculation Timers (Optional)
- Configuring OSPF over On-Demand Circuits (Optional)
- Logging Neighbors Going Up or Down (Optional)
- Changing the LSA Group Pacing (Optional)
- Blocking OSPF LSA Flooding (Optional)
- Reducing LSA Flooding (Optional)
- Ignoring MOSPF LSA Packets (Optional)
- Displaying OSPF Update Packet Pacing (Optional)
- Monitoring and Maintaining OSPF (Optional)

In addition, you can specify route redistribution; see the task “Redistribute Routing Information” in the chapter “Configuring IP Routing Protocol-Independent Features” for information on how to configure route redistribution.

Enabling OSPF

As with other routing protocols, enabling OSPF requires that you create an OSPF routing process, specify the range of IP addresses to be associated with the routing process, and assign area IDs to be associated with that range of IP addresses. To do so, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router ospf process-id`	Enables OSPF routing, which places you in router configuration mode.
Step 2	`Router(config-router)# network ip-address wildcard-mask area area-id`	Defines an interface on which OSPF runs and define the area ID for that interface.

Configuring OSPF Interface Parameters

Our OSPF implementation allows you to alter certain interface-specific OSPF parameters, as needed. You are not required to alter any of these parameters, but some interface parameters must be consistent across all routers in an attached network. Those parameters are controlled by the **ip ospf hello-interval**, **ip ospf dead-interval**, and **ip ospf authentication-key** interface configuration commands. Therefore, be sure that if you do configure any of these parameters, the configurations for all routers on your network have compatible values.

To specify interface parameters for your network, use the following commands in interface configuration mode, as needed:

Command	Purpose
`Router(config-if)# ip ospf cost cost`	Explicitly specifies the cost of sending a packet on an OSPF interface.
`Router(config-if)# ip ospf retransmit-interval seconds`	Specifies the number of seconds between link-state advertisement (LSA) retransmissions for adjacencies belonging to an OSPF interface.
`Router(config-if)# ip ospf transmit-delay seconds`	Sets the estimated number of seconds required to send a link-state update packet on an OSPF interface.
`Router(config-if)# ip ospf priority number-value`	Sets priority to help determine the OSPF designated router for a network.
`Router(config-if)# ip ospf hello-interval seconds`	Specifies the length of time between the hello packets that the Cisco IOS software sends on an OSPF interface.
`Router(config-if)# ip ospf dead-interval seconds`	Sets the number of seconds that a device must wait before it declares a neighbor OSPF router down because it has not received a hello packet.
`Router(config-if)# ip ospf authentication-key key`	Assigns a password to be used by neighboring OSPF routers on a network segment that is using the OSPF simple password authentication.

Command	Purpose
`Router(config-if)#` **`ip ospf message-digest-key`** *`key-id`* **`md5`** *`key`*	Enables OSPF MD5 authentication. The values for the *key-id* and *key* arguments must match values specified for other neighbors on a network segment.
`Router(config-if)#` **`ip ospf authentication`** [**`message-digest`** | **`null`**]	Specifies the authentication type for an interface.

Configuring OSPF over Different Physical Networks

OSPF classifies different media into the following three types of networks by default:

- Broadcast networks (Ethernet, Token Ring, and FDDI)
- Nonbroadcast multiaccess (NBMA) networks (Switched Multimegabit Data Service (SMDS), Frame Relay, and X.25)
- Point-to-point networks (High-Level Data Link Control [HDLC], PPP)

You can configure your network as either a broadcast or an NBMA network.

X.25 and Frame Relay provide an optional broadcast capability that can be configured in the map to allow OSPF to run as a broadcast network. Refer to the **x25 map** and **frame-relay map** command descriptions in the *Cisco IOS Wide-Area Networking Command Reference* publication for more detail.

Configuring Your OSPF Network Type

You have the choice of configuring your OSPF network type as either broadcast or NBMA, regardless of the default media type. Using this feature, you can configure broadcast networks as NBMA networks when, for example, you have routers in your network that do not support multicast addressing. You also can configure NBMA networks (such as X.25, Frame Relay, and SMDS) as broadcast networks. This feature saves you from needing to configure neighbors, as described in the section "Configuring OSPF for Nonbroadcast Networks" later in this chapter.

Configuring NBMA, multiaccess networks as either broadcast or nonbroadcast assumes that there are virtual circuits (VCs) from every router to every router or fully meshed network. This is not true for some cases, for example, because of cost constraints, or when you have only a partially meshed network. In these cases, you can configure the OSPF network type as a point-to-multipoint network. Routing between two routers not directly connected will go through the router that has VCs to both routers. Note that you need not configure neighbors when using this feature.

An OSPF point-to-multipoint interface is defined as a numbered point-to-point interface having one or more neighbors. It creates multiple host routes. An OSPF point-to-multipoint network has the following benefits compared to NBMA and point-to-point networks:

- Point-to-multipoint is easier to configure because it requires no configuration of neighbor commands, it consumes only one IP subnet, and it requires no designated router election.
- It costs less because it does not require a fully meshed topology.
- It is more reliable because it maintains connectivity in the event of VC failure.

To configure your OSPF network type, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip ospf network {broadcast | non-broadcast | {point-to-multipoint [non-broadcast] | point-to-point}}`	Configures the OSPF network type for a specified interface.

See the "OSPF Point-to-Multipoint Example" section at the end of this chapter for an example of an OSPF point-to-multipoint network.

Configuring Point-to-Multipoint, Broadcast Networks

On point-to-multipoint, broadcast networks, there is no need to specify neighbors. However, you can specify neighbors with the **neighbor** router configuration command, in which case you should specify a cost to that neighbor.

Before the **point-to-multipoint** keyword was added to the **ip ospf network** interface configuration command, some OSPF point-to-multipoint protocol traffic was treated as multicast traffic. Therefore, the **neighbor** router configuration command was not needed for point-to-multipoint interfaces because multicast took care of the traffic. Hello, update, and acknowledgment messages were sent using multicast. In particular, multicast hello messages discovered all neighbors dynamically.

On any point-to-multipoint interface (broadcast or not), the Cisco IOS software assumed that the cost to each neighbor was equal. The cost was configured with the **ip ospf cost** interface confutation command. In reality, the bandwidth to each neighbor is different, so the cost should differ. With this feature, you can configure a separate cost to each neighbor. This feature applies to point-to-multipoint interfaces only.

To treat an interface as point-to-multipoint broadcast and assign a cost to each neighbor, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# ip ospf network point-to-multipoint`	Configures an interface as point-to-multipoint for broadcast media.
Step 2	`Router(config-if)# exit`	Enters global configuration mode.
Step 3	`Router(config)# router ospf process-id`	Configures an OSPF routing process and enters router configuration mode.
Step 4	`Router(config-router)# neighbor ip-address cost number`	Specifies a neighbor and assigns a cost to the neighbor.

Repeat Step 4 for each neighbor if you want to specify a cost. Otherwise, neighbors will assume the cost of the interface, based on the **ip ospf cost** interface configuration command.

Configuring OSPF for Nonbroadcast Networks

Because many routers might be attached to an OSPF network, a *designated router* is selected for the network. Special configuration parameters are needed in the designated router selection if broadcast capability is not configured.

These parameters need only be configured in those devices that are themselves eligible to become the designated router or backup designated router (in other words, routers with a nonzero router priority value).

To configure routers that interconnect to nonbroadcast networks, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor ip-address [priority number] [poll-interval seconds]`	Configures a router interconnecting to nonbroadcast networks.

You can specify the following neighbor parameters, as required:

- Priority for a neighboring router
- Nonbroadcast poll interval

On point-to-multipoint, nonbroadcast networks, you now use the **neighbor** router configuration command to identify neighbors. Assigning a cost to a neighbor is optional.

Prior to Cisco IOS Release 12.0, some customers were using point-to-multipoint on nonbroadcast media (such as classic IP over ATM), so their routers could not dynamically discover their neighbors. This feature allows the **neighbor** router configuration command to be used on point-to-multipoint interfaces.

On any point-to-multipoint interface (broadcast or not), the Cisco IOS software assumed the cost to each neighbor was equal. The cost was configured with the **ip ospf cost** interface configuration command. In reality, the bandwidth to each neighbor is different, so the cost should differ. With this feature, you can configure a separate cost to each neighbor. This feature applies to point-to-multipoint interfaces only.

To treat the interface as point-to-multipoint when the media does not support broadcast, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# ip ospf network point-to-multipoint non-broadcast`	Configures an interface as point-to-multipoint for nonbroadcast media.
Step 2	`Router(config-if)# exit`	Enters global configuration mode.
Step 3	`Router(config)# router ospf process-id`	Configures an OSPF routing process and enters router configuration mode.
Step 4	`Router(config-router)# neighbor ip-address [cost number]`	Specifies a neighbor and assigns a cost to the neighbor.

Repeat Step 4 for each neighbor if you want to specify a cost. Otherwise, neighbors will assume the cost of the interface, based on the **ip ospf cost** interface configuration command.

Configuring OSPF Area Parameters

Our OSPF software allows you to configure several area parameters. These area parameters, shown in the following task table, include authentication, defining stub areas, and assigning specific costs to the default summary route. *Authentication* allows password-based protection against unauthorized access to an area.

Stub areas are areas into which information on external routes is not sent. Instead, there is a default external route generated by the ABR, into the stub area for destinations outside the autonomous system. To take advantage of the OSPF stub area support, *default routing* must be used in the stub area. To further reduce the number of LSAs sent into a stub area, you can configure the **no-summary** keyword of the **area stub** router configuration command on the ABR to prevent it from sending summary link advertisement (LSAs type 3) into the stub area.

To specify an area parameter for your network, use the following commands in router configuration mode as needed:

Command	Purpose
`Router(config-router)# area` *area-id* **authentication**	Enables authentication for an OSPF area.
`Router(config-router)# area` *area-id* **authentication message-digest**	Enables MD5 authentication for an OSPF area.
`Router(config-router)# area` *area-id* **stub** [**no-summary**]	Defines an area to be a stub area.
`Router(config-router)# area` *area-id* **default-cost** *cost*	Assigns a specific cost to the default summary route used for the stub area.

Configuring OSPF NSSA

The OSPF implementation of NSSA is similar to OSPF stub area. NSSA does not flood type 5 external LSAs from the core into the area, but it can import autonomous system external routes in a limited fashion within the area.

NSSA allows importing of type 7 autonomous system external routes within NSSA area by redistribution. These type 7 LSAs are translated into type 5 LSAs by NSSA ABRs, which are flooded throughout the whole routing domain. Summarization and filtering are supported during the translation.

Use NSSA to simplify administration if you are an Internet service provider (ISP) or a network administrator that must connect a central site using OSPF to a remote site that is using a different routing protocol.

Prior to NSSA, the connection between the corporate site border router and the remote router could not be run as OSPF stub area because routes for the remote site could not be redistributed into stub area, and two routing protocols needed to be maintained. A simple protocol like RIP was usually run and handled the redistribution. With NSSA, you can extend OSPF to cover the remote connection by defining the area between the corporate router and the remote router as an NSSA.

To specify area parameters as needed to configure OSPF NSSA, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# area` *area-id* **nssa** [**no-redistribution**] [**default-information-originate**]	Defines an area to be NSSA.

To control summarization and filtering of type 7 LSAs into type 5 LSAs, use the following command in router configuration mode on the ABR:

Command	Purpose
`Router(config-router)# summary address {ip-address mask | prefix mask} [not advertise] [tag tag]`	Controls the summarization and filtering during the translation.

Implementation Considerations

Evaluate the following considerations before you implement this feature:

- You can set a type 7 default route that can be used to reach external destinations. When configured, the router generates a type 7 default into the NSSA or the NSSA ABR.
- Every router within the same area must agree that the area is NSSA; otherwise, the routers will not be able to communicate.

Configuring Route Summarization Between OSPF Areas

Route summarization is the consolidation of advertised addresses. This feature causes a single summary route to be advertised to other areas by an ABR. In OSPF, an ABR will advertise networks in one area into another area. If the network numbers in an area are assigned in a way such that they are contiguous, you can configure the ABR to advertise a summary route that covers all the individual networks within the area that fall into the specified range.

To specify an address range, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# area area-id range ip-address mask [advertise | not-advertise][cost cost]`	Specifies an address range for which a single route will be advertised.

Configuring Route Summarization When Redistributing Routes into OSPF

When routes from other protocols are redistributed into OSPF (as described in the chapter "Configuring IP Routing Protocol-Independent Features"), each route is advertised individually in an external LSA. However, you can configure the Cisco IOS software to advertise a single route for all the redistributed routes that are covered by a specified network address and mask. Doing so helps decrease the size of the OSPF link-state database.

To have the software advertise one summary route for all redistributed routes covered by a network address and mask, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# summary-address {{ip-address mask} | {prefix mask}} [not-advertise][tag tag]`	Specifies an address and mask that covers redistributed routes, so only one summary route is advertised. Use the optional **not-advertise** keyword to filter out a set of routes.

Creating Virtual Links

In OSPF, all areas must be connected to a backbone area. If there is a break in backbone continuity, or the backbone is purposefully partitioned, you can establish a *virtual link*. The two endpoints of a virtual link are ABRs. The virtual link must be configured in both routers. The configuration information in each router consists of the other virtual endpoint (the other ABR) and the nonbackbone area that the two routers have in common (called the *transit area*). Note that virtual links cannot be configured through stub areas.

To establish a virtual link, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# area transit-area-id virtual-link transit-router-id [authentication {message-digest | null}] [hello-interval seconds] [retransmit-interval seconds] [transmit-delay seconds] [dead-interval seconds] [{authentication-key key} | message-digest-key key-id | md5 key}]`	Establishes a virtual link.

To display information about virtual links, use the **show ip ospf virtual-links** EXEC command. To display the router ID of an OSPF router, use the **show ip ospf** EXEC command.

Generating a Default Route

You can force an ASBR to generate a default route into an OSPF routing domain. Whenever you specifically configure redistribution of routes into an OSPF routing domain, the router automatically becomes an ASBR. However, an ASBR does not, by default, generate a *default route* into the OSPF routing domain.

To force the ASBR to generate a default route, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# default-information originate [always] [metric metric-value] [metric-type type-value] [route-map map-name]`	Forces the autonomous system boundary router to generate a default route into the OSPF routing domain.

For a discussion of redistribution of routes, see the "Configuring IP Routing Protocol-Independent Features" chapter.

Configuring Lookup of DNS Names

You can configure OSPF to look up Domain Naming System (DNS) names for use in all OSPF **show** EXEC command displays. This feature makes it easier to identify a router, because the router is displayed by name rather than by its router ID or neighbor ID.

To configure DNS name lookup, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip ospf name-lookup`	Configures DNS name lookup.

Forcing the Router ID Choice with a Loopback Interface

OSPF uses the largest IP address configured on the interfaces as its router ID. If the interface associated with this IP address is ever brought down, or if the address is removed, the OSPF process must recalculate a new router ID and resend all its routing information out its interfaces.

If a loopback interface is configured with an IP address, the Cisco IOS software will use this IP address as its router ID, even if other interfaces have larger IP addresses. Because loopback interfaces never go down, greater stability in the routing table is achieved.

OSPF automatically prefers a loopback interface over any other kind, and it chooses the highest IP address among all loopback interfaces. If no loopback interfaces are present, the highest IP address in the router is chosen. You cannot tell OSPF to use any particular interface.

To configure an IP address on a loopback interface, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface loopback 0`	Creates a loopback interface, which places the router in interface configuration mode.
Step 2	`Router(config-if)# ip address` *ip-address mask*	Assigns an IP address to this interface.

Controlling Default Metrics

In Cisco IOS Release 10.3 and later releases, by default OSPF calculates the OSPF metric for an interface according to the bandwidth of the interface. For example, a 64-kbps link gets a metric of 1562, while a T1 link gets a metric of 64.

The OSPF metric is calculated as the *ref-bw* value divided by the *bandwidth* value, with the *ref-bw* value equal to 10^8 by default, and the *bandwidth* value determined by the **bandwidth** interface configuration command. The calculation gives FDDI a metric of 1. If you have multiple links with high bandwidth, you might want to specify a larger number to differentiate the cost on those links. To do so, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# auto-cost reference-bandwidth` *ref-bw*	Differentiates high bandwidth links.

Changing the OSPF Administrative Distances

An administrative distance is a rating of the trustworthiness of a routing information source, such as an individual router or a group of routers. Numerically, an administrative distance is an integer from 0 to 255. In general, the higher the value, the lower the trust rating. An administrative distance of 255 means the routing information source cannot be trusted at all and should be ignored.

OSPF uses three different administrative distances: intra-area, interarea, and external. Routes within an area are intra-area; routes to another area are interarea; and routes from another routing domain learned via redistribution are external. The default distance for each type of route is 110.

To change any of the OSPF distance values, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# distance ospf {[intra-area dist1] [inter-area dist2] [external dist3]}`	Changes the OSPF distance values.

For an example of changing administrative distance, see the section "Changing OSPF Administrative Distance Example" at the end of this chapter.

Configuring OSPF on Simplex Ethernet Interfaces

Because simplex interfaces between two devices on an Ethernet represent only one network segment, for OSPF you must configure the sending interface to be a passive interface. This configuration prevents OSPF from sending hello packets for the sending interface. Both devices are able to see each other via the hello packet generated for the receiving interface.

To configure OSPF on simplex Ethernet interfaces, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# passive-interface interface-type interface-number`	Suppresses the sending of hello packets through the specified interface.

Configuring Route Calculation Timers

You can configure the delay time between when OSPF receives a topology change and when it starts a shortest path first (SPF) calculation. You can also configure the hold time between two consecutive SPF calculations. To do so, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# timers spf spf-delay spf-holdtime`	Configures route calculation timers.

Configuring OSPF over On-Demand Circuits

The OSPF on-demand circuit is an enhancement to the OSPF protocol that allows efficient operation over on-demand circuits like ISDN, X.25 switched virtual circuits (SVCs), and dialup lines. This feature supports RFC 1793, *Extending OSPF to Support Demand Circuits*.

Prior to this feature, OSPF periodic hello and LSA updates would be exchanged between routers that connected the on-demand link, even when no changes occurred in the hello or LSA information.

With this feature, periodic hellos are suppressed and the periodic refreshes of LSAs are not flooded over the demand circuit. These packets bring up the link only when they are exchanged for the first time, or when a change occurs in the information they contain. This operation allows the underlying data link layer to be closed when the network topology is stable.

This feature is useful when you want to connect telecommuters or branch offices to an OSPF backbone at a central site. In this case, OSPF for on-demand circuits allows the benefits of OSPF over the entire domain, without excess connection costs. Periodic refreshes of hello updates, LSA updates, and other protocol overhead are prevented from enabling the on-demand circuit when there is no "real" data to send.

Overhead protocols such as hellos and LSAs are transferred over the on-demand circuit only upon initial setup and when they reflect a change in the topology. This means that critical changes to the topology that require new SPF calculations are sent in order to maintain network topology integrity. Periodic refreshes that do not include changes, however, are not sent across the link.

To configure OSPF for on-demand circuits, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router ospf process-id`	Enables OSPF operation.
Step 2	`Router(config)# interface interface-type interface-number`	Enters interface configuration mode.
Step 3	`Router(config-if)# ip ospf demand-circuit`	Configures OSPF on an on-demand circuit.

If the router is part of a point-to-point topology, then only one end of the demand circuit must be configured with this command. However, all routers must have this feature loaded.

If the router is part of a point-to-multipoint topology, only the multipoint end must be configured with this command.

For an example of OSPF over an on-demand circuit, see the section "OSPF over On-Demand Routing Example" at the end of this chapter.

Implementation Considerations

Evaluate the following considerations before implementing this feature:

- Because LSAs that include topology changes are flooded over an on-demand circuit, we recommend that you put demand circuits within OSPF stub areas or within NSSAs to isolate the demand circuits from as many topology changes as possible.
- To take advantage of the on-demand circuit functionality within a stub area or NSSA, every router in the area must have this feature loaded. If this feature is deployed within a regular area, all other regular areas must also support this feature before the demand circuit functionality can take effect because type 5 external LSAs are flooded throughout all areas.
- Hub-and-spoke network topologies that have a point-to-multipoint (p2mp) OSPF interface type on a hub might not revert back to non-demand circuit mode when needed. You must simultaneously reconfigure OSPF on all interfaces on the p2mp segment when reverting them from demand circuit mode to non-demand circuit mode.
- Do not implement this feature on a broadcast-based network topology because the overhead protocols (such as hello and LSA packets) cannot be successfully suppressed, which means the link will remain up.
- Configuring the router for an OSPF on-demand circuit with an asynchronous interface is not a supported configuration. The supported configuration is to use dialer interfaces on both ends of the circuit. For more information, refer to the following TAC URL:

  http://www.cisco.com/warp/public/104/dcprob.html#reason5

Logging Neighbors Going Up or Down

By default, the system sends a syslog message when an OSPF neighbor goes up or down. If you turned off this feature and want to restore it, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# log-adjacency-changes [detail]`	Sends syslog message when an OSPF neighbor goes up or down.

Configure this command if you want to know about OSPF neighbors going up or down without turning on the **debug ip ospf adjacency** EXEC command. The **log-adjacency-changes** router configuration command provides a higher level view of the peer relationship with less output. Configure **log-adjacency-changes detail** if you want to see messages for each state change.

Changing the LSA Group Pacing

The OSPF LSA group pacing feature allows the router to group OSPF LSAs and pace the refreshing, checksumming, and aging functions. The group pacing results in more efficient use of the router.

The router groups OSPF LSAs and paces the refreshing, checksumming, and aging functions so that sudden increases in CPU usage and network resources are avoided. This feature is most beneficial to large OSPF networks.

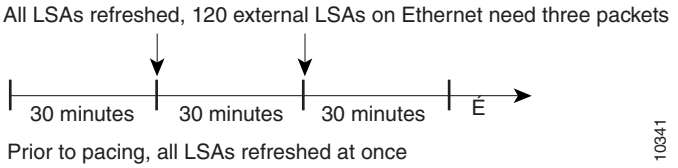
OSPF LSA group pacing is enabled by default. For typical customers, the default group pacing interval for refreshing, checksumming, and aging is appropriate and you need not configure this feature.

Original LSA Behavior

Each OSPF LSA has an age, which indicates whether the LSA is still valid. Once the LSA reaches the maximum age (1 hour), it is discarded. During the aging process, the originating router sends a refresh packet every 30 minutes to refresh the LSA. Refresh packets are sent to keep the LSA from expiring, whether there has been a change in the network topology or not. Checksumming is performed on all LSAs every 10 minutes. The router keeps track of LSAs it generates and LSAs it receives from other routers. The router refreshes LSAs it generated; it ages the LSAs it received from other routers.

Prior to the LSA group pacing feature, the Cisco IOS software would perform refreshing on a single timer, and checksumming and aging on another timer. In the case of refreshing, for example, the software would scan the whole database every 30 minutes, refreshing every LSA the router generated, no matter how old it was. Figure 39 illustrates all the LSAs being refreshed at once. This process wasted CPU resources because only a small portion of the database needed to be refreshed. A large OSPF database (several thousand LSAs) could have thousands of LSAs with different ages. Refreshing on a single timer resulted in the age of all LSAs becoming synchronized, which resulted in much CPU processing at once. Furthermore, a large number of LSAs could cause a sudden increase of network traffic, consuming a large amount of network resources in a short period of time.

Figure 39 OSPF LSAs on a Single Timer Without Group Pacing



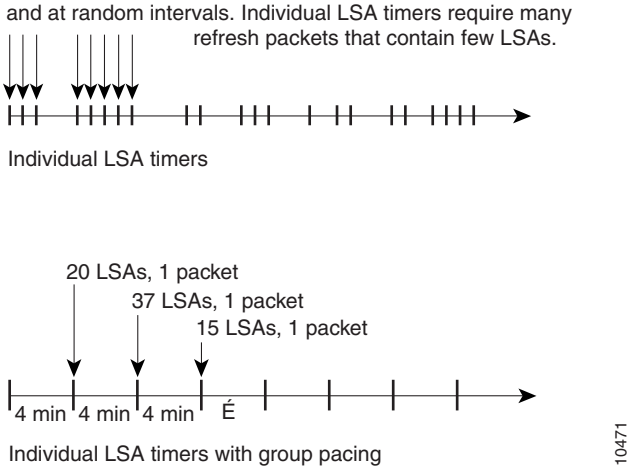
LSA Group Pacing With Multiple Timers

This problem is solved by configuring each LSA to have its own timer. To again use the example of refreshing, each LSA gets refreshed when it is 30 minutes old, independent of other LSAs. So the CPU is used only when necessary. However, LSAs being refreshed at frequent, random intervals would require many packets for the few refreshed LSAs the router must send out, which would be inefficient use of bandwidth.

Therefore, the router delays the LSA refresh function for an interval of time instead of performing it when the individual timers are reached. The accumulated LSAs constitute a group, which is then refreshed and sent out in one packet or more. Thus, the refresh packets are paced, as are the checksumming and aging. The pacing interval is configurable; it defaults to 4 minutes, which is randomized to further avoid synchronization.

Figure 40 illustrates the case of refresh packets. The first timeline illustrates individual LSA timers; the second timeline illustrates individual LSA timers with group pacing.

Figure 40 OSPF LSAs on Individual Timers with Group Pacing



The group pacing interval is inversely proportional to the number of LSAs the router is refreshing, checksumming, and aging. For example, if you have approximately 10,000 LSAs, decreasing the pacing interval would benefit you. If you have a very small database (40 to 100 LSAs), increasing the pacing interval to 10 to 20 minutes might benefit you slightly.

The default value of pacing between LSA groups is 240 seconds (4 minutes). The range is from 10 seconds to 1800 seconds (30 minutes). To change the LSA group pacing interval, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# timers lsa-group-pacing` *seconds*	Changes the group pacing of LSAs.

For an example, see the section "LSA Group Pacing Example" at the end of this chapter.

Blocking OSPF LSA Flooding

By default, OSPF floods new LSAs over all interfaces in the same area, except the interface on which the LSA arrives. Some redundancy is desirable, because it ensures robust flooding. However, too much redundancy can waste bandwidth and might destabilize the network due to excessive link and CPU usage in certain topologies. An example would be a fully meshed topology.

You can block OSPF flooding of LSAs two ways, depending on the type of networks:

- On broadcast, nonbroadcast, and point-to-point networks, you can block flooding over specified OSPF interfaces.
- On point-to-multipoint networks, you can block flooding to a specified neighbor.

On broadcast, nonbroadcast, and point-to-point networks, to prevent flooding of OSPF LSAs, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ospf database-filter all out`	Blocks the flooding of OSPF LSA packets to the interface.

On point-to-multipoint networks, to prevent flooding of OSPF LSAs, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor ip-address database-filter all out`	Blocks the flooding of OSPF LSA packets to the specified neighbor.

For an example of blocking LSA flooding, see the section "Block LSA Flooding Example" at the end of this chapter.

Reducing LSA Flooding

The explosive growth of the Internet has placed the focus on the scalability of IGPs such as OSPF. By design, OSPF requires LSAs to be refreshed as they expire after 3600 seconds. Some implementations have tried to improve the flooding by reducing the frequency to refresh from 30 minutes to about 50 minutes. This solution reduces the amount of refresh traffic but requires at least one refresh before the LSA expires. The OSPF flooding reduction solution works by reducing unnecessary refreshing and flooding of already known and unchanged information. To achieve this reduction, the LSAs are now flooded with the higher bit set. The LSAs are now set as "do not age."

To reduce unnecessary refreshing and flooding of LSAs on your network, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip ospf flood-reduction`	Suppresses the unnecessary flooding of LSAs in stable topologies.

Ignoring MOSPF LSA Packets

Cisco routers do not support LSA type 6 Multicast OSPF (MOSPF), and they generate syslog messages if they receive such packets. If the router is receiving many MOSPF packets, you might want to configure the router to ignore the packets and thus prevent a large number of syslog messages. To do so, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# ignore lsa mospf`	Prevents the router from generating syslog messages when it receives MOSPF LSA packets.

For an example of suppressing MOSPF LSA packets, see the section "Ignore MOSPF LSA Packets Example" at the end of this chapter.

Displaying OSPF Update Packet Pacing

The former OSPF implementation for sending update packets needed to be more efficient. Some update packets were getting lost in cases where the link was slow, a neighbor could not receive the updates quickly enough, or the router was out of buffer space. For example, packets might be dropped if either of the following topologies existed:

- A fast router was connected to a slower router over a point-to-point link.
- During flooding, several neighbors sent updates to a single router at the same time.

OSPF update packets are now automatically paced so they are not sent less than 33 milliseconds apart. Pacing is also added between resends to increase efficiency and minimize lost retransmissions. Also, you can display the LSAs waiting to be sent out an interface. The benefit of the pacing is that OSPF update and retransmission packets are sent more efficiently.

There are no configuration tasks for this feature; it occurs automatically.

To observe OSPF packet pacing by displaying a list of LSAs waiting to be flooded over a specified interface, use the following command in EXEC mode:

Command	Purpose
`Router# show ip ospf flood-list` *interface-type interface-number*	Displays a list of LSAs waiting to be flooded over an interface.

Monitoring and Maintaining OSPF

You can display specific statistics such as the contents of IP routing tables, caches, and databases. Information provided can be used to determine resource utilization and solve network problems. You can also display information about node reachability and discover the routing path that your device packets are taking through the network.

To display various routing statistics, use the following commands in EXEC mode, as needed:

Command	Purpose
Router# **show ip ospf** [*process-id*]	Displays general information about OSPF routing processes.
Router# **show ip ospf border-routers**	Displays the internal OSPF routing table entries to the ABR and ASBR.
Router# **show ip ospf** [*process-id* [*area-id*]] **database** Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**database-summary**] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**router**] [**self-originate**] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**router**] [**adv-router** [*ip-address*]] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**router**] [*link-state-id*] Router# **show ip ospf** [*process-id [area-id*]] **database** [**network**] [*link-state-id*] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**summary**] [*link-state-id*] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**asbr-summary**] [*link-state-id*] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**external**] [*link-state-id*] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**nssa-external**] [*link-state-id*] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**opaque-link**] [*link-state-id*] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**opaque-area**] [*link-state-id*] Router# **show ip ospf** [*process-id* [*area-id*]] **database** [**opaque-as**] [*link-state-id*]	Displays lists of information related to the OSPF database.
Router# **show ip ospf flood-list interface** *interface-type*	Displays a list of LSAs waiting to be flooded over an interface (to observe OSPF packet pacing).
Router# **show ip ospf interface** [*interface-type interface-number*]	Displays OSPF-related interface information.

Command	Purpose
Router# **show ip ospf neighbor** [*interface-name*] [*neighbor-id*] **detail**	Displays OSPF neighbor information on a per-interface basis.
Router# **show ip ospf request-list** [*neighbor*] [*interface*] [*interface-neighbor*]	Displays a list of all LSAs requested by a router.
Router# **show ip ospf retransmission-list** [*neighbor*] [*interface*] [*interface-neighbor*]	Displays a list of all LSAs waiting to be resent.
Router# **show ip ospf** [*process-id*]**summary-address**	Displays a list of all summary address redistribution information configured under an OSPF process.
Router# **show ip ospf virtual-links**	Displays OSPF-related virtual links information.

To restart an OSPF process, use the following command in EXEC mode:

Command	Purpose
Router# **clear ip ospf** [*pid*] {**process** | **redistribution** | **counters** [**neighbor** [*neighbor-interface*] [*neighbor-id*]]}	Clears redistribution based on the OSPF routing process ID. If the *pid* option is not specified, all OSPF processes are cleared.

OSPF Configuration Examples

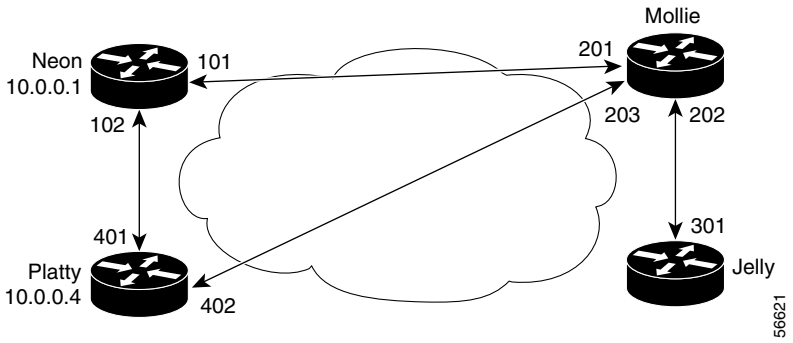
The following sections provide OSPF configuration examples:

- OSPF Point-to-Multipoint Example
- OSPF Point-to-Multipoint, Broadcast Example
- OSPF Point-to-Multipoint, Nonbroadcast Example
- Variable-Length Subnet Masks Example
- OSPF Routing and Route Redistribution Examples
- Route Map Examples
- Changing OSPF Administrative Distance Example
- OSPF over On-Demand Routing Example
- LSA Group Pacing Example
- Block LSA Flooding Example
- Ignore MOSPF LSA Packets Example

OSPF Point-to-Multipoint Example

In Figure 41, the router named Mollie uses data-link connection identifier (DLCI) 201 to communicate with the router named Neon, DLCI 202 to the router named Jelly, and DLCI 203 to the router named Platty. Neon uses DLCI 101 to communicate with Mollie and DLCI 102 to communicate with Platty. Platty communicates with Neon (DLCI 401) and Mollie (DLCI 402). Jelly communicates with Mollie (DLCI 301). Configuration examples follow the figure.

Figure 41 OSPF Point-to-Multipoint Example



Mollie Configuration

```
hostname mollie
!
interface serial 1
 ip address 10.0.0.2 255.0.0.0
 ip ospf network point-to-multipoint
 encapsulation frame-relay
 frame-relay map ip 10.0.0.1 201 broadcast
 frame-relay map ip 10.0.0.3 202 broadcast
 frame-relay map ip 10.0.0.4 203 broadcast
!
router ospf 1
 network 10.0.0.0 0.0.0.255 area 0
```

Neon Configuration

```
hostname neon
!
interface serial 0
 ip address 10.0.0.1 255.0.0.0
 ip ospf network point-to-multipoint
 encapsulation frame-relay
 frame-relay map ip 10.0.0.2 101 broadcast
 frame-relay map ip 10.0.0.4 102 broadcast
!
router ospf 1
 network 10.0.0.0 0.0.0.255 area 0
```

Platty Configuration

```
hostname platty
!
interface serial 3
 ip address 10.0.0.4 255.0.0.0
 ip ospf network point-to-multipoint
 encapsulation frame-relay
 clock rate 1000000
 frame-relay map ip 10.0.0.1 401 broadcast
 frame-relay map ip 10.0.0.2 402 broadcast
!
router ospf 1
 network 10.0.0.0 0.0.0.255 area 0
```

Jelly Configuration

```
hostname jelly
!
interface serial 2
 ip address 10.0.0.3 255.0.0.0
 ip ospf network point-to-multipoint
 encapsulation frame-relay
 clock rate 2000000
 frame-relay map ip 10.0.0.2 301 broadcast
!
router ospf 1
 network 10.0.0.0 0.0.0.255 area 0
```

OSPF Point-to-Multipoint, Broadcast Example

The following example illustrates a point-to-multipoint network with broadcast:

```
interface Serial0
 ip address 10.0.1.1 255.255.255.0
 encapsulation frame-relay
 ip ospf cost 100
 ip ospf network point-to-multipoint
 frame-relay map ip 10.0.1.3 202 broadcast
 frame-relay map ip 10.0.1.4 203 broadcast
 frame-relay map ip 10.0.1.5 204 broadcast
 frame-relay local-dlci 200
!
router ospf 1
 network 10.0.1.0 0.0.0.255 area 0
 neighbor 10.0.1.5 cost 5
 neighbor 10.0.1.4 cost 10
```

The following example shows the configuration of the neighbor at 10.0.1.3:

```
interface serial 0
 ip address 10.0.1.3 255.255.255.0
 ip ospf network point-to-multipoint
 encapsulation frame-relay
 frame-relay local-dlci 301
 frame-relay map ip 10.0.1.1 300 broadcast
 no shut
!
 router ospf 1
 network 10.0.1.0 0.0.0.255 area 0
```

The output shown for neighbors in the first configuration is as follows:

```
Router# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
4.1.1.1           1   FULL/  -        00:01:50    10.0.1.5        Serial0
3.1.1.1           1   FULL/  -        00:01:47    10.0.1.4        Serial0
2.1.1.1           1   FULL/  -        00:01:45    10.0.1.3        Serial0
```

The route information in the first configuration is as follows:

```
Router# show ip route

Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, * - candidate default
```

```
       U - per-user static route, o - ODR
Gateway of last resort is not set
C    1.0.0.0/8 is directly connected, Loopback0
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O       10.0.1.3/32 [110/100] via 10.0.1.3, 00:39:08, Serial0
C       10.0.1.0/24 is directly connected, Serial0
O       10.0.1.5/32 [110/5] via 10.0.1.5, 00:39:08, Serial0
O       10.0.1.4/32 [110/10] via 10.0.1.4, 00:39:08, Serial0
```

OSPF Point-to-Multipoint, Nonbroadcast Example

The following example illustrates a point-to-multipoint network with nonbroadcast:

```
interface Serial0
ip address 10.0.1.1 255.255.255.0
ip ospf network point-to-multipoint non-broadcast
encapsulation frame-relay
no keepalive
frame-relay local-dlci 200
frame-relay map ip 10.0.1.3 202
frame-relay map ip 10.0.1.4 203
frame-relay map ip 10.0.1.5 204
no shut
!
router ospf 1
network 10.0.1.0 0.0.0.255 area 0
neighbor 10.0.1.3 cost 5
neighbor 10.0.1.4 cost 10
neighbor 10.0.1.5 cost 15
```

The following example is the configuration for the router on the other side:

```
interface Serial9/2
 ip address 10.0.1.3 255.255.255.0
 encapsulation frame-relay
 ip ospf network point-to-multipoint non-broadcast
 no ip mroute-cache
 no keepalive
 no fair-queue
 frame-relay local-dlci 301
 frame-relay map ip 10.0.1.1 300
 no shut
 !
 router ospf 1
 network 10.0.1.0 0.0.0.255 area 0
```

The output shown for neighbors in the first configuration is as follows:

```
Router# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
4.1.1.1           1   FULL/  -        00:01:52    10.0.1.5        Serial0
3.1.1.1           1   FULL/  -        00:01:52    10.0.1.4        Serial0
2.1.1.1           1   FULL/  -        00:01:52    10.0.1.3        Serial0
```

Variable-Length Subnet Masks Example

OSPF, static routes, and IS-IS support variable-length subnet masks (VLSMs). With VLSMs, you can use different masks for the same network number on different interfaces, which allows you to conserve IP addresses and more efficiently use available address space.

In the following example, a 30-bit subnet mask is used, leaving two bits of address space reserved for serial line host addresses. There is sufficient host address space for two host endpoints on a point-to-point serial link.

```
interface ethernet 0
 ip address 131.107.1.1 255.255.255.0
! 8 bits of host address space reserved for ethernets

interface serial 0
 ip address 131.107.254.1 255.255.255.252
! 2 bits of address space reserved for serial lines

! Router is configured for OSPF and assigned AS 107
router ospf 107
! Specifies network directly connected to the router
 network 131.107.0.0 0.0.255.255 area 0.0.0.0
```

OSPF Routing and Route Redistribution Examples

OSPF typically requires coordination among many internal routers, ABRs, and ASBRs. At a minimum, OSPF-based routers can be configured with all default parameter values, with no authentication, and with interfaces assigned to areas.

Three types of examples follow:

- The first is a simple configuration illustrating basic OSPF commands.
- The second example illustrates a configuration for an internal router, ABR, and ASBRs within a single, arbitrarily assigned, OSPF autonomous system.
- The third example illustrates a more complex configuration and the application of various tools available for controlling OSPF-based routing environments.

Basic OSPF Configuration Examples

The following example illustrates a simple OSPF configuration that enables OSPF routing process 9000, attaches Ethernet interface 0 to area 0.0.0.0, and redistributes RIP into OSPF, and OSPF into RIP:

```
interface ethernet 0
 ip address 10.93.1.1 255.255.255.0
 ip ospf cost 1
!
interface ethernet 1
 ip address 10.94.1.1 255.255.255.0
!
router ospf 9000
 network 10.93.0.0 0.0.255.255 area 0.0.0.0
 redistribute rip metric 1 subnets
!
router rip
 network 10.94.0.0
 redistribute ospf 9000
 default-metric 1
```

Basic OSPF Configuration Example for Internal Router, ABR, and ASBRs

The following example illustrates the assignment of four area IDs to four IP address ranges. In the example, OSPF routing process 109 is initialized, and four OSPF areas are defined: 10.9.50.0, 2, 3, and 0. Areas 10.9.50.0, 2, and 3 mask specific address ranges, and area 0 enables OSPF for *all other* networks.

```
router ospf 109
 network 131.108.20.0 0.0.0.255 area 10.9.50.0
 network 131.108.0.0 0.0.255.255 area 2
 network 131.109.10.0 0.0.0.255 area 3
 network 0.0.0.0 255.255.255.255 area 0
!
! Interface Ethernet0 is in area 10.9.50.0:
interface ethernet 0
 ip address 131.108.20.5 255.255.255.0
!
! Interface Ethernet1 is in area 2:
interface ethernet 1
 ip address 131.108.1.5 255.255.255.0
!
! Interface Ethernet2 is in area 2:
interface ethernet 2
 ip address 131.108.2.5 255.255.255.0
!
! Interface Ethernet3 is in area 3:
interface ethernet 3
 ip address 131.109.10.5 255.255.255.0
!
! Interface Ethernet4 is in area 0:
interface ethernet 4
 ip address 131.109.1.1 255.255.255.0
!
! Interface Ethernet5 is in area 0:
interface ethernet 5
 ip address 10.1.0.1 255.255.0.0
```

Each **network area** router configuration command is evaluated sequentially, so the order of these commands in the configuration is important. The Cisco IOS software sequentially evaluates the address/wildcard-mask pair for each interface. See the "OSPF Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* publication for more information.

Consider the first **network area** command. Area ID 10.9.50.0 is configured for the interface on which subnet 131.108.20.0 is located. Assume that a match is determined for Ethernet interface 0. Ethernet interface 0 is attached to area 10.9.50.0 only.

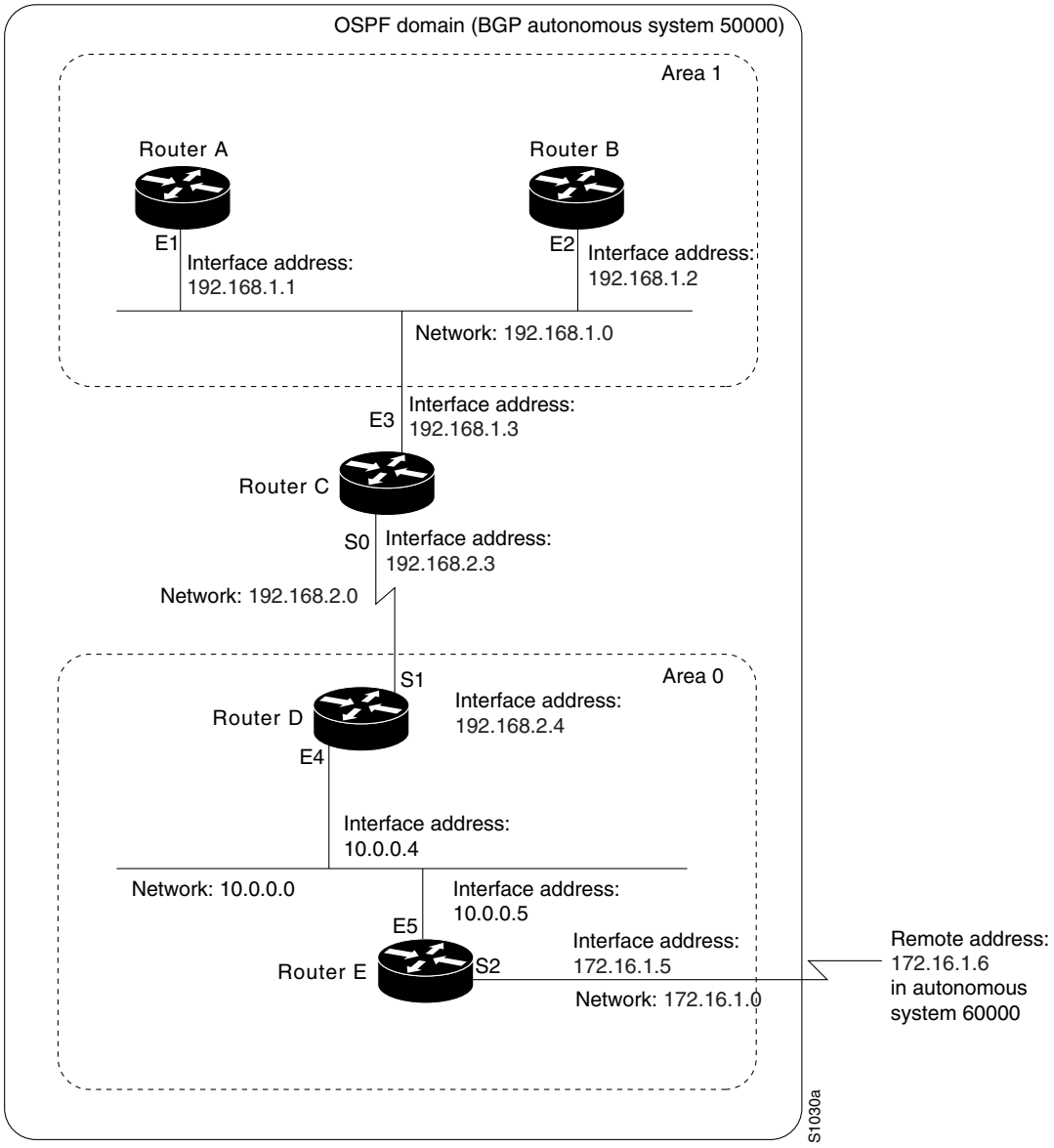
The second **network area** command is evaluated next. For area 2, the same process is then applied to all interfaces (except Ethernet interface 0). Assume that a match is determined for interface Ethernet 1. OSPF is then enabled for that interface and Ethernet interface 1 is attached to area 2.

This process of attaching interfaces to OSPF areas continues for all **network area** commands. Note that the last **network area** command in this example is a special case. With this command, all available interfaces (not explicitly attached to another area) are attached to area 0.

Complex Internal Router, ABR, and ASBRs Example

The following example outlines a configuration for several routers within a single OSPF autonomous system. Figure 42 provides a general network map that illustrates this example configuration.

Figure 42 Sample OSPF Autonomous System Network Map



In this configuration, five routers are configured with OSPF:

- Router A and Router B are both internal routers within area 1.
- Router C is an OSPF ABR. Note that for Router C, Area 1 is assigned to E3 and area 0 is assigned to S0.
- Router D is an internal router in area 0 (backbone area). In this case, both **network** router configuration commands specify the same area (area 0, or the backbone area).
- Router E is an OSPF ASBR. Note that BGP routes are redistributed into OSPF and that these routes are advertised by OSPF.

Note It is not necessary to include definitions of all areas in an OSPF autonomous system in the configuration of all routers in the autonomous system. You must only define the *directly* connected areas. In the example that follows, routes in area 0 are learned by the routers in area 1 (Router A and Router B) when the ABR (Router C) injects summary LSAs into area 1.

The OSPF domain in BGP autonomous system 109 is connected to the outside world via the BGP link to the external peer at IP address 11.0.0.6. Example configurations follow.

Following is the sample configuration for the general network map shown in Figure 42.

Router A Configuration—Internal Router

```
interface ethernet 1
 ip address 131.108.1.1 255.255.255.0

router ospf 1
 network 131.108.0.0 0.0.255.255 area 1
```

Router B Configuration—Internal Router

```
interface ethernet 2
 ip address 131.108.1.2 255.255.255.0

router ospf 202
 network 131.108.0.0 0.0.255.255 area 1
```

Router C Configuration—ABR

```
interface ethernet 3
 ip address 131.108.1.3 255.255.255.0

interface serial 0
 ip address 131.108.2.3 255.255.255.0

router ospf 999
 network 131.108.1.0 0.0.0.255 area 1
 network 131.108.2.0 0.0.0.255 area 0
```

Router D Configuration—Internal Router

```
interface ethernet 4
 ip address 10.0.0.4 255.0.0.0

interface serial 1
 ip address 131.108.2.4 255.255.255.0

router ospf 50
 network 131.108.2.0 0.0.0.255 area 0
 network 10.0.0.0 0.255.255.255 area 0
```

Router E Configuration—ASBR

```
interface ethernet 5
 ip address 10.0.0.5 255.0.0.0

interface serial 2
 ip address 11.0.0.5 255.0.0.0

router ospf 65001
 network 10.0.0.0 0.255.255.255 area 0
 redistribute bgp 109 metric 1 metric-type 1
```

```
router bgp 109
 network 131.108.0.0
 network 10.0.0.0
 neighbor 11.0.0.6 remote-as 110
```

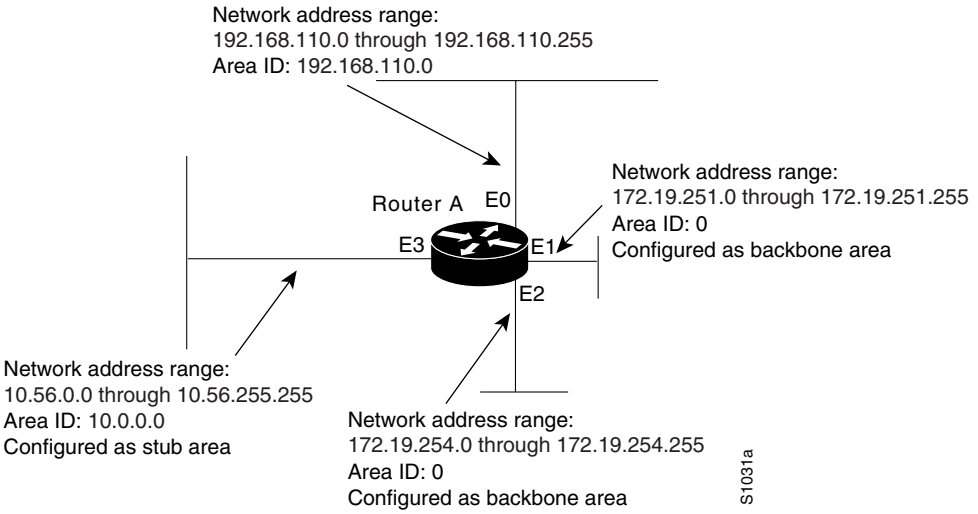
Complex OSPF Configuration for ABR Examples

The following example configuration accomplishes several tasks in setting up an ABR. These tasks can be split into two general categories:

- Basic OSPF configuration
- Route redistribution

The specific tasks outlined in this configuration are detailed briefly in the following descriptions. Figure 43 illustrates the network address ranges and area assignments for the interfaces.

Figure 43 Interface and Area Specifications for OSPF Example Configuration



The basic configuration tasks in this example are as follows:

- Configure address ranges for Ethernet interface 0 through Ethernet interface 3.
- Enable OSPF on each interface.
- Set up an OSPF authentication password for each area and network.
- Assign link-state metrics and other OSPF interface configuration options.
- Create a *stub area* with area ID 36.0.0.0. (Note that the **authentication** and **stub** options of the **area** router configuration command are specified with separate **area** command entries, but can be merged into a single **area** command.)
- Specify the backbone area (area 0).

Configuration tasks associated with redistribution are as follows:

- Redistribute IGRP and RIP into OSPF with various options set (including **metric-type**, **metric**, **tag**, and **subnet**).
- Redistribute IGRP and OSPF into RIP.

The following is an example OSPF configuration:

```
interface ethernet 0
 ip address 192.42.110.201 255.255.255.0
 ip ospf authentication-key abcdefgh
 ip ospf cost 10
!
interface ethernet 1
 ip address 131.119.251.201 255.255.255.0
 ip ospf authentication-key ijklmnop
 ip ospf cost 20
 ip ospf retransmit-interval 10
 ip ospf transmit-delay 2
 ip ospf priority 4
!
interface ethernet 2
 ip address 131.119.254.201 255.255.255.0
 ip ospf authentication-key abcdefgh
 ip ospf cost 10
!
interface ethernet 3
 ip address 36.56.0.201 255.255.0.0
 ip ospf authentication-key ijklmnop
 ip ospf cost 20
 ip ospf dead-interval 80
```

In the following configuration OSPF is on network 131.119.0.0:

```
router ospf 201
 network 36.0.0.0 0.255.255.255 area 36.0.0.0
 network 192.42.110.0 0.0.0.255 area 192.42.110.0
 network 131.119.0.0 0.0.255.255 area 0
 area 0 authentication
 area 36.0.0.0 stub
 area 36.0.0.0 authentication
 area 36.0.0.0 default-cost 20
 area 192.42.110.0 authentication
 area 36.0.0.0 range 36.0.0.0 255.0.0.0
 area 192.42.110.0 range 192.42.110.0 255.255.255.0
 area 0 range 131.119.251.0 255.255.255.0
 area 0 range 131.119.254.0 255.255.255.0
 redistribute igrp 200 metric-type 2 metric 1 tag 200 subnets
 redistribute rip metric-type 2 metric 1 tag 200
```

In the following configuration IGRP autonomous system 200 is on 131.119.0.0:

```
router igrp 200
 network 131.119.0.0
!
! RIP for 192.42.110
!
router rip
 network 192.42.110.0
 redistribute igrp 200 metric 1
 redistribute ospf 201 metric 1
```

Route Map Examples

The examples in this section illustrate the use of redistribution, with and without route maps. Examples from both the IP and Connectionless Network Service (CLNS) routing protocols are given.

The following example redistributes all OSPF routes into IGRP:

```
router igrp 109
 redistribute ospf 110
```

The following example redistributes RIP routes with a hop count equal to 1 into OSPF. These routes will be redistributed into OSPF as external LSAs with a metric of 5, a metric type of type 1, and a tag equal to 1.

```
router ospf 109
 redistribute rip route-map rip-to-ospf
!
route-map rip-to-ospf permit
 match metric 1
 set metric 5
 set metric-type type1
 set tag 1
```

The following example redistributes OSPF learned routes with tag 7 as a RIP metric of 15:

```
router rip
 redistribute ospf 109 route-map 5
!
route-map 5 permit
 match tag 7
 set metric 15
```

The following example redistributes OSPF intra-area and interarea routes with next hop routers on serial interface 0 into BGP with an INTER_AS metric of 5:

```
router bgp 109
 redistribute ospf 109 route-map 10
!
route-map 10 permit
 match route-type internal
 match interface serial 0
 set metric 5
```

The following example redistributes two types of routes into the integrated IS-IS routing table (supporting both IP and CLNS). The first type is OSPF external IP routes with tag 5; these routes are inserted into Level 2 IS-IS LSPs with a metric of 5. The second type is ISO-IGRP derived CLNS prefix routes that match CLNS access list 2000; these routes will be redistributed into IS-IS as Level 2 LSPs with a metric of 30.

```
router isis
 redistribute ospf 109 route-map 2
 redistribute iso-igrp nsfnet route-map 3
!
route-map 2 permit
 match route-type external
 match tag 5
 set metric 5
 set level level-2
!
route-map 3 permit
 match address 2000
 set metric 30
```

With the following configuration, OSPF external routes with tags 1, 2, 3, and 5 are redistributed into RIP with metrics of 1, 1, 5, and 5, respectively. The OSPF routes with a tag of 4 are not redistributed.

```
router rip
 redistribute ospf 109 route-map 1
!
route-map 1 permit
 match tag 1 2
 set metric 1
!
```

```
route-map 1 permit
 match tag 3
 set metric 5
!
route-map 1 deny
 match tag 4
!
route map 1 permit
 match tag 5
 set metric 5
```

In the following configuration, a RIP learned route for network 160.89.0.0 and an ISO-IGRP learned route with prefix 49.0001.0002 will be redistributed into an IS-IS Level 2 LSP with a metric of 5:

```
router isis
 redistribute rip route-map 1
 redistribute iso-igrp remote route-map 1
!
route-map 1 permit
 match ip address 1
 match clns address 2
 set metric 5
 set level level-2
!
 access-list 1 permit 160.89.0.0 0.0.255.255
 clns filter-set 2 permit 49.0001.0002...
```

The following configuration example illustrates how a route map is referenced by the **default-information** router configuration command. This type of reference is called *conditional default origination*. OSPF will originate the default route (network 0.0.0.0) with a type 2 metric of 5 if 140.222.0.0 is in the routing table.

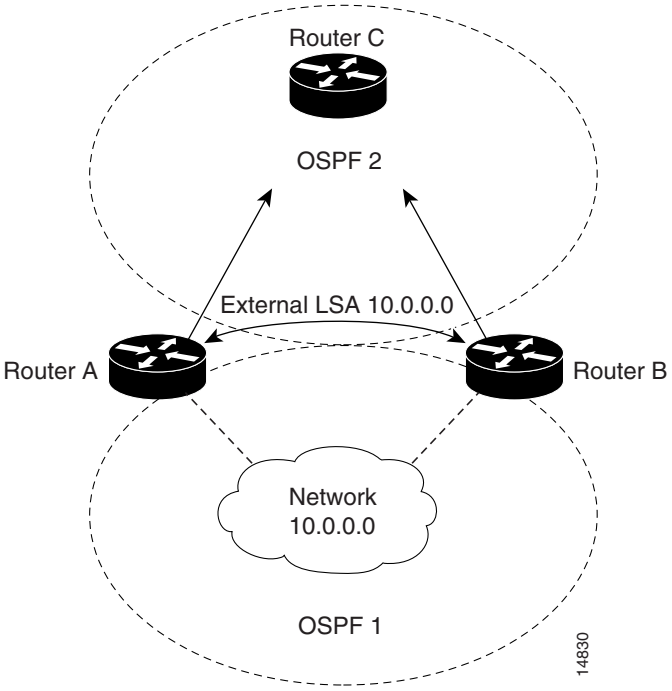
Note Only routes external to the OSPF process can be used for tracking, such as non-OSPF routes or OSPF routes from a separate OSPF process.

```
route-map ospf-default permit
 match ip address 1
 set metric 5
 set metric-type type-2
!
 access-list 1 permit 140.222.0.0 0.0.255.255
!
router ospf 109
 default-information originate route-map ospf-default
```

Changing OSPF Administrative Distance Example

The following configuration changes the external distance to 200, making it less trustworthy. Figure 44 illustrates the example.

Figure 44 OSPF Administrative Distance



Router A Configuration

```
router ospf 1
 redistribute ospf 2 subnet
 distance ospf external 200
!
router ospf 2
 redistribute ospf 1 subnet
 distance ospf external 200
```

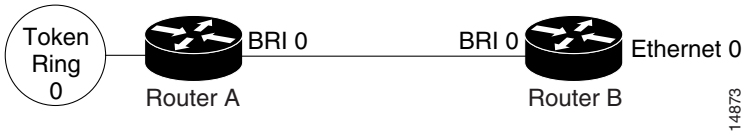
Router B Configuration

```
router ospf 1
 redistribute ospf 2 subnet
 distance ospf external 200
!
router ospf 2
 redistribute ospf 1 subnet
 distance ospf external 200
```

OSPF over On-Demand Routing Example

The following configuration allows OSPF over an on-demand circuit, as shown in Figure 45. Note that the on-demand circuit is defined on one side only BRI 0 on Router A). It is not required to be configured on both sides.

Figure 45 OSPF over On-Demand Circuit



Router A Configuration

```
username RouterB password 7 060C1A2F47
isdn switch-type basic-5ess
ip routing
!
interface TokenRing0
 ip address 140.10.20.7 255.255.255.0
 no shut
!
interface BRI0
 no cdp enable
 description connected PBX 1485
 ip address 140.10.10.7 255.255.255.0
 encapsulation ppp
 ip ospf demand-circuit
 dialer map ip 140.10.10.6 name RouterB broadcast 61484
 dialer-group 1
 ppp authentication chap
 no shut
!
router ospf 100
 network 140.10.10.0 0.0.0.255 area 0
 network 140.10.20.0 0.0.0.255 area 0
!
dialer-list 1 protocol ip permit
```

Router B Configuration

```
username RouterA password 7 04511E0804
isdn switch-type basic-5ess
ip routing
!
interface Ethernet0
 ip address 140.10.60.6 255.255.255.0
 no shut
!
interface BRI0
 no cdp enable
 description connected PBX 1484
 ip address  140.10.10.6 255.255.255.0
 encapsulation ppp
 dialer map ip 140.10.10.7 name RouterA broadcast 61485
 dialer-group 1
 ppp authentication chap
 no shut
!
router ospf 100
 network 140.10.10.0 0.0.0.255 area 0
 network 140.10.60.0 0.0.0.255 area 0
!
dialer-list 1 protocol ip permit
```

LSA Group Pacing Example

The following example changes the OSPF pacing between LSA groups to 60 seconds:

```
router ospf
 timers lsa-group-pacing 60
```

Block LSA Flooding Example

The following example prevents flooding of OSPF LSAs to broadcast, nonbroadcast, or point-to-point networks reachable through Ethernet interface 0:

```
interface ethernet 0
 ospf database-filter all out
```

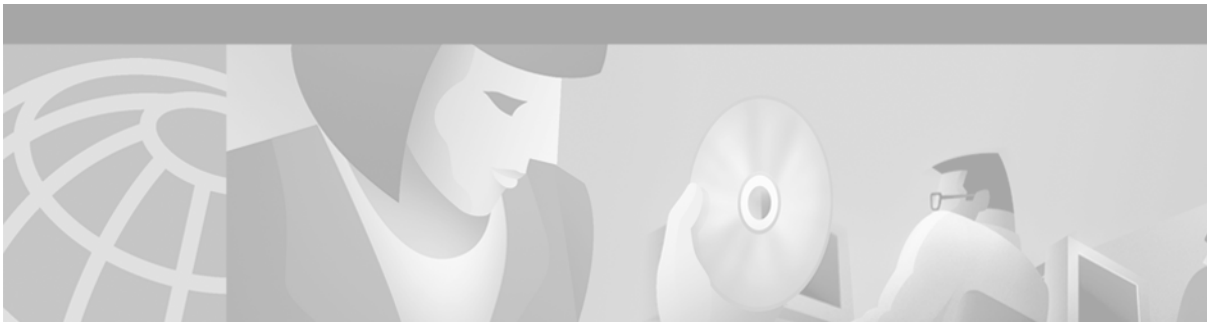
The following example prevents flooding of OSPF LSAs to point-to-multipoint networks to the neighbor at IP address 1.2.3.4:

```
router ospf 109
 neighbor 1.2.3.4 database-filter all out
```

Ignore MOSPF LSA Packets Example

The following example configures the router to suppress the sending of syslog messages when it receives MOSPF packets:

```
router ospf 109
 ignore lsa mospf
```



Configuring EIGRP

This chapter describes how to configure Enhanced Interior Gateway Routing Protocol (EIGRP). For a complete description of the EIGRP commands listed in this chapter, refer to the "EIGRP Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* publication. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

Refer to the *Cisco IOS AppleTalk and Novell IPX Configuration Guide* for information on AppleTalk EIGRP or Internetwork Packet Exchange (IPX) EIGRP.

For protocol-independent features that work with EIGRP, see the chapter "Configuring IP Routing Protocol-Independent Features" in this document.

EIGRP is an enhanced version of the IGRP developed by Cisco. EIGRP uses the same distance vector algorithm and distance information as IGRP. However, the convergence properties and the operating efficiency of EIGRP have improved substantially over IGRP.

The convergence technology is based on research conducted at SRI International and employs an algorithm referred to as the Diffusing Update Algorithm (DUAL). This algorithm guarantees loop-free operation at every instant throughout a route computation and allows all devices involved in a topology change to synchronize at the same time. Routers that are not affected by topology changes are not involved in recomputations. The convergence time with DUAL rivals that of any other existing routing protocol.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

The Cisco EIGRP Implementation

EIGRP provides the following features:

- Automatic redistribution—IGRP routes can be automatically redistributed into EIGRP, and EIGRP routes can be automatically redistributed into IGRP. If desired, you can turn off redistribution. You can also completely turn off EIGRP and IGRP on the router or on individual interfaces.
- Increased network width—With IP Routing Information Protocol (RIP), the largest possible width of your network is 15 hops. When EIGRP is enabled, the largest possible width is increased to 100 hops, and the metric is large enough to support thousands of hops.

Note Redistribution between EIGRP and IGRP differs from normal redistribution in that the metrics of IGRP routes are compared with the metrics of external EIGRP routes. The rules of normal administrative distances are not followed, and routes with the lowest metric are selected.

EIGRP offers the following features:

- Fast convergence—The DUAL algorithm allows routing information to converge as quickly as any currently available routing protocol.
- Partial updates—EIGRP sends incremental updates when the state of a destination changes, instead of sending the entire contents of the routing table. This feature minimizes the bandwidth required for EIGRP packets.
- Less CPU usage than IGRP—This occurs because full update packets need not be processed each time they are received.
- Neighbor discovery mechanism—This is a simple hello mechanism used to learn about neighboring routers. It is protocol-independent.
- Variable-length subnet masks (VLSMs).
- Arbitrary route summarization.
- Scaling—EIGRP scales to large networks.

EIGRP has the following four basic components:

- Neighbor discovery of neighbor recovery
- Reliable transport protocol
- DUAL finite state machine
- Protocol-dependent modules

Neighbor discovery of neighbor recovery is the process that routers use to dynamically learn of other routers on their directly attached networks. Routers must also discover when their neighbors become unreachable or inoperative. Neighbor discovery of neighbor recovery is achieved with low overhead by periodically sending small hello packets. As long as hello packets are received, the Cisco IOS software can determine that a neighbor is alive and functioning. Once this status is determined, the neighboring routers can exchange routing information.

The reliable transport protocol is responsible for guaranteed, ordered delivery of EIGRP packets to all neighbors. It supports intermixed transmission of multicast and unicast packets. Some EIGRP packets must be sent reliably and others need not be. For efficiency, reliability is provided only when necessary. For example, on a multiaccess network that has multicast capabilities (such as Ethernet) it is not necessary to send hello packets reliably to all neighbors individually. Therefore, EIGRP sends a single multicast hello with an indication in the packet informing the receivers that the packet need not be acknowledged. Other types of packets (such as updates) require acknowledgment, which is indicated in the packet. The reliable transport has a provision to send multicast packets quickly when unacknowledged packets are pending. This provision helps to ensure that convergence time remains low in the presence of varying speed links.

The DUAL finite state machine embodies the decision process for all route computations. It tracks all routes advertised by all neighbors. DUAL uses the distance information (known as a metric) to select efficient, loop-free paths. DUAL selects routes to be inserted into a routing table based on feasible successors. A successor is a neighboring router used for packet forwarding that has a least-cost path to a destination that is guaranteed not to be part of a routing loop. When there are no feasible successors but there are neighbors advertising the destination, a recomputation must occur. This is the process whereby a new successor is determined. The amount of time required to recompute the route affects the

convergence time. Recomputation is processor-intensive; it is advantageous to avoid unneeded recomputation. When a topology change occurs, DUAL will test for feasible successors. If there are feasible successors, it will use any it finds in order to avoid unnecessary recomputation.

The protocol-dependent modules are responsible for network layer protocol-specific tasks. An example is the EIGRP module, which is responsible for sending and receiving EIGRP packets that are encapsulated in IP. It is also responsible for parsing EIGRP packets and informing DUAL of the new information received. EIGRP asks DUAL to make routing decisions, but the results are stored in the IP routing table. Also, EIGRP is responsible for redistributing routes learned by other IP routing protocols.

EIGRP Configuration Task List

To configure EIGRP, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional:

- Enabling EIGRP (Required)
- Making the Transition from IGRP to EIGRP (Optional)
- Logging EIGRP Neighbor Adjacency Changes (Optional)
- Configuring the Percentage of Link Bandwidth Used (Optional)
- Adjusting the EIGRP Metric Weights (Optional)
- Applying Offsets to Routing Metrics (Optional)
- Disabling Route Summarization (Optional)
- Configuring Summary Aggregate Addresses (Optional)
- Configuring Floating Summary Routes (Optional)
- Configuring EIGRP Route Authentication (Optional)
- Configuring EIGRP Protocol-Independent Parameters (Optional)
- Configuring EIGRP Stub Routing (Optional)
- Monitoring and Maintaining EIGRP(Optional)

See the section “EIGRP Configuration Examples” at the end of this chapter for configuration examples.

Enabling EIGRP

To create an EIGRP routing process, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router eigrp autonomous-system`	Enables an EIGRP routing process in global configuration mode.
Step 2	`Router(config-router)# network network-number`	Associates networks with an EIGRP routing process in router configuration mode.

EIGRP sends updates to the interfaces in the specified networks. If you do not specify the network of an interface, the interface will not be advertised in any EIGRP update.

Making the Transition from IGRP to EIGRP

If you have routers on your network that are configured for IGRP, and you want to make a transition to routing EIGRP, you must designate transition routers that have both IGRP and EIGRP configured. In these cases, perform the tasks as noted in the previous section, "Enabling EIGRP," and also see the chapter "Configuring IGRP" in this document. You must use the same autonomous system number in order for routes to be redistributed automatically.

Logging EIGRP Neighbor Adjacency Changes

You can enable the logging of neighbor adjacency changes to monitor the stability of the routing system and to help you detect problems. By default, adjacency changes are not logged. To enable such logging, use the following command in global configuration mode:

Command	Purpose
`Router(config)# eigrp log-neighbor-changes`	Enables logging of EIGRP neighbor adjacency changes.

Configuring the Percentage of Link Bandwidth Used

By default, EIGRP packets consume a maximum of 50 percent of the link bandwidth, as configured with the **bandwidth** interface configuration command. You might want to change that value if a different level of link utilization is required or if the configured bandwidth does not match the actual link bandwidth (it may have been configured to influence route metric calculations).

To configure the percentage of bandwidth that may be used by EIGRP on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip bandwidth-percent eigrp` *percent*	Configures the percentage of bandwidth that may be used by EIGRP on an interface.

Adjusting the EIGRP Metric Weights

EIGRP uses the minimum bandwidth on the path to a destination network and the total delay to compute routing metrics. You can use the **eigrp metric weights** command to adjust the default behavior of EIGRP routing and metric computations. For example, this adjustment allows you to tune system behavior to allow for satellite transmission. EIGRP metric defaults have been carefully selected to provide optimal performance in most networks.

Note Adjusting EIGRP metric weights can dramatically affect network performance. Because of the complexity of this task, we recommend that you do not change the default values without guidance from an experienced network designer.

To adjust the EIGRP metric weights, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# metric weights tos k1 k2 k3 k4 k5`	Adjusts the EIGRP metric or K value. EIGRP uses the following formula to determine the total metric to the network: metric = [K1*bandwidth + (K2*bandwidth)/(256 - load) + K3*delay] * [K5/(reliability + K4)]

By default, the EIGRP composite metric is a 32-bit quantity that is a sum of the segment delays and the lowest segment bandwidth (scaled and inverted) for a given route. For a network of homogeneous media, this metric reduces to a hop count. For a network of mixed media (FDDI, Ethernet, and serial lines running from 9600 bits per second to T1 rates), the route with the lowest metric reflects the most desirable path to a destination.

Mismatched K Values

Mismatched K values (EIGRP metrics) can prevent neighbor relationships from being established and can negatively impact network convergence. The following example explains this behavior between 2 EIGRP peers (ROUTER-A and ROUTER-B).

The following error message is displayed in the console of ROUTER-B because the K values are mismatched:

```
*Apr 26 13:48:41.811: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 10.1.1.1 (Ethernet0/0) is
down: K-value mismatch
```

There are two scenarios where this error message can be displayed:

- The two routers are connected on the same link and configured to establish a neighbor relationship. However, each router is configured with different K values.

  The following configuration is applied to ROUTER-A. The K values are changed with the **metric weights** command. A value of 2 is entered for the *k1* argument to adjust the bandwidth calculation. The value of 1 is entered for the *k3* argument to adjust the delay calculation.

  ```
  hostname ROUTER-A!
  interface serial 0
   ip address 10.1.1.1 255.255.255.0
   exit
  router eigrp 100
   network 10.1.1.0 0.0.0.255
   metric weights 0 2 0 1 0 0
  ```

  The following configuration is applied to ROUTER-B. However, the **metric weights** command is not applied and the default K values are used. The default K values are 1, 0, 1, 0, and 0.

  ```
  hostname ROUTER-B!
  interface serial 0
   ip address 10.1.1.2 255.255.255.0!
   exit
  router eigrp 100
   network 10.1.1.0 0.0.0.255
  ```

  The bandwidth calculation is set to 2 on ROUTER-A and set to 1 (by default) on ROUTER-B. This configuration prevents these peers from forming a neighbor relationship.

- The K-value mismatch error message can also be displayed if one of the two peers has transmitted a “goodbye” message, and the receiving router does not support this message. In this case, the receiving router will interpret this message as a K-value mismatch.

The Goodbye Message

The goodbye message is a feature designed to improve EIGRP network convergence. The goodbye message is broadcast when an EIGRP routing process is shutdown to inform adjacent peers about the impending topology change. This feature allows supporting EIGRP peers to synchronize and recalculate neighbor relationships more efficiently than would occur if the peers discovered the topology change after the hold timer expired.

The goodbye message is supported in Cisco IOS Release 12.3(2), 12.3(3)B, and 12.3(2)T and later releases. The following message is displayed by routers that run a supported release when a goodbye message is received:

```
 *Apr 26 13:48:42.523: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 10.1.1.1
(Ethernet0/0) is down: Interface Goodbye received
```

A Cisco router that runs a software release that does not support the goodbye message can misinterpret the message as a K-value mismatch and display the following message:

```
 *Apr 26 13:48:41.811: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor     10.1.1.1
(Ethernet0/0) is down: K-value mismatch
```

Note The receipt of a goodbye message by a nonsupporting peer does not disrupt normal network operation. The nonsupporting peer will terminate session when the hold timer expires. The sending and receiving routers will reconverge normally after the sender reloads.

Applying Offsets to Routing Metrics

An offset list is the mechanism for increasing incoming and outgoing metrics to routes learned via EIGRP. An offset list provides a local mechanism for increasing the value of routing metrics. Optionally, you can limit the offset list with either an access list or an interface. To increase the value of routing metrics, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# offset-list [access-list-number | access-list-name] {in | out} offset [interface-type interface-number]`	Applies an offset to routing metrics.

Disabling Route Summarization

You can configure EIGRP to perform automatic summarization of subnet routes into network-level routes. For example, you can configure subnet 131.108.1.0 to be advertised as 131.108.0.0 over interfaces that have subnets of 192.31.7.0 configured. Automatic summarization is performed when there are two or more **network** router configuration commands configured for the EIGRP process. By default, this feature is enabled.

To disable automatic summarization, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no auto-summary`	Disables automatic summarization.

Route summarization works in conjunction with the **ip summary-address eigrp** interface configuration command, in which additional summarization can be performed. If automatic summarization is in effect, there usually is no need to configure network level summaries using the **ip summary-address eigrp** command.

Configuring Summary Aggregate Addresses

You can configure a summary aggregate address for a specified interface. If any more specific routes are in the routing table, EIGRP will advertise the summary address out the interface with a metric equal to the minimum of all more specific routes.

To configure a summary aggregate address, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip summary-address eigrp` *autonomous-system-number ip-address mask*	Configures a summary aggregate address.

See the "Route Summarization Example" at the end of this chapter for an example of summarizing aggregate addresses.

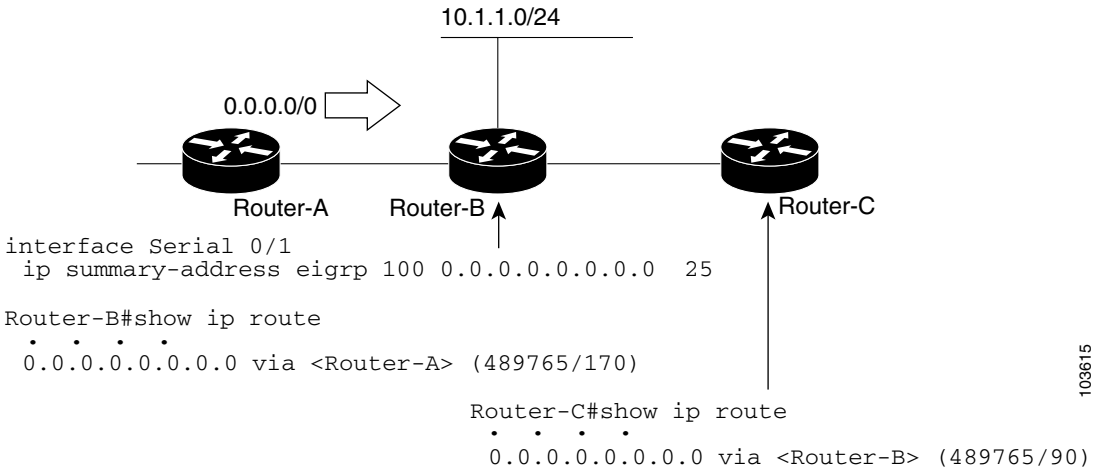
Configuring Floating Summary Routes

You can also use a floating summary route when configuring the **ip summary-address eigrp** command. This enhancement was introduced in Cisco IOS Release 12.2. The floating summary route is created by applying a default route and administrative distance at the interface level. The following scenarios illustrates the behavior of this enhancement.

Figure 46 shows a network with three routers, Router-A, Router-B, and Router-C. Router-A learns a default route from elsewhere in the network and then advertises this route to Router-B. Router-B is configured so that only a default summary route is advertised to Router-C. The default summary route is applied to interface 0/1 on Router-B with the following configuration:

```
Router(config)# interface Serial 0/1
Router(config-if)# ip summary-address eigrp 100 0.0.0.0 0.0.0.0
```

Figure 46 Floating Summary Route is Applied to Router-B



The configuration of the default summary route on Router-B sends a 0.0.0.0/0 summary route to Router-C and blocks all other routes, including the 10.1.1.0/24 route, from being advertised to Router-C. However, this also generates a local discard route on Router-B, a route for 0.0.0.0/0 to the null 0 interface with an administrative distance of 5. When this route is created, it overrides the EIGRP learned default route. Router-B will no longer be able to reach destinations that it would normally reach through the 0.0.0.0/0 route.

This problem is resolved by applying a floating summary route to the interface on Router-B that connects to Router-C. The floating summary route is applied by applying an administrative distance to the default summary route on the interface of Router-B with the following statement:

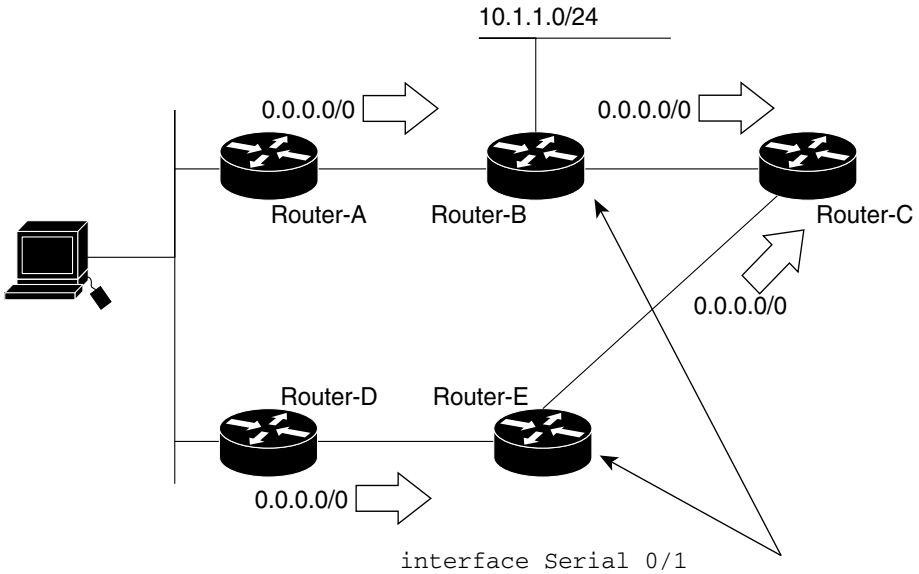
```
Router(config-if)# ip summary-address eigrp 100 0.0.0.0 0.0.0.0 250
```

The administrative distance of 250, applied in the above statement, is now assigned to the discard route generated on Router-B. The 0.0.0.0/0, from Router-A, is learned through EIGRP and installed in the local routing table. Routing to Router-C is restored.

If Router-A loses the connection to Router-B, Router-B will continue to advertise a default route to Router-C, which allows traffic to continue to reach destinations attached to Router-B. However, traffic destined to networks to Router-A or behind Router-A will be dropped when it reaches Router-B.

Figure 47 shows a network with two connections from the core, Router-A and Router-D. Both routers have floating summary routes configured on the interfaces connected to Router-C. If the connection between Router-E and Router-C fails, the network will continue to operate normally. All traffic will flow from Router-C through Router-B to the hosts attached to Router-A and Router-D.

Figure 47 Floating Summary Route Applied for Dual-Homed Remotes




```
interface Serial 0/1
 ip summary-address eigrp 100 0.0.0.0.0.0.0.0 250

Router-B#show ip route
  .  .  .  .
 0.0.0.0.0.0.0.0  via <Router-A> (489765/170)
```

However, if the link between Router-D and Router-E fails, the network may blackhole traffic because Router-E will continue to advertise the default route(0.0.0.0/0) to Router-C, as long as at least one link, (other than the link to Router-C) to Router-E is still active. In this scenario, Router-C still forwards traffic to Router-E, but Router-E drops the traffic creating the black hole. To avoid this problem, you should configure the summary address with an administrative distance on only single-homed remote routers or areas where there is only one exit point between to segments of the network. If two or more exit points exist (from one segment of the network to another), configuring the floating default route can cause a black hole to be formed.

Configuring EIGRP Route Authentication

EIGRP route authentication provides Message Digest 5 (MD5) authentication of routing updates from the EIGRP routing protocol. The MD5 keyed digest in each EIGRP packet prevents the introduction of unauthorized or false routing messages from unapproved sources.

Before you can enable EIGRP route authentication, you must enable EIGRP.

To enable authentication of EIGRP packets, use the following commands beginning in interface configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface` *type number*	Configure an interface type and enter interface configuration mode
Step 2	`Router(config-if)# ip authentication mode eigrp` *autonomous-system* `md5`	Enables MD5 authentication in EIGRP packets.

	Command	Purpose
Step 3	`Router(config-if)# ip authentication key-chain eigrp autonomous-system key-chain`	Enables authentication of EIGRP packets.
Step 4	`Router(config-if)# exit` `Router(config)#`	Exits to global configuration mode.
Step 5	`Router(config)# key chain name-of-chain`	Identifies a key chain. (Match the name configured in Step 1.)
Step 6	`Router(config-keychain)# key number`	In keychain configuration mode, identifies the key number.
Step 7	`Router(config-keychain-key)# key-string text`	In keychain key configuration mode, identifies the key string.
Step 8	`Router(config-keychain-key)# accept-lifetime start-time {infinite | end-time | duration seconds}`	Optionally specifies the time period during which the key can be received.
Step 9	`Router(config-keychain-key)# send-lifetime start-time {infinite | end-time | duration seconds}`	Optionally specifies the time period during which the key can be sent.

Each key has its own key identifier (specified with the **key** *number* key chain configuration command), which is stored locally. The combination of the key identifier and the interface associated with the message uniquely identifies the authentication algorithm and MD5 authentication key in use.

You can configure multiple keys with lifetimes. Only one authentication packet is sent, regardless of how many valid keys exist. The software examines the key numbers in order from lowest to highest, and uses the first valid key it encounters. Note that the router needs to know the time. Refer to the Network Time Protocol (NTP) and calendar commands in the "Performing Basic System Management" chapter of the *Cisco IOS Configuration Fundamentals Configuration Guide*.

For an example of route authentication, see the section "Route Authentication Example" at the end of this chapter.

Configuring EIGRP Protocol-Independent Parameters

EIGRP works with AppleTalk, IP, and IPX. The bulk of this chapter describes EIGRP. However, this section describes EIGRP features that work for AppleTalk, IP, and IPX. To configure such protocol-independent parameters, perform one or more of the tasks in the following sections:

- Adjusting the Interval Between Hello Packets and the Hold Time
- Disabling Split Horizon

For more protocol-independent features that work with EIGRP, see the chapter "Configuring IP Routing Protocol-Independent Features" in this document.

Adjusting the Interval Between Hello Packets and the Hold Time

You can adjust the interval between hello packets and the hold time.

Routing devices periodically send hello packets to each other to dynamically learn of other routers on their directly attached networks. This information is used to discover neighbors and to learn when neighbors become unreachable or inoperative.

By default, hello packets are sent every 5 seconds. The exception is on low-speed, nonbroadcast multiaccess (NBMA) media, where the default hello interval is 60 seconds. Low speed is considered to be a rate of T1 or slower, as specified with the **bandwidth** interface configuration command. The default hello interval remains 5 seconds for high-speed NBMA networks. Note that for the purposes of EIGRP, Frame Relay and Switched Multimegabit Data Service (SMDS) networks may or may not be considered to be NBMA. These networks are considered NBMA if the interface has not been configured to use physical multicasting; otherwise they are not considered NBMA.

You can configure the hold time on a specified interface for a particular EIGRP routing process designated by the autonomous system number. The hold time is advertised in hello packets and indicates to neighbors the length of time they should consider the sender valid. The default hold time is three times the hello interval, or 15 seconds. For slow-speed NBMA networks, the default hold time is 180 seconds.

To change the interval between hello packets, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip hello-interval eigrp` *autonomous-system-number seconds*	Configures the hello interval for an EIGRP routing process.

On very congested and large networks, the default hold time might not be sufficient time for all routers to receive hello packets from their neighbors. In this case, you may want to increase the hold time.

To change the hold time, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip hold-time eigrp` *autonomous-system-number seconds*	Configures the hold time for an EIGRP routing process.

Note Do not adjust the hold time without advising your technical support personnel.

Disabling Split Horizon

Split horizon controls the sending of EIGRP update and query packets. When split horizon is enabled on an interface, update and query packets are not sent for destinations for which this interface is the next hop. Controlling update and query packets in this manner reduces the possibility of routing loops.

By default, split horizon is enabled on all interfaces.

Split horizon blocks route information from being advertised by a router out of any interface from which that information originated. This behavior usually optimizes communications among multiple routing devices, particularly when links are broken. However, with nonbroadcast networks (such as Frame Relay and SMDS), situations can arise for which this behavior is less than ideal. For these situations, including networks in which you have EIGRP configured, you may want to disable split horizon.

To disable split horizon, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# no ip split-horizon eigrp` *autonomous-system-number*	Disables split horizon.

Configuring EIGRP Stub Routing

The EIGRP Stub Routing feature improves network stability, reduces resource utilization, and simplifies stub router configuration.

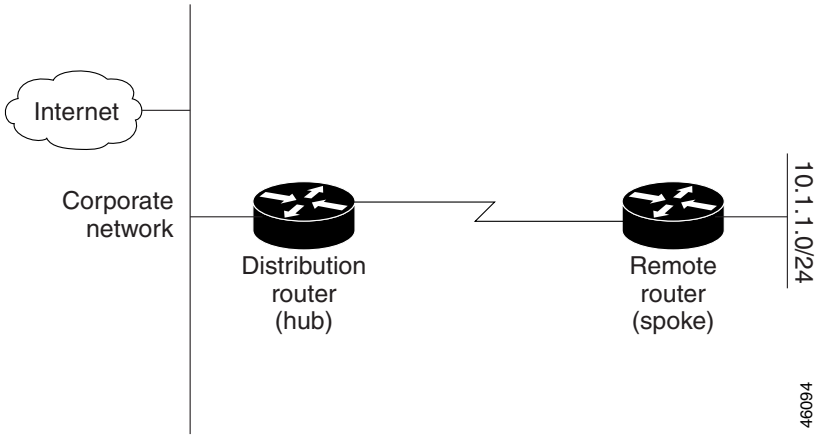
Stub routing is commonly used in a hub-and-spoke network topology. In a hub-and-spoke network, one or more end (stub) networks are connected to a remote router (the spoke) that is connected to one or more distribution routers (the hub). The remote router is adjacent only to one or more distribution routers. The only route for IP traffic to follow into the remote router is through a distribution router. This type of configuration is commonly used in WAN topologies where the distribution router is directly connected to a WAN. The distribution router can be connected to many more remote routers. Often, the distribution router will be connected to 100 or more remote routers. In a hub-and-spoke topology, the remote router must forward all nonlocal traffic to a distribution router, so it becomes unnecessary for the remote router to hold a complete routing table. Generally, the distribution router need not send anything more than a default route to the remote router.

When using the EIGRP Stub Routing feature, you need to configure the distribution and remote routers to use EIGRP, and to configure only the remote router as a stub. Only specified routes are propagated from the remote (stub) router. The stub router responds to all queries for summaries, connected routes, redistributed static routes, external routes, and internal routes with the message "inaccessible." A router that is configured as a stub will send a special peer information packet to all neighboring routers to report its status as a stub router.

Any neighbor that receives a packet informing it of the stub status will not query the stub router for any routes, and a router that has a stub peer will not query that peer. The stub router will depend on the distribution router to send the proper updates to all peers.

Figure 48 shows a simple hub-and-spoke configuration.

Figure 48 Simple Hub-and-Spoke Network



The stub routing feature by itself does not prevent routes from being advertised to the remote router. In the example in Figure 48, the remote router can access the corporate network and the Internet through the distribution router only. Having a full route table on the remote router, in this example, would serve no functional purpose because the path to the corporate network and the Internet would always be through the distribution router. The larger route table would only reduce the amount of memory required by the remote router. Bandwidth and memory can be conserved by summarizing and filtering routes in the distribution router. The remote router need not receive routes that have been learned from other networks because the remote router must send all nonlocal traffic, regardless of destination, to the distribution router. If a true stub network is desired, the distribution router should be configured to send

only a default route to the remote router. The EIGRP Stub Routing feature does not automatically enable summarization on the distribution router. In most cases, the network administrator will need to configure summarization on the distribution routers.

Note When configuring the distribution router to send only a default route to the remote router, you must use the **ip classless** command on the remote router. By default, the **ip classless** command is enabled in all Cisco IOS images that support the EIGRP Stub Routing feature.

Without the stub feature, even after the routes that are sent from the distribution router to the remote router have been filtered or summarized, a problem might occur. If a route is lost somewhere in the corporate network, EIGRP could send a query to the distribution router, which in turn will send a query to the remote router even if routes are being summarized. If there is a problem communicating over the WAN link between the distribution router and the remote router, an EIGRP stuck in active (SIA) condition could occur and cause instability elsewhere in the network. The EIGRP Stub Routing feature allows a network administrator to prevent queries from being sent to the remote router.

Dual-Homed Remote Topology

In addition to a simple hub-and-spoke network where a remote router is connected to a single distribution router, the remote router can be dual-homed to two or more distribution routers. This configuration adds redundancy and introduces unique issues, and the stub feature helps to address some of these issues.

A dual-homed remote router will have two or more distribution (hub) routers. However, the principles of stub routing are the same as they are with a hub-and-spoke topology. Figure 49 shows a common dual-homed remote topology with one remote router, but 100 or more routers could be connected on the same interfaces on distribution router 1 and distribution router 2. The remote router will use the best route to reach its destination. If distribution router 1 experiences a failure, the remote router can still use distribution router 2 to reach the corporate network.

Figure 49 Simple Dual-Homed Remote Topology

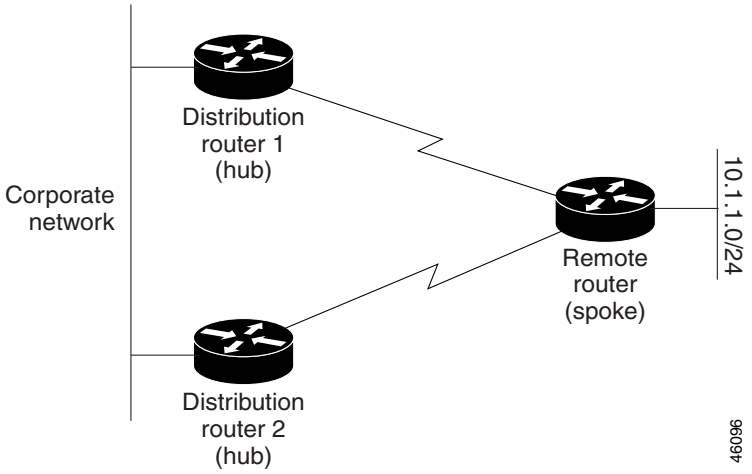


Figure 49 shows a simple dual-homed remote with one remote router and two distribution routers. Both distribution routers maintain routes to the corporate network and stub network 10.1.1.0/24.

Dual-homed routing can introduce instability into an EIGRP network. In Figure 50, distribution router 1 is directly connected to network 10.3.1.0/24. If summarization or filtering is applied on distribution router 1, the router will advertise network 10.3.1.0/24 to all of its directly connected EIGRP neighbors (distribution router 2 and the remote router).

Figure 50 Dual-Homed Remote Topology With Distribution Router 1 Connected to Two Networks

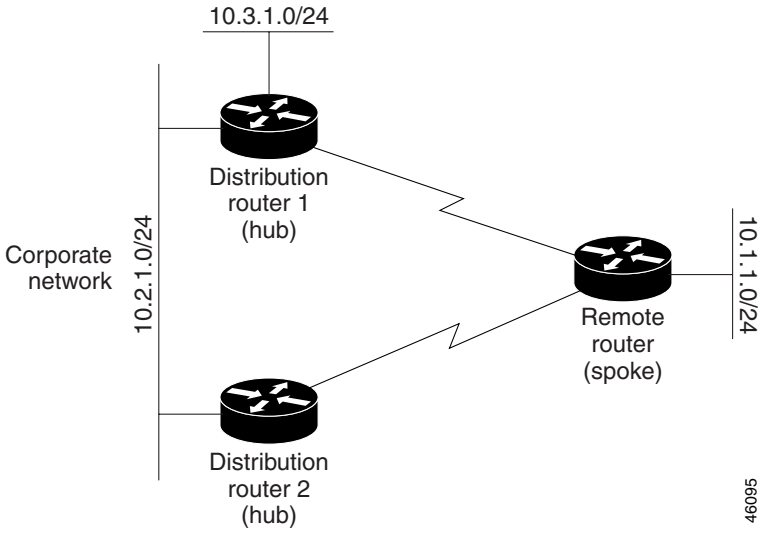
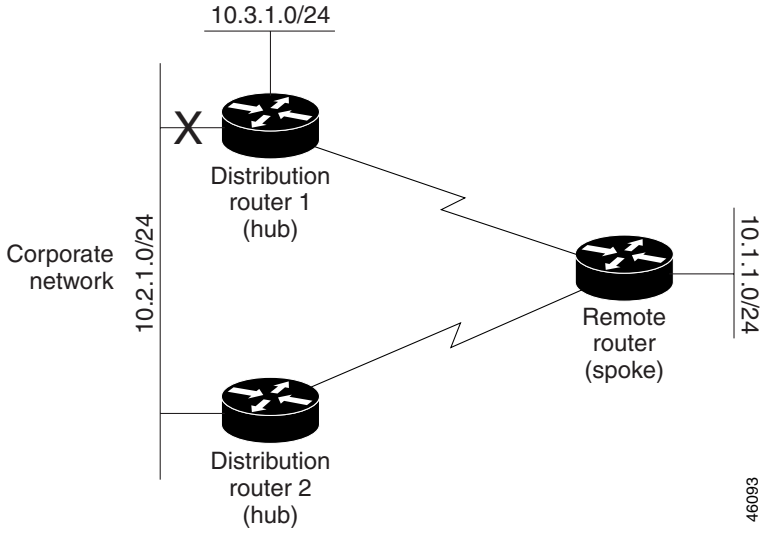


Figure 50 shows a simple dual-homed remote router where distribution router 1 is connected to both network 10.3.1.0/24 and network 10.2.1.0/24.

If the 10.2.1.0/24 link between distribution router 1 and distribution router 2 has failed, the lowest cost path to network 10.3.1.0/24 from distribution router 2 is through the remote router (see Figure 51). This route is not desirable because the traffic that was previously traveling across the corporate network 10.2.1.0/24 would now be sent across a much lower bandwidth connection. The over utilization of the lower bandwidth WAN connection can cause a number of problems that might affect the entire corporate network. The use of the lower bandwidth route that passes through the remote router might cause WAN EIGRP distribution routers to be dropped. Serial lines on distribution and remote routers could also be dropped, and EIGRP SIA errors on the distribution and core routers could occur.

Figure 51 Dual-Homed Remote Topology with a Failed Route to a Distribution Router



It is not desirable for traffic from distribution router 2 to travel through any remote router in order to reach network 10.3.1.0/24. If the links are sized to handle the load, it would be acceptable to use one of the backup routes. However, most networks of this type have remote routers located at remote offices with relatively slow links. This problem can be prevented if proper summarization is configured on the distribution router and remote router.

It is typically undesirable for traffic from a distribution router to use a remote router as a transit path. A typical connection from a distribution router to a remote router would have much less bandwidth than a connection at the network core. Attempting to use a remote router with a limited bandwidth connection as a transit path would generally produce excessive congestion to the remote router. The EIGRP Stub Routing feature can prevent this problem by preventing the remote router from advertising core routes back to distribution routers. Routes learned by the remote router from distribution router 1 will not be advertised to distribution router 2. Since the remote router will not advertise core routes to distribution router 2, the distribution router will not use the remote router as a transit for traffic destined for the network core.

The EIGRP Stub Routing feature can help to provide greater network stability. In the event of network instability, this feature prevents EIGRP queries from being sent over limited bandwidth links to nontransit routers. Instead, distribution routers to which the stub router is connected answer the query on behalf of the stub router. This feature greatly reduces the chance of further network instability due to congested or problematic WAN links. The EIGRP Stub Routing feature also simplifies the configuration and maintenance of hub-and-spoke networks. When stub routing is enabled in dual-homed remote configurations, it is no longer necessary to configure filtering on remote routers to prevent those remote routers from appearing as transit paths to the hub routers.

Caution EIGRP Stub Routing should only be used on stub routers. A stub router is defined as a router connected to the network core or distribution layer through which core transit traffic should not flow. A stub router should not have any EIGRP neighbors other than distribution routers. Ignoring this restriction will cause undesirable behavior.

Note Multi-access interfaces, such as ATM, Ethernet, Frame Relay, ISDN PRI, and X.25, are supported by the EIGRP Stub Routing feature only when all routers on that interface, except the hub, are configured as stub routers.

EIGRP Stub Routing Configuration Task List

To configure EIGRP Stub Routing, perform the tasks described in the following sections. The tasks in the first section are required; the task in the last section is optional.

- Configuring EIGRP Stub Routing (required)
- Verifying EIGRP Stub Routing (optional)

Configuring EIGRP Stub Routing

To configure a remote or spoke router for EIGRP stub routing, use the following commands beginning in router configuration mode:

	Command	Purpose
Step 1	`router(config)# router eigrp 1`	Configures a remote or distribution router to run an EIGRP process.
Step 2	`router(config-router)# network network-number`	Specifies the network address of the EIGRP distribution router.
Step 3	`router(config-router)# eigrp stub [receive-only | connected | static | summary]`	Configures a remote router as an EIGRP stub router.

Verifying EIGRP Stub Routing

To verify that a remote router has been configured as a stub router with EIGRP, use the **show ip eigrp neighbor detail** command from the distribution router in privileged EXEC mode. The last line of the output will show the stub status of the remote or spoke router. The following example shows output is from the **show ip eigrp neighbor detail** command:

```
router# show ip eigrp neighbor detail

IP-EIGRP neighbors for process 1
H   Address                 Interface   Hold Uptime   SRTT   RTO  Q  Seq Type
                                        (sec)         (ms)       Cnt Num
0   10.1.1.2                Se3/1         11 00:00:59    1  4500  0  7
   Version 12.1/1.2, Retrans: 2, Retries: 0
   Stub Peer Advertising ( CONNECTED SUMMARY ) Routes
```

Monitoring and Maintaining EIGRP

To delete neighbors from the neighbor table, use the following command in EXEC mode:

Command	Purpose
`Router# clear ip eigrp neighbors [ip-address | interface-type]`	Deletes neighbors from the neighbor table.

To display various routing statistics, use the following commands in EXEC mode, as needed:

Command	Purpose
Router# **show ip eigrp interfaces** [*interface-type* | interface-number] [*as-number*]	Displays information about interfaces configured for EIGRP.
Router# **show ip eigrp neighbors** [*interface-type* | as-*number* | **static**]	Displays the EIGRP discovered neighbors.
Router# **show ip eigrp topology** [*as-number* | [[*ip-address*] *mask*]]	Displays the EIGRP topology table for a given process.
Router# **show ip eigrp traffic** [*as-number*]	Displays the number of packets sent and received for all or a specified EIGRP process.

To enable EIGRP Stub Routing packet debugging, use the following command in privileged EXEC mode:

Command	Purpose
Router# **debug eigrp packet stub**	Displays debug information about the stub status of peer routers.

EIGRP Configuration Examples

This section contains the following examples:

- Route Summarization Example
- Route Authentication Example
- Stub Routing Example

Route Summarization Example

The following example configures route summarization on the interface and also configures the automatic summary feature. This configuration causes EIGRP to summarize network 10.0.0.0 out Ethernet interface 0 only. In addition, this example disables automatic summarization.

```
interface Ethernet 0
 ip summary-address eigrp 1 10.0.0.0 255.0.0.0
!
router eigrp 1
 network 172.16.0.0
 no auto-summary
```

Note You should not use the **ip summary-address eigrp** summarization command to generate the default route (0.0.0.0) from an interface. This causes the creation of an EIGRP summary default route to the null 0 interface with an administrative distance of 5. The low administrative distance of this default route can cause this route to displace default routes learned from other neighbors from the routing table. If the default route learned from the neighbors is displaced by the summary default route, or if the summary route is the only default route present, all traffic destined for the default route will not leave the router,

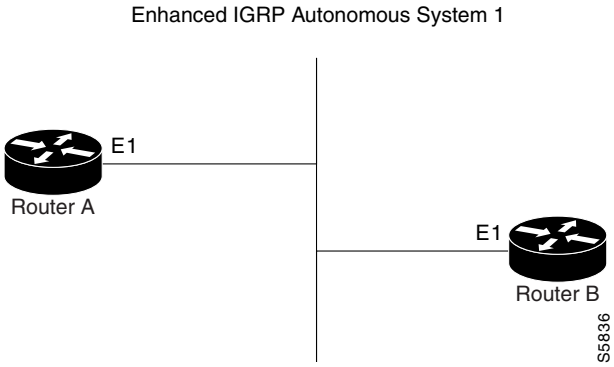
instead, this traffic will be sent to the null 0 interface where it is dropped.

The recommended way to send only the default route out a given interface is to use a **distribute-list** command. You can configure this command to filter all outbound route advertisements sent out the interface with the exception of the default (0.0.0.0).

Route Authentication Example

The following example enables MD5 authentication on EIGRP packets in autonomous system 1. Figure 52 shows the scenario.

Figure 52 EIGRP Route Authentication Scenario



Router A Configuration

```
interface ethernet 1
 ip authentication mode eigrp 1 md5
 ip authentication key-chain eigrp 1 holly
key chain holly
 key 1
  key-string 0987654321
  accept-lifetime 04:00:00 Dec 4 1996 infinite
  send-lifetime 04:00:00 Dec 4 1996 04:48:00 Dec 4 1996
 exit
 key 2
  key-string 1234567890
  accept-lifetime 04:00:00 Dec 4 1996 infinite
  send-lifetime 04:45:00 Dec 4 1996 infinite
```

Router B Configuration

```
interface ethernet 1
 ip authentication mode eigrp 1 md5
 ip authentication key-chain eigrp 1 mikel
key chain mikel
 key 1
  key-string 0987654321
  accept-lifetime 04:00:00 Dec 4 1996 infinite
  send-lifetime 04:00:00 Dec 4 1996 infinite
 exit
 key 2
  key-string 1234567890
  accept-lifetime 04:00:00 Dec 4 1996 infinite
  send-lifetime 04:45:00 Dec 4 1996 infinite
```

Router A will accept and attempt to verify the MD5 digest of any EIGRP packet with a key equal to 1. It will also accept a packet with a key equal to 2. All other MD5 packets will be dropped. Router A will send all EIGRP packets with key 2.

Router B will accept key 1 or key 2, and will send key 1. In this scenario, MD5 will authenticate.

Stub Routing Example

A router that is configured as a stub with the **eigrp stub** command shares connected and summary routing information with all neighbor routers by default. Four optional keywords can be used with the **eigrp stub** command to modify this behavior:

- **receive-only**
- **connected**
- **static**
- **summary**

This section provides configuration examples for all forms of the **eigrp stub** command. The **eigrp stub** command can be modified with several options, and these options can be used in any combination except for the **receive-only** keyword. The **receive-only** keyword will restrict the router from sharing any of its routes with any other router in that EIGRP autonomous system, and the **receive-only** keyword will not permit any other option to be specified because it prevents any type of route from being sent. The three other optional keywords (**connected**, **static**, and **summary**) can be used in any combination but cannot be used with the **receive-only** keyword. If any of these three keywords is used individually with the **eigrp stub** command, connected and summary routes will not be sent automatically.

The **connected** keyword will permit the EIGRP Stub Routing feature to send connected routes. If the connected routes are not covered by a network statement, it may be necessary to redistribute connected routes with the **redistribute connected** command under the EIGRP process. This option is enabled by default.

The **static** keyword will permit the EIGRP Stub Routing feature to send static routes. Without this option, EIGRP will not send any static routes, including internal static routes that normally would be automatically redistributed. It will still be necessary to redistribute static routes with the **redistribute static** command.

The **summary** keyword will permit the EIGRP Stub Routing feature to send summary routes. Summary routes can be created manually with the **summary address** command or automatically at a major network border router with the **auto-summary** command enabled. This option is enabled by default.

In the following example, the **eigrp stub** command is used to configure the router as a stub that advertises connected and summary routes:

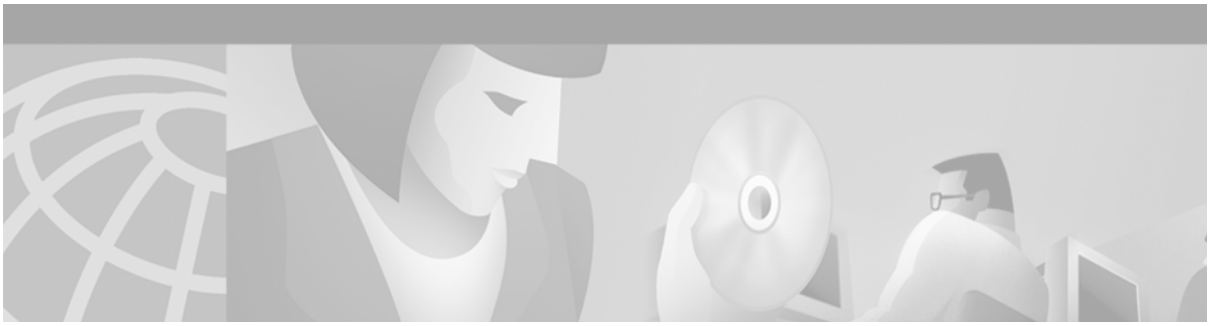
```
router eigrp 1
network 10.0.0.0
eigrp stub
```

In the following example, the **eigrp stub connected static** command is used to configure the router as a stub that advertises connected and static routes (sending summary routes will not be permitted):

```
router eigrp 1
network 10.0.0.0
eigrp stub connected static
```

In the following example, the **eigrp stub receive-only** command is used to configure the router as a stub, and connected, summary, or static routes will not be sent:

```
router eigrp 1
network 10.0.0.0 eigrp
stub receive-only
```



Configuring Integrated IS-IS

This chapter describes how to configure Integrated Intermediate System-to-Intermediate System (IS-IS). For a complete description of the integrated IS-IS commands listed in this chapter, refer to the "Integrated IS-IS Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* publication. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

IS-IS is an International Organization for Standardization (ISO) dynamic routing specification. IS-IS is described in ISO 10589. The Cisco implementation of IS-IS allows you to configure IS-IS as an IP routing protocol.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

IS-IS Configuration Task List

To configure IS-IS, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional:

- Enabling IS-IS and Assigning Areas (Required)
- Enabling IP Routing for an Area on an Interface (Optional)
- Monitoring IS-IS (Optional)

In addition, you can filter routing information and specify route redistribution. For more information about these features, see the "Filter Routing Information" and "Redistribute Routing Information" sections, respectively, in the "Configuring IP Routing Protocol-Independent Features" chapter of this document.

Enabling IS-IS and Assigning Areas

Unlike other routing protocols, enabling IS-IS requires that you create an IS-IS routing process and assign it to a specific interface, rather than to a network. You can specify more than one IS-IS routing process per Cisco router, using the multiarea IS-IS configuration syntax. You then configure the parameters for each instance of the IS-IS routing process.

Note Multiarea IS-IS is supported only for ISO CLNS.

Small IS-IS networks are built as a single area that includes all the routers in the network. As the network grows larger, it is usually reorganized into a backbone area made up of the connected set of all Level 2 routers from all areas, which is in turn connected to local areas. Within a local area, routers know how to reach all system IDs. Between areas, routers know how to reach the backbone, and the backbone routers know how to reach other areas.

Routers establish Level 1 adjacencies to perform routing within a local area (intra-area routing). Routers establish Level 2 adjacencies to perform routing between Level 1 areas (interarea routing).

Some networks use legacy equipment that supports only Level 1 routing. These devices are typically organized into many small areas that cannot be aggregated due to performance limitations. Cisco routers are used to interconnect each area to the Level 2 backbone.

A single Cisco router can participate in routing in up to 29 areas, and can perform Level 2 routing in the backbone. In general, each routing process corresponds to an area. By default, the first instance of the routing process configured performs both Level 1 and Level 2 routing. You can configure additional router instances, which are automatically treated as Level 1 areas. You must configure the parameters for each instance of the IS-IS routing process individually.

For IS-IS multiarea routing, you can configure only one process to perform Level 2 routing, although you can define up to 29 Level 1 areas for each Cisco router. If Level 2 routing is configured on any process, all additional processes are automatically configured as Level 1. You can configure this process to perform Level 1 routing at the same time. If Level 2 routing is not desired for a router instance, remove the Level 2 capability using the **is-type** router configuration command. Use the **is-type** router configuration command also to configure a different router instance as a Level 2 router.

Network entity titles (NETs) define the area addresses for the IS-IS area and the system ID of the router. Refer to the "Configuring ISO CLNS" chapter in the *Cisco IOS Apollo Domain, Banyan VINES, ISO CLNS, and XNS Configuration Guide* for a more detailed discussion of NETs.

To enable IS-IS and specify the area for each instance of the IS-IS routing process, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router isis [area tag]`	Enables IS-IS routing for the specified routing process, and places the router in router configuration mode. Use the *area tag* arguments to identify the area to which this IS-IS router instance is assigned. A value for *tag* is required if you are configuring multiple IS-IS areas. The first IS-IS instance configured is Level 1-2 by default. Later instances are automatically Level 1. You can change the level of routing to be performed by a particular routing process using the **is-type** router configuration command.
Step 2	`Router(config)# net network-entity-title`	Configures NETs for the routing process. Specify a NET for each routing process if you are configuring multiarea IS-IS. You can specify a name for a NET and for an address. **Note** Multiarea IS-IS is supported only for ISO CLNS.

See the "IS-IS Configuration Examples" section at the end of this chapter for examples of configuring IS-IS as an IP routing protocol.

Enabling IP Routing for an Area on an Interface

To enable IP routing and specify the area for each instance of the IS-IS routing process, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface interface-type interface-number`	Enters interface configuration mode.
Step 2	`Router(config-if)# ip router isis [area tag]`	Configures an IS-IS routing process for ISO Connectionless Network Service (CLNS) on an interface and attaches an area designator to the routing process.
Step 3	`Router(config-if)# ip address ip-address-mask`	Defines the IP address for the interface. An IP address is required on all interfaces in an area enabled for IS-IS if any one interface is configured for IS-IS routing.

See the "IS-IS Configuration Examples" section at the end of this chapter for examples of configuring IS-IS as an IP routing protocol.

IS-IS Interface Parameters Configuration Task List

The Cisco IS-IS implementation allows you to alter certain interface-specific IS-IS parameters. Most interface configuration commands can be configured independently from other attached routers. The **isis password** interface configuration command should configure the same password on all routers on a network. The settings of other commands (**isis hello-interval**, **isis hello-multiplier**, **isis retransmit-interval**, **isis retransmit-throttle-interval**, **isis csnp-interval**, and so on) can be different on different routers or interfaces. However, if you decide to change certain values from the defaults, it makes sense to configure them on multiple routers and interfaces.

To alter IS-IS parameters, perform the optional tasks described in the following sections:

- Configuring IS-IS Link-State Metrics (Optional)
- Setting the Advertised Hello Interval (Optional)
- Setting the Advertised CSNP Interval (Optional)
- Setting the Retransmission Interval (Optional)
- Setting the LSP Transmissions Interval (Optional)
- Setting the Retransmission Throttle Interval (Optional)
- Setting the Hello Multiplier (Optional)
- Specifying Designated Router Election (Optional)
- Specifying the Interface Circuit Type (Optional)
- Assigning a Password for an Interface (Optional)
- Limiting LSP Flooding (Optional)

Configuring IS-IS Link-State Metrics

You can configure a cost for a specified interface. You can configure the *default-metric* value for Level 1 or Level 2 routing. To configure the metric for the specified interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis metric default-metric [level-1 | level-2]`	Configures the metric (or cost) for the specified interface.

Setting the Advertised Hello Interval

You can specify the length of time (in seconds) between hello packets that the Cisco IOS software sends on the interface.

To specify the length of time between hello packets for the specified interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis hello-interval {seconds | minimal} [level-1 | level-2]`	Specifies the length of time (in seconds) between hello packets the Cisco IOS software sends on the specified interface.

The hello interval can be configured independently for Level 1 and Level 2, except on serial point-to-point interfaces. (Because only a single type of hello packet is sent on serial links, it is independent of Level 1 or Level 2.) Specify an optional level for X.25, Switched Multimegabit Data Service (SMDS), and Frame Relay multiaccess networks. X25, SMDS, ATM, and Frame Relay networks should be configured with point-to-point subinterfaces.

Setting the Advertised CSNP Interval

Complete sequence number protocol data units (CSNPs) are sent by the designated router to maintain database synchronization. You can configure the IS-IS CSNP interval for the interface.

To configure the CSNP interval for the specified interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis csnp-interval seconds {level-1 | level-2}`	Configures the IS-IS CSNP interval for the specified interface.

This feature does not apply to serial point-to-point interfaces. It applies to WAN connections if the WAN is viewed as a multiaccess meshed network.

Setting the Retransmission Interval

You can configure the number of seconds between retransmission of IS-IS link-state packets (LSPs) for point-to-point links. To set the retransmission level, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis retransmit-interval` *seconds*	Configures the number of seconds between retransmission of IS-IS LSPs for point-to-point links.

The value you specify should be an integer greater than the expected round-trip delay between any two routers on the attached network. The setting of this parameter should be conservative, or needless retransmission will result. The value should be larger for serial lines.

Setting the LSP Transmissions Interval

To configure the delay between successive IS-IS LSP transmissions, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis lsp-interval` *milliseconds*	Configures the delay between successive IS-IS LSP transmissions.

Setting the Retransmission Throttle Interval

You can configure the maximum rate at which IS-IS LSPs will be re-sent on point-to-point links, in terms of the number of milliseconds between packets. This configuration is different from the retransmission interval, which is the amount of time between successive retransmissions of the same LSP.

The retransmission throttle interval is typically not necessary, except in cases of very large networks with high point-to-point neighbor counts. To set the retransmission throttle interval, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis retransmit-throttle-interval` *milliseconds*	Configures the IS-IS LSP retransmission throttle interval.

Setting the Hello Multiplier

To specify the number of IS-IS hello packets a neighbor must miss before the router should declare the adjacency as down, use the following command in interface configuration command. The default value is 3.

Command	Purpose
`Router(config-if)# isis hello-multiplier` *multiplier* [**level-1** | **level-2**]	Sets the hello multiplier.

Specifying Designated Router Election

You can configure the priority to use for designated router election. Priorities can be configured for Level 1 and Level 2 individually.

To specify the designated router election, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis priority` *number-value* [**level-1** | **level-2**]	Configures the priority to use for designated router election.

Specifying the Interface Circuit Type

You can specify adjacency levels on a specified interface. This parameter is also referred to as the *interface circuit type*.

To specify the interface circuit type, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis circuit-type` [**level-1** | **level-1-2** | **level-2-only**]	Configures the type of adjacency desired for neighbors on the specified interface (the interface circuit type).

Assigning a Password for an Interface

You can assign different passwords for different routing levels. Specifying Level 1 or Level 2 configures the password for only Level 1 or Level 2 routing, respectively. If you do not specify a level, the default is Level 1. By default, authentication is disabled.

To configure a password for the specified level, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# isis password` *password* [**level-1** | **level-2**]	Configures the authentication password for a specified interface.

Limiting LSP Flooding

Limiting LSP flooding is important to IS-IS networks in general, and is not limited to configuring multiarea IS-IS networks. In a network with a high degree of redundancy, such as a fully meshed set of point-to-point links over a nonbroadcast multiaccess (NBMA) transport, flooding of LSPs can limit network scalability. You can reduce LSP flooding in two ways:

- Blocking Flooding on Specific Interfaces

  The advantage of full blocking over mesh groups is that it is easier to configure and understand, and fewer LSPs are flooded. Blocking flooding on all links permits the best scaling performance, but results in a less robust network structure. Permitting flooding on all links results in poor scaling performance.

- Configuring Mesh Groups

  The advantage of mesh groups over full blocking is that mesh groups allow LSPs to be flooded over one hop to all routers on the mesh, while full blocking allows some routers to receive LSPs over multiple hops. This relatively small delay in flooding can have an impact on convergence times, but the delay is negligible compared to overall convergence times.

Blocking Flooding on Specific Interfaces

You can completely block flooding (full blocking) on specific interfaces, so that new LSPs will not be flooded out over those interfaces. However, if flooding is blocked on a large number of links, and all remaining links go down, routers cannot synchronize their link-state databases even though there is connectivity to the rest of the network. When the link-state database is no longer updated, routing loops usually result.

To use CSNPs on selected point-to-point links to synchronize the link-state database, configure a CSNP interval using the **isis csnp-interval** interface configuration command on selected point-to-point links over which normal flooding is blocked. You should use CSNPs for this purpose only as a last resort.

Configuring Mesh Groups

Configuring mesh groups (a set of interfaces on a router) can help to limit redundant flooding. All routers reachable over the interfaces in a particular mesh group are assumed to be densely connected (each router has many links to other routers), where many links can fail without isolating one or more routers from the network.

Normally, when a new LSP is received on an interface, it is flooded out over all other interfaces on the router. When the new LSP is received over an interface that is part of a mesh group, the new LSP will not be flooded out over the other interfaces that are part of that same mesh group.

Mesh groups rely on a full mesh of links between a group of routers. If one or more links in the full mesh go down, the full mesh is broken, and some routers might miss new LSPs, even though there is connectivity to the rest of the network. When you configure mesh groups to optimize or limit LSP flooding, be sure to select alternative paths over which to flood in case interfaces in the mesh group go down.

To minimize the possibility of incomplete flooding, you should allow unrestricted flooding over at least a minimal set of links in the mesh. Selecting the smallest set of logical links that covers all physical paths results in very low flooding, but less robustness. Ideally you should select only enough links to ensure that LSP flooding is not detrimental to scaling performance, but enough links to ensure that under most failure scenarios no router will be logically disconnected from the rest of the network.

Miscellaneous IS-IS Parameters Configuration Task List

The following tasks differ from the preceding interface-specific IS-IS tasks because they configure IS-IS itself, rather than the interface.

To configure optional IS-IS parameters as described in the following sections:

- Generating a Default Route (Required)
- Specifying the System Type (Optional)
- Configuring IS-IS Authentication Passwords (Optional)
- Summarizing Address Ranges (Optional)
- Setting the Overload Bit (Optional)
- Changing the Routing Level for an Area (Optional)
- Tuning LSP Interval and Lifetime (Optional)
- Customizing IS-IS Throttling of LSP Generation, SPF Calculation, and PRC (Optional)
- Modifying the Output of show Commands (Optional)

Generating a Default Route

You can force a default route into an IS-IS routing domain. Whenever you specifically configure redistribution of routes into an IS-IS routing domain, the Cisco IOS software does not, by default, redistribute the *default route* into the IS-IS routing domain. The following command generates a default route into IS-IS, which can be controlled by a route map. You can use the route map to identify the level into which the default route is to be announced, and you can specify other filtering options configurable under a route map. You can use a route map to conditionally advertise the default route, depending on the existence of another route in the routing table of the router.

To generate a default route, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# default-information originate [route-map map-name]`	Forces a default route into the IS-IS routing domain.

See also the discussion of redistribution of routes in the "Configuring IP Routing Protocol-Independent Features" chapter of this document.

Specifying the System Type

You can configure the router to act as a Level 1 (intra-area) router, as both a Level 1 router and a Level 2 (interarea) router, or as an interarea router only.

To specify router level support, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# is-type {level-1 | level-1-2 | level-2-only}`	Configures the system type (area or backbone router).

Configuring IS-IS Authentication Passwords

You can assign passwords to areas and domains.

The area authentication password is inserted in Level 1 (station router level) LSPs, and the routing domain authentication password is inserted in Level 2 (area router level) LSPs.

To configure either area or domain authentication passwords, use the following commands in router configuration mode, as needed:

Command	Purpose
`Router(config-router)# area-password password`	Configures the area authentication password.
`Router(config-router)# domain-password password`	Configures the routing domain authentication password.

Summarizing Address Ranges

You can create aggregate addresses that are represented in the routing table by a summary address. This process is called *route summarization*. One summary address can include multiple groups of addresses for a given level. Routes learned from other routing protocols also can be summarized. The metric used to advertise the summary is the smallest metric of all the more-specific routes.

To create a summary of addresses for a given level, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# summary-address address mask {level-1 | level-1-2 | level-2}`	Creates a summary of addresses for a given level.

Setting the Overload Bit

You can configure the router to set the overload bit (also known as the hippity bit) in its nonpseudonode LSPs. Normally the setting of the overload bit is allowed only when a router runs into problems. For example, when a router is experiencing a memory shortage, the link-state database may not be complete, resulting in an incomplete or inaccurate routing table. By setting the overload bit in their LSPs, other routers can ignore the unreliable router in their shortest path first (SPF) calculations until the router has recovered from its problems.

The result will be that no paths through this router are seen by other routers in the IS-IS area. However, IP and CLNS prefixes directly connected to this router will be still be reachable.

This command can be useful when you want to connect a router to an IS-IS network, but do not want real traffic flowing through it under any circumstances. Examples are as follows:

- A test router in the lab, connected to a production network.
- A router configured as an LSP flooding server, for example, on an NBMA network, in combination with the mesh-group feature.
- A router that is aggregating virtual circuits (VCs) used only for network management. In this case, the network management stations must be on a network directly connected to the router with the **set-overload-bit** router configuration command configured.

Unless you specify the **on-startup** keyword, this command sets the overload bit immediately and it remains set until the **no set-overload-bit** command is specified. If you specify the **on-startup** keyword, you must indicate whether it is set for a specified number of *seconds* or until BGP has converged. If BGP does not signal IS-IS that it has converged, IS-IS will turn off the overload bit after 10 minutes.

In addition to setting the overload bit, you might also want to suppress certain types of IP prefix advertisements from LSPs. For example, allowing IP prefix propagation between Level1 and Level 2 effectively makes a node a transit node for IP traffic, which may be undesirable. The **suppress** keyword used with the **interlevel** or **external** keyword (or both) accomplishes that suppression while the overload bit is set.

To set the overload bit, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# set-overload-bit [on-startup {seconds | wait-for-bgp}] [suppress {[interlevel] [external]}]`	Sets the overload bit.

Changing the Routing Level for an Area

You can change the routing level configured for an area using the **is-type** router configuration command. If the router instance has been configured for a Level 1-2 area (the default for the first instance of the IS-IS routing process in a Cisco router), you can remove Level 2 (interarea) routing for the area using the **is-type** command and change the routing level to Level 1 (intra-area). You can also configure Level 2 routing for an area using the **is-type** command, but the instance of the IS-IS router configured for Level 2 on the Cisco router must be the only instance configured for Level 2.

To change the routing level for an IS-IS routing process in a given area, use the following command in router configuration mode:

Command	Purpose
`Router (config)# is-type {level-1 | level-1-2 | level-2-only}`	Configures the routing level for an instance of the IS-IS routing process.

Tuning LSP Interval and Lifetime

By default, the router sends a periodic LSP refresh every 15 minutes. LSPs remain in a database for 20 minutes by default. If they are not refreshed by that time, they are deleted. You can change the LSP refresh interval or the LSP lifetime. The LSP interval should be less than the LSP lifetime or else LSPs will time out before they are refreshed. The software will adjust the LSP refresh interval if necessary to prevent the LSPs from timing out.

To change the LSP refresh interval or lifetime, use the appropriate command in router configuration mode:

Command	Purpose
`Router (config-router)# lsp-refresh-interval seconds`	Sets the LSP refresh interval.
`Router (config-router)# max-lsp-lifetime seconds`	Sets the maximum time that link-state packets (LSPs) can remain in a router's database without being refreshed.

Customizing IS-IS Throttling of LSP Generation, SPF Calculation, and PRC

Partial Route Computation (PRC)

PRC is the software's process of calculating routes without performing an SPF calculation. This is possible when the topology of the routing system itself has not changed, but a change is detected in the information announced by a particular IS or when it is necessary to attempt to reinstall such routes in the RIB.

Benefits of Throttling IS-IS LSP Generation, SPF Calculation, and PRC

IS-IS throttles three main events: link-state PDU (LSP) generation, Shortest Part First (SPF) computation, and partial route computation (PRC). Throttling slows down the frequency of these events during times of network instability. Although throttling these events slows down network convergence, not throttling could result in a network not functioning. If network topology is unstable, throttling slows down the scheduling of these intervals until the topology becomes stable.

The throttling of LSP generation prevents flapping links from cause many LSPs to be flooded through the network. The throttling of SPF computation and PRC prevents the router from crashing from the demand of too many calculations.

How Throttling of IS-IS LSP Generation, SPF Calculation, and PRC Works

IS-IS throttling of LSP generation, SPF calculations, and PRC occurs by default. You can customize the throttling of these events with the **lsp-gen-interval, spf-interval**, and **prc-interval** commands, respectively.

The arguments in each command behave similarly. For each command:

- The first argument indicates the maximum number of seconds between LSP generations or calculations.
- The second argument indicates the initial wait time (in milliseconds) before running the first LSP generation or calculation.
- The third argument indicates the minimum amount of time to wait (in milliseconds) between the first and second LSP generation or calculation. (In addition to this wait time, there might be some other system overhead between LSP generations or calculations.)

Each subsequent wait interval is twice as long as the previous one until the wait interval reaches the maximum wait time specified, upon which the wait interval remains constant. After the network calms down and there are no triggers for 2 times the maximum interval, fast behavior is restored (the initial wait time).

Other commands are available to control the delay between successive LSPs, the retransmission of the same LSA, and the retransmission of LSPs on a point-to-point interface.

Perform this task to customize throttling of LSP generation, SPF calculation, PRC, or any combination of the three, beginning in router configuration mode:

Command	Purpose
`Router(config-router)# lsp-gen-interval [level-1 | level-2] lsp-max-wait [lsp-initial-wait lsp-second-wait]`	Sets IS-IS LSP generation throttling timers. • The default *lsp-max-wait* interval is 5 seconds. • The default *lsp-initial-wait* interval is 50 milliseconds. • The default *lsp-second-wait* interval is 5000 milliseconds.
`Router(config-router)# spf-interval [level-1 | level-2] spf-max-wait [spf-initial-wait spf-second-wait]`	Sets IS-IS SPF throttling timers. • The default *spf-max-wait* interval is 10 seconds. • The default *spf-initial-wait* interval is 5500 milliseconds. • The default *spf-second-wait* interval is 5500 milliseconds.
`Router(config-router)# prc-interval prc-max-wait [prc-initial-wait prc-second-wait]`	Sets IS-IS partial route computation throttling timers. • The default *prc-max-wait* interval is 10 seconds. • The default *prc-initial-wait* interval is 2000 milliseconds. • The default *prc-second-wait* interval is 5000 milliseconds.

Modifying the Output of show Commands

To customize display output when the IS-IS multiarea feature is used, making the display easier to read, use the following command in EXEC mode:

Command	Purpose
`Router# isis display delimiter [return count | character count]`	Specifies the delimiter to be used to separate displays of information about individual IS-IS areas.

For example, the following command causes information about individual areas to be separated by 14 dashes (-) in the display:

```
isis display delimiter - 14
```

The output for a configuration with two Level 1 areas and one Level 2 area configured is as follows:

```
dtp-5# show clns neighbors
--------------
Area L2BB:
System Id      Interface   SNPA            State  Holdtime  Type Protocol
0000.0000.0009 Tu529       172.21.39.9     Up     25        L1L2 IS-IS
--------------
```

```
Area A3253-01:
System Id      Interface   SNPA            State  Holdtime  Type Protocol
0000.0000.0053 Et1         0060.3e58.ccdb  Up     22        L1   IS-IS
0000.0000.0003 Et1         0000.0c03.6944  Up     20        L1   IS-IS
--------------
Area A3253-02:
System Id      Interface   SNPA            State  Holdtime  Type Protocol
0000.0000.0002 Et2         0000.0c03.6bc5  Up     27        L1   IS-IS
0000.0000.0053 Et2         0060.3e58.ccde  Up     24        L1   IS-IS
```

Monitoring IS-IS

To monitor the IS-IS tables and databases, use the following commands in EXEC mode, as needed:

Command	Purpose
Router# **show isis database** [**level-1**] [**level-2**] [**l1**] [**l2**] [**detail**] [**lspid**]	Displays the IS-IS link-state database.
Router# **show isis** *area-tag* **routes**	Displays the IS-IS Level 1 routing table.
Router# **show isis spf-log**	Displays how often and why the router has run a full SPF calculation.
Router# **show isis** *area-tag* **topology**	Displays a list of all connected routers in all areas.

IS-IS Configuration Examples

This section includes the following examples:

- Enabling IS-IS Configuration Example
- Multiarea IS-IS Configuration for CLNS Network Example
- IS-IS Throttle Timers Example

Enabling IS-IS Configuration Example

The following example shows how to configure three routers to run IS-IS as an IP routing protocol. Figure 53 illustrates the example configuration.

Router A Configuration

```
router isis
 net 49.0001.0000.0000.000a.00
interface ethernet 0
 ip router isis
interface serial 0
 ip router isis
```

Router B Configuration

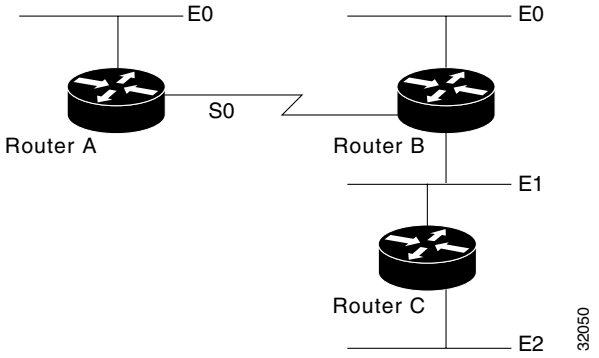
```
router isis
 net 49.0001.0000.0000.000b.00
interface ethernet 0
 ip router isis
interface ethernet 1
 ip router isis
```

```
interface serial 0
 ip router isis
```

Router C Configuration

```
router isis
 net 49.0001.0000.0000.000c.00
interface ethernet 1
 ip router isis
interface ethernet 2
 ip router isis
```

Figure 53 IS-IS Routing



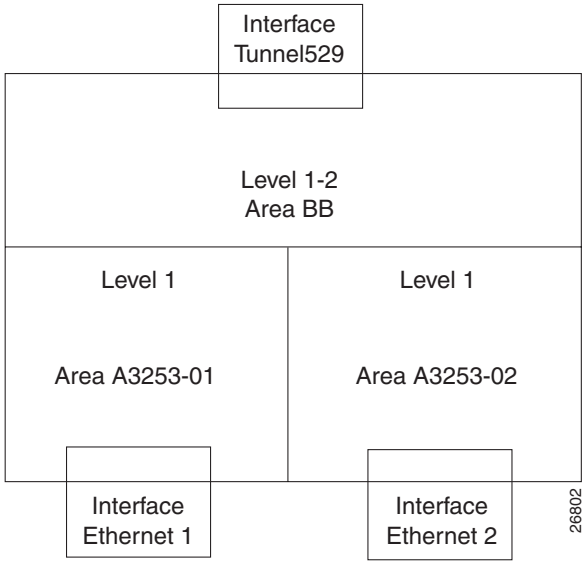
Multiarea IS-IS Configuration for CLNS Network Example

The following example shows a multiarea IS-IS configuration with two Level 1 areas and one Level 1-2 area. Figure 54 illustrates this configuration.

```
clns routing

.
.
.

interface Tunnel529
 ip address 10.0.0.5 255.255.255.0
 ip router isis BB
 clns router isis BB

interface Ethernet1
 ip address 10.1.1.5 255.255.255.0
 ip router isis A3253-01
 clns router isis A3253-01
!
interface Ethernet2
 ip address 10.2.2.5 255.255.255.0
 ip router isis A3253-02
 clns router isis A3253-02

.
.
.
```

```
router isis BB                          ! Defaults to "is-type level-1-2"
 net 49.2222.0000.0000.0005.00
!
router isis A3253-01
 net 49.0553.0001.0000.0000.0005.00
 is-type level-1
!
router isis A3253-02
 net 49.0553.0002.0000.0000.0005.00
 is-type level-1
```

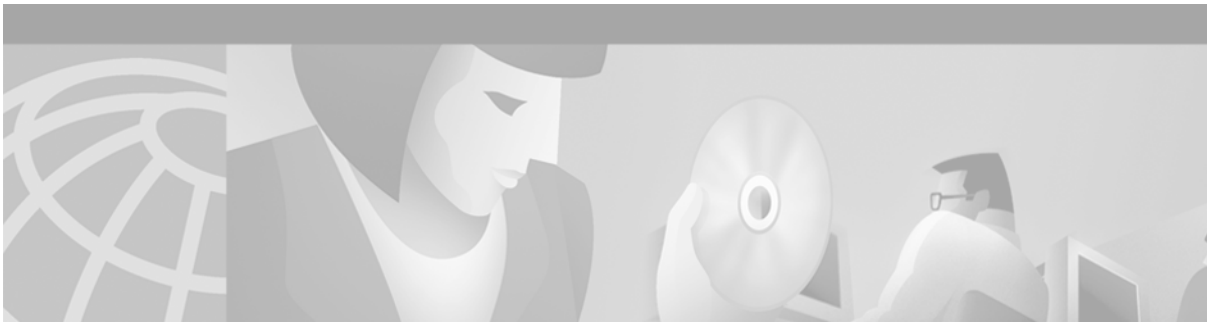
Figure 54 Multiarea IS-IS Configuration with Three Level 1 Areas and One Level 2 Area



IS-IS Throttle Timers Example

This example shows a system configured with IS-IS throttling of LSP generations, SPF calculations and PRC:

```
router isis
 spf-interval 5 10 20
 prc-interval 5 10 20
 lsp-gen-interval 2 50 100
```



Configuring BGP

This chapter describes how to configure Border Gateway Protocol (BGP). For a complete description of the BGP commands in this chapter, refer to the "BGP Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols*. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online. For multiprotocol BGP configuration information and examples, refer to the "Configuring Multiprotocol BGP Extensions for IP Multicast" chapter of the *Cisco IOS IP Configuration Guide*. For multiprotocol BGP command descriptions, refer to the "Multiprotocol BGP Extensions for IP Multicast Commands" chapter of the *Cisco IOS IP Command Reference*.

BGP, as defined in RFCs 1163 and 1267, is an Exterior Gateway Protocol (EGP). It allows you to set up an interdomain routing system that automatically guarantees the loop-free exchange of routing information between autonomous systems.

For protocol-independent features, see the chapter "Configuring IP Routing Protocol-Independent Features" in this book.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

The Cisco BGP Implementation

In BGP, each route consists of a network number, a list of autonomous systems that information has passed through (called the *autonomous system path*), and a list of other *path attributes*. We support BGP Versions 2, 3, and 4, as defined in RFCs 1163, 1267, and 1771, respectively.

The primary function of a BGP system is to exchange network reachability information with other BGP systems, including information about the list of autonomous system paths. This information can be used to construct a graph of autonomous system connectivity from which routing loops can be pruned and with which autonomous system-level policy decisions can be enforced.

You can configure the value for the Multi Exit Discriminator (MED) metric attribute using route maps. (The name of this metric for BGP Versions 2 and 3 is INTER_AS_METRIC.) When an update is sent to an internal BGP (iBGP) peer, the MED is passed along without any change. This action enables all the peers in the same autonomous system to make a consistent path selection.

A next hop router address is used in the NEXT_HOP attribute, regardless of the autonomous system of that router. The Cisco IOS software automatically calculates the value for this attribute.

Transitive, optional path attributes are passed along to other BGP-speaking routers.

BGP Version 4 supports classless interdomain routing (CIDR), which lets you reduce the size of your routing tables by creating aggregate routes, resulting in *supernets*. CIDR eliminates the concept of network classes within BGP and supports the advertising of IP prefixes. CIDR routes can be carried by Open Shortest Path First (OSPF), Enhanced IGRP (EIGRP), and Intermediate System-to-Intermediate System (ISIS)-IP, and Routing Information Protocol (RIP).

See the "BGP Route Map Examples" section at the end of this chapter for examples of how to use route maps to redistribute BGP Version 4 routes.

How BGP Selects Paths

A router running Cisco IOS Release 12.0 or later does not select or use an iBGP route unless both of the following conditions are true:

- The router has a route available to the next hop router:
- The router has received synchronization via an IGP (unless IGP synchronization has been disabled).

BGP bases its decision process on the attribute values. When faced with multiple routes to the same destination, BGP chooses the best route for routing traffic toward the destination. The following process summarizes how BGP chooses the best route.

1. If the next hop is inaccessible, do not consider it.

   This decision is why it is important to have an IGP route to the next hop.

2. If the path is internal, synchronization is enabled, and the route is not in the IGP, do not consider the route.
3. Prefer the path with the largest weight (weight is a Cisco proprietary parameter).
4. If the routes have the same weight, prefer the route with the largest local preference.
5. If the routes have the same local preference, prefer the route that was originated by the local router.

   For example, a route might be originated by the local router using the **network bgp** router configuration command, or through redistribution from an IGP.

6. If the local preference is the same, or if no route was originated by the local router, prefer the route with the shortest autonomous system path.
7. If the autonomous system path length is the same, prefer the route with the lowest origin code (IGP < EGP < INCOMPLETE).
8. If the origin codes are the same, prefer the route with the lowest MED metric attribute.

   This comparison is only made if the neighboring autonomous system is the same for all routes considered, unless the **bgp always-compare-med** router configuration command is enabled.

   Note The most recent Internet Engineering Task Force (IETF) decision regarding BGP MED assigns a value of infinity to the missing MED, making the route lacking the MED variable the least preferred. The default behavior of BGP routers running Cisco IOS software is to treat routes without the MED attribute as having a MED of 0, making the route lacking the MED variable the most preferred. To configure the router to conform to the IETF standard, use the **bgp bestpath med missing-as-worst** router configuration command**.**

9. Prefer the external BGP (eBGP) path over the iBGP path.

   All confederation paths are considered internal paths.

10. Prefer the route that can be reached through the closest IGP neighbor (the lowest IGP metric).

    The router will prefer the shortest internal path within the autonomous system to reach the destination (the shortest path to the BGP next hop).

11. If the following conditions are all true, insert the route for this path into the IP routing table:
    - Both the best route and this route are external.
    - Both the best route and this route are from the same neighboring autonomous system.
    - The **maximum-paths** router configuration command is enabled.

    Note eBGP load sharing can occur at this point, which means that multiple paths can be installed in the forwarding table.

12. If multipath is not enabled, prefer the route with the lowest IP address value for the BGP router ID.

    The router ID is usually the highest IP address on the router or the loopback (virtual) address, but might be implementation-specific.

BGP Multipath Support

When a BGP speaker learns two identical eBGP paths for a prefix from a neighboring autonomous system, it will choose the path with the lowest route ID as the best path. This best path is installed in the IP routing table. If BGP multipath support is enabled and the eBGP paths are learned from the same neighboring autonomous system, instead of one best path being picked, multiple paths are installed in the IP routing table.

During packet switching, depending on the switching mode, either per-packet or per-destination load balancing is performed among the multiple paths. A maximum of six paths is supported. The **maximum-paths** router configuration command controls the number of paths allowed. By default, BGP will install only one path to the IP routing table.

Basic BGP Configuration Task List

The BGP configuration tasks are divided into basic and advanced tasks, which are described in the following sections. The basic tasks described in the first two sections are required to configure BGP; the basic and advanced tasks in the remaining sections are optional:

- Enabling BGP Routing (Required)
- Configuring BGP Neighbors (Required)
- Managing Routing Policy Changes (Optional)
- Verifying BGP Soft Reset (Optional)
- Configuring BGP Interactions with IGPs (Optional)
- Configuring BGP Weights (Optional)
- Disabling Autonomous System Path Comparison (Optional)
- Configuring BGP Route Filtering by Neighbor (Optional)
- Configuring BGP Filtering Using Prefix Lists (Optional)
- Configuring BGP Path Filtering by Neighbor (Optional)

- Disabling Next Hop Processing on BGP Updates (Optional)
- Configuring the BGP Version (Optional)
- Configuring the MED Metric (Optional)

Advanced BGP Configuration Task List

Advanced, optional BGP configuration tasks are described in the following sections:

- Using Route Maps to Modify Updates (Optional)
- Resetting eBGP Connections Immediately upon Link Failure (Optional)
- Configuring Aggregate Addresses (Optional)
- Disabling Automatic Summarization of Network Numbers (Optional)
- Configuring BGP Community Filtering (Optional)
- Configuring BGP Conditional Advertisement (Optional)
- Configuring a Routing Domain Confederation (Optional)
- Configuring a Route Reflector (Optional)
- Configuring BGP Peer Groups (Optional)
- Disabling a Peer or Peer Group (Optional)
- Indicating Backdoor Routes (Optional)
- Modifying Parameters While Updating the IP Routing Table (Optional)
- Setting Administrative Distance (Optional)
- Adjusting BGP Timers (Optional)
- Changing the Default Local Preference Value (Optional)
- Redistributing Network 0.0.0.0 (Optional)
- Configuring the Router to Consider a Missing MED as Worst Path (Optional)
- Selecting Path Based on MEDs from Other Autonomous Systems (Optional)
- Configuring the Router to Use the MED to Choose a Path from Subautonomous System Paths (Optional)
- Configuring the Router to Use the MED to Choose a Path in a Confederation (Optional)
- Configuring Route Dampening (Optional)

For information on configuring features that apply to multiple IP routing protocols (such as redistributing routing information), see the chapter “Configuring IP Routing Protocol-Independent Features.”

Configuring Basic BGP Features

The tasks described in this section are for configuring basic BGP features.

Enabling BGP Routing

To enable BGP routing and establish a BGP routing process, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp as-number`	Enables a BGP routing process, which places the router in router configuration mode.
Step 2	`Router(config-router)# network network-number [mask network-mask] [route-map route-map-name]`	Flags a network as local to this autonomous system and enters it to the BGP table.

Note For exterior protocols, a reference to an IP network from the **network** router configuration command controls only which networks are advertised. This behavior is in contrast to IGP, such as IGRP, which also use the **network** command to determine where to send updates.

Note The **network** command is used to inject IGP routes into the BGP table. The *network-mask* portion of the command allows supernetting and subnetting. The resources of the router, such as configured NVRAM or RAM, determine the upper limit of the number of **network** commands you can use. Alternatively, you could use the **redistribute** router configuration command to achieve the same result.

Configuring BGP Neighbors

Like other EGPs, BGP must completely understand the relationships it has with its neighbors. Therefore, this task is required.

BGP supports two kinds of neighbors: internal and external. *Internal neighbors* are in the same autonomous system; *external neighbors* are in different autonomous systems. Normally, external neighbors are adjacent to each other and share a subnet, while internal neighbors may be anywhere in the same autonomous system.

To configure BGP neighbors, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor {ip-address | peer-group-name} remote-as as-number`	Specifies a BGP neighbor.

See the "BGP Neighbor Configuration Examples" section at the end of this chapter for an example of configuring BGP neighbors.

Managing Routing Policy Changes

Routing policies for a peer include all the configurations such as route-map, distribute-list, prefix-list, and filter-list that may impact inbound or outbound routing table updates. Whenever there is a change in the routing policy, the BGP session must be soft cleared, or soft reset, for the new policy to take effect. Performing inbound reset enables the new inbound policy to take effect. Performing outbound reset causes the new local outbound policy take effect without resetting the BGP session. As a new set of updates is sent during outbound policy reset, a new inbound policy of the neighbor can also take effect.

There are two types of reset, hard reset and soft reset. Table 8 lists their advantages and disadvantages.

Table 8 Advantages and Disadvantages of Hard and Soft Resets

Type of Reset	Advantages	Disadvantages
Hard reset	No memory overhead.	The prefixes in the BGP, IP, and Forwarding Information Base (FIB) tables provided by the neighbor are lost. Not recommended.
Outbound soft reset	No configuration, no storing of routing table updates. The procedure for an outbound reset is described in the section "Configuring BGP Soft Reset Using Stored Routing Policy Information."	Does not reset inbound routing table updates.
Dynamic inbound soft reset	Does not clear the BGP session and cache. Does not require storing of routing table updates, and has no memory overhead.	Both BGP routers must support the route refresh capability (in Cisco IOS Release 12.1 and later releases).
Configured inbound soft reset (uses the **neighbor soft-reconfiguration** router configuration command)	Can be used when both BGP routers do not support the automatic route refresh capability.	Requires preconfiguration. Stores all received (inbound) routing policy updates without modification; is memory-intensive. Recommended only when absolutely necessary, such as when both BGP routers do not support the automatic route refresh capability.

Once you have defined two routers to be BGP neighbors, they will form a BGP connection and exchange routing information. If you subsequently change a BGP filter, weight, distance, version, or timer, or make a similar configuration change, you must reset BGP connections for the configuration change to take effect.

A soft reset updates the routing table for inbound and outbound routing updates. Cisco IOS software Release 12.1 and later releases support soft reset without any prior configuration. This soft reset allows the dynamic exchange of route refresh requests and routing information between BGP routers, and the subsequent re-advertisement of the respective outbound routing table. There are two types of soft reset:

- When soft reset is used to generate inbound updates from a neighbor, it is called dynamic inbound soft reset.
- When soft reset is used to send a new set of updates to a neighbor, it is called outbound soft reset.

To use soft reset without preconfiguration, both BGP peers must support the soft route refresh capability, which is advertised in the OPEN message sent when the peers establish a TCP session. Routers running Cisco IOS software releases prior to Release 12.1 do not support the route refresh capability and must clear the BGP session using the **neighbor soft-reconfiguration** router configuration command, described in "Configuring BGP Soft Reset Using Stored Routing Policy Information." Clearing the BGP session in this way will have a negative impact upon network operations and should only be used as a last resort.

Resetting a Router Using BGP Dynamic Inbound Soft Reset

If both the local BGP router and the neighbor router support the route refresh capability, you can perform a dynamic soft inbound reset. This type of reset has the following advantages over a soft inbound reset using stored routing update information:

- Does not require preconfiguration
- Does not require additional memory for storing routing update information

To determine whether a router supports the route refresh capability, use the **show ip bgp neighbors** command in EXEC mode:

Command	Purpose
`Router# show ip bgp neighbors` *ip-address*	Displays whether a neighbor supports the route refresh capability. If the specified router supports the route refresh capability, the following message is displayed: Received route refresh capability from peer.

If all the BGP routers support the route refresh capability, you can use the dynamic soft reset method for resetting the inbound routing table. To perform a dynamic soft reset of the inbound routing table, use the following command in EXEC mode:

Command	Purpose
`Router# clear ip bgp {* |` *neighbor-address* `|` *peer-group-name*`}` **soft in**	Performs a dynamic soft reset on the connection specified in the command. The *neighbor-address* argument specifies the connection to be reset. Use the * keyword to specify that all connections be reset.

See the "BGP Soft Reset Examples" section at the end of this chapter for examples of both types of BGP soft resets.

Resetting a Router Using BGP Outbound Soft Reset

Outbound soft resets do not require any preconfiguration. Using the **soft** keyword specifies that a soft reset be performed. To perform an outbound soft reset, use the following command in EXEC mode:

Command	Purpose
`Router# clear ip bgp {* | neighbor-address | peer-group-name} soft out`	Performs a soft reset on the connection specified in the command. The *neighbor-address* argument specifies the connection to be reset. Use the * keyword to specify that all connections be reset.

Configuring BGP Soft Reset Using Stored Routing Policy Information

If all of the BGP routers in the connection do not support the route refresh capability, use the soft reset method that generates a new set of inbound routing table updates from information previously stored. To initiate storage of inbound routing table updates, you must first preconfigure the router using the **neighbor soft-reconfiguration** router configuration command. The **clear ip bgp EXEC** command initiates the soft reset, which generates a new set of inbound routing table updates using the stored information.

Remember that the memory requirements for storing the inbound update information can become quite large.To configure BGP soft reset using stored routing policy information, use the following commands beginning in router configuration mode:

	Command	Purpose
Step 1	`Router(config-router)# neighbor {ip-address | peer-group-name} soft-reconfiguration inbound`	Resets the BGP session and initiates storage of inbound routing table updates from the specified neighbor or peer group. From that point forward, a copy of the BGP routing table for the specified neighbor or peer group is maintained on the router. The Cisco implementation of BGP supports BGP Versions 2, 3, and 4. If the neighbor does not accept default Version 4, dynamic version negotiation is implemented to negotiate down to Version 2. If you specify a BGP peer group by using the *peer-group-name* argument, all members of the peer group will inherit the characteristic configured with this command.
Step 2	`Router# clear ip bgp {* | neighbor-address | peer-group-name} soft in`	Performs a soft reset on the connection specified in the command, using the stored routing table information for that connection.

See the "BGP Path Filtering by Neighbor Examples" section at the end of this chapter for an example of BGP path filtering by neighbor.

Verifying BGP Soft Reset

To verify whether a soft reset is successful and check information about the routing table and about BGP neighbors, perform the following steps:

Step 1 Enter the **show ip bgp** EXEC command to display entries in the BGP routing table. The following output shows that the peer supports the route refresh capability:

```
Router# show ip bgp

BGP table version is 5, local router ID is 10.0.33.34
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 1.0.0.0          0.0.0.0                  0         32768 ?
*  2.0.0.0          10.0.33.35              10             0 35 ?
*>                  0.0.0.0                  0         32768 ?
*  10.0.0.0         10.0.33.35              10             0 35 ?
*>                  0.0.0.0                  0         32768 ?
*> 192.168.0.0/16   10.0.33.35              10             0 35 ?
```

Step 2 Enter the **show ip bgp neighbors** EXEC command to display information about the BGP and TCP connections to neighbors:

```
Router# show ip bgp neighbors 171.69.232.178

BGP neighbor is 172.16.232.178,  remote AS 35, external link
  BGP version 4, remote router ID 192.168.3.3
  BGP state = Established, up for 1w1d
  Last read 00:00:53, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received
    Address family IPv4 Unicast: advertised and received
    Address family IPv4 Multicast: advertised and received
  Received 12519 messages, 0 notifications, 0 in queue
  Sent 12523 messages, 0 notifications, 0 in queue
  Route refresh request: received 0, sent 0
  Minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  BGP table version 5, neighbor version 5
  Index 1, Offset 0, Mask 0x2
  Community attribute sent to this neighbor
  Inbound path policy configured
  Outbound path policy configured
  Route map for incoming advertisements is uni-in
  Route map for outgoing advertisements is uni-out
  3 accepted prefixes consume 108 bytes
  Prefix advertised 6, suppressed 0, withdrawn 0

 For address family: IPv4 Multicast
  BGP table version 5, neighbor version 5
  Index 1, Offset 0, Mask 0x2
  Inbound path policy configured
  Outbound path policy configured
  Route map for incoming advertisements is mul-in
  Route map for outgoing advertisements is mul-out
  3 accepted prefixes consume 108 bytes
  Prefix advertised 6, suppressed 0, withdrawn 0

  Connections established 2; dropped 1
  Last reset 1w1d, due to Peer closed the session
```

```
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Local host: 172.16.232.178, Local port: 179
Foreign host: 172.16.232.179, Foreign port: 11002

Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x2CF49CF8):
Timer          Starts    Wakeups            Next
Retrans         12518          0             0x0
TimeWait            0          0             0x0
AckHold         12514      12281             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0

iss:  273358651  snduna:  273596614  sndnxt:  273596614     sndwnd:  15434
irs:  190480283  rcvnxt:  190718186  rcvwnd:      15491  delrcvwnd:    893

SRTT: 300 ms, RTTO: 607 ms, RTV: 3 ms, KRTT: 0 ms
minRTT: 0 ms, maxRTT: 300 ms, ACK hold: 200 ms
Flags: passive open, nagle, gen tcbs

Datagrams (max data segment is 1460 bytes):
Rcvd: 24889 (out of order: 0), with data: 12515, total data bytes: 237921
Sent: 24963 (retransmit: 0), with data: 12518, total data bytes: 237981
```

Configuring BGP Interactions with IGPs

If your autonomous system will be passing traffic through it from another autonomous system to a third autonomous system, make sure that your autonomous system is consistent about the routes that it advertises. For example, if your BGP were to advertise a route before all routers in your network had learned about the route through your IGP, your autonomous system could receive traffic that some routers cannot yet route. To prevent this condition from occurring, BGP must wait until the IGP has propagated routing information across your autonomous system, thus causing BGP to be synchronized with the IGP. Synchronization is enabled by default.

In some cases, you need not synchronize. If you will not be passing traffic from a different autonomous system through your autonomous system, or if all routers in your autonomous system will be running BGP, you can disable synchronization. Disabling this feature can allow you to carry fewer routes in your IGP and allow BGP to converge more quickly. To disable synchronization, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no synchronization`	Disables synchronization between BGP and an IGP.

See the "BGP Path Filtering by Neighbor Examples" section at the end of this chapter for an example of BGP synchronization.

In general, you will not want to redistribute most BGP routes into your IGP. A common design is to redistribute one or two routes and to make them exterior routes in IGRP, or have your BGP speaker generate a default route for your autonomous system. When redistributing from BGP into IGP, only the routes learned using eBGP get redistributed.

In most circumstances, you also will not want to redistribute your IGP into BGP. List the networks in your autonomous system with **network** router configuration commands and your networks will be advertised. Networks that are listed this way are referred to as *local networks* and have a BGP origin attribute of "IGP." They must appear in the main IP routing table and can have any source; for example, they can be directly connected or learned via an IGP. The BGP routing process periodically scans the main IP routing table to detect the presence or absence of local networks, updating the BGP routing table as appropriate.

If you do perform redistribution into BGP, you must be very careful about the routes that can be in your IGP, especially if the routes were redistributed from BGP into the IGP elsewhere. Redistributing routes from BGP into the IGP elsewhere creates a situation where BGP is potentially injecting information into the IGP and then sending such information back into BGP, and vice versa. Incorrectly redistributing routes into BGP can result in the loss of critical information, such as the autonomous system path, that is required for BGP to function properly.

Networks that are redistributed into BGP from the EGP protocol will be given the BGP origin attribute "EGP." Other networks that are redistributed into BGP will have the BGP origin attribute of "incomplete." The origin attribute in the Cisco implementation is only used in the path selection process.

Configuring BGP Weights

A weight is a number that you can assign to a path so that you can control the path selection process. The administrative weight is local to the router. A weight can be a number from 0 to 65535. Any path that a Cisco router originates will have a default weight of 32768; other paths have weight 0. If you have particular neighbors that you want to prefer for most of your traffic, you can assign a higher weight to all routes learned from that neighbor.

Weights can be assigned based on autonomous system path access lists. A given weight becomes the weight of the route if the autonomous system path is accepted by the access list. Any number of weight filters are allowed. Weights can only be assigned via route maps.

Disabling Autonomous System Path Comparison

RFC 1771, the IETF document defining BGP, does not include autonomous system path as part of the "tie-breaker" decision algorithm. By default, Cisco IOS software considers the autonomous system path as a part of the decision algorithm. This enhancement makes it possible to modify the decision algorithm, bringing the behavior of the router in selecting a path more in line with the IETF specification.

To prevent the router from considering the autonomous system path length when selecting a route, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp bestpath as-path ignore`	Configures the router to ignore autonomous system path length in selecting a route.

Configuring BGP Route Filtering by Neighbor

You can filter BGP advertisements in two ways:

- Use autonomous system path filters, as with the **ip as-path access-list** global configuration command and the **neighbor filter-list** router configuration command
- Use access or prefix lists, as with the **neighbor distribute-list** router configuration command.

Filtering using prefix lists is described in the "Configuring BGP Filtering Using Prefix Lists" section.

If you want to restrict the routing information that the Cisco IOS software learns or advertises, you can filter BGP routing updates to and from particular neighbors. You can either define an access list or a prefix list and apply it to the updates.

Note Distribute-list filters are applied to network numbers and not autonomous system paths.

To filter BGP routing updates, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor {ip-address | peer-group-name} distribute-list {access-list-number | access-list-name} {in | out}`	Filters BGP routing updates to and from neighbors as specified in an access list. **Note** The **neighbor prefix-list** router configuration command can be used as an alternative to the **neighbor distribute-list** router configuration command, but you cannot use both commands to configure the same BGP peer in any specific direction. These two commands are mutually exclusive, and only one command (**neighbor prefix-list** or **neighbor distribute-list**) an be applied for each inbound or outbound direction.

Note Although the **neighbor prefix-list** router configuration command can be used as an alternative to the **neighbor distribute-list** command, do not use attempt to apply both the **neighbor prefix-list** and **neighbor distribute-list** command filtering to the same neighbor in any given direction. These two commands are mutually exclusive, and only one command (**neighbor prefix-list** or **neighbor distribute-list**) can be applied for each inbound or outbound direction.

Configuring BGP Filtering Using Prefix Lists

Prefix lists can be used as an alternative to access lists in many BGP route filtering commands. The section "How the System Filters Traffic by Prefix List" describes the way prefix list filtering works. The advantages of using prefix lists are as follows:

- Significant performance improvement in loading and route lookup of large lists.
- Support for incremental updates. Filtering using extended access lists does not support incremental updates.

- More user-friendly command-line interface (CLI). The command-line interface for using access lists to filter BGP updates is difficult to understand and use because it uses the packet filtering format.
- Greater flexibility

Before using a prefix list in a command, you must set up a prefix list, and you may want to assign sequence numbers to the entries in the prefix list.

How the System Filters Traffic by Prefix List

Filtering by prefix list involves matching the prefixes of routes with those listed in the prefix list. When there is a match, the route is used. More specifically, whether a prefix is permitted or denied is based upon the following rules:

- An empty prefix list permits all prefixes.
- An implicit deny is assumed if a given prefix does not match any entries of a prefix list.
- When multiple entries of a prefix list match a given prefix, the longest, most specific match is chosen.

  The router begins the search at the top of the prefix list, with the sequence number 1. Once a match or deny occurs, the router need not go through the rest of the prefix list. For efficiency, you may want to put the most common matches or denies near the top of the list, using the **seq** argument in the **ip prefix-list** global configuration command. The **show** commands always include the sequence numbers in their output.

Sequence numbers are generated automatically unless you disable this automatic generation. If you disable the automatic generation of sequence numbers, you must specify the sequence number for each entry using the *sequence-value* argument of the **ip prefix-list** global configuration command.

Regardless of whether the default sequence numbers are used in configuring a prefix list, a sequence number need not be specified when removing a configuration entry.

show commands include the sequence numbers in their output.

Creating a Prefix List

To create a prefix list, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# ip prefix-list list-name [seq sequence-value] {deny | permit network/length} [ge ge-value] [le le-value]`	Creates a prefix list with the name specified for the *list-name* argument.

Note To create a prefix list you must enter at least one **permit** or **deny** clause.

To remove a prefix list and all of its entries, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no ip prefix-list list-name [seq sequence-value] {deny | permit network/length} [ge ge-value] [le le-value]`	Removes a prefix list with the name specified for *list-name*.

Configuring a Prefix List Entry

You can add entries to a prefix list individually. To configure an entry in a prefix list, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# ip prefix-list` *list-name* [**seq** *sequence-value*] {**deny** | **permit** *network/length*} [**ge** *ge-value*] [**le** *le-value*]	Creates an entry in a prefix list and assigns a sequence number to the entry.

The optional **ge** and **le** keywords can be used to specify the range of the prefix length to be matched for prefixes that are more specific than the *network/length* argument. An exact match is assumed when neither **ge** nor **le** is specified. The range is assumed to be from *ge-value* to 32 if only the **ge** attribute is specified, and from **len** to *le-value* if only the **le** attribute is specified.

A specified *ge-value* or *le-value* must satisfy the following condition:

```
len < ge-value <= le-value <= 32
```

For example, to deny all prefixes matching /24 in 128.0.0.0/8, use the following command:

```
ip prefix-list abc deny  128.0.0.0/8 ge 24 le 24
```

Note You can specify sequence values for prefix list entries in any increments you want (the automatically generated numbers are incremented in units of 5). If you specify the sequence values in increments of 1, you cannot insert additional entries into the prefix list. If you choose very large increments, you could run out of sequence values.

Configuring How Sequence Numbers of Prefix List Entries Are Specified

By default, the sequence numbers are automatically generated when you create a prefix list entry. Sequence numbers can be suppressed with the **no ip prefix-list sequence-number** global configuration command. Sequence values are generated in increments of 5. The first sequence value generated in a prefix list would be 5, then 10, then 15, and so on. If you specify a value for an entry and then do not specify values for subsequent entries, the assigned (generated) sequence values are incremented in units of five. For example, if you specify that the first entry in the prefix list has a sequence value of 3, and then do not specify sequence values for the other entries, the automatically generated numbers will be 8, 13, 18, and so on.

To disable the automatic generation of sequence numbers, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)#` **`no ip prefix-list sequence-number`**	Disables the automatic generation of the sequence numbers for prefix list entries.

To re-enable automatic generation of the sequence numbers of prefix list entries, use the **ip prefix-list sequence number** command in router configuration mode:

Command	Purpose
`Router(config-router)# ip prefix-list sequence-number`	Enables the automatic generation of the sequence numbers of prefix list entries. The default is enable.

If you disable automatic generation of sequence numbers in a prefix list, you must specify the sequence number for each entry using the *sequence-value* argument of the **ip prefix-list** global configuration command.

Regardless of whether the default sequence numbers are used in configuring a prefix list, a sequence number need not be specified when deconfiguring an entry. **show** commands include the sequence numbers in their output.

Deleting a Prefix List or Prefix List Entries

To delete a prefix list, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no ip prefix-list list-name`	Deletes a prefix list.

You can delete entries from a prefix list individually. To delete an entry in a prefix list, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no ip prefix-list seq sequence-value`	Deletes an entry in a prefix list.

Note The sequence number of an entry need not be specified when you delete the entry.

Displaying Prefix Entries

To display information about prefix tables, prefix table entries, the policy associated with a node, or specific information about an entry, use the following commands in EXEC mode as needed:

Command	Purpose
`Router# show ip prefix-list [detail | summary]`	Displays information about all prefix lists.
`Router# show ip prefix-list [detail | summary] prefix-list-name`	Displays a table showing the entries in a prefix list.
`Router# show ip prefix-list prefix-list-name [network/length]`	Displays the policy associated with the node.
`Router# show ip prefix-list prefix-list-name [seq sequence-number]`	Displays the prefix list entry with a given sequence number.

`Router# show ip prefix-list prefix-list-name [network/length] longer`	Displays all entries of a prefix list that are more specific than the given network and length.
`Router# show ip prefix-list prefix-list-name [network/length] first-match`	Displays the entry of a prefix list that matches the given prefix (network and length of prefix).

Clearing the Hit Count Table of Prefix List Entries

To clear the hit count table of prefix list entries, use the following command in EXEC mode:

Command	Purpose
`Router# clear ip prefix-list prefix-list-name [network/length]`	Clears the hit count table of the prefix list entries.

Configuring BGP Path Filtering by Neighbor

In addition to filtering routing updates based on network numbers, you can specify an access list filter on both incoming and outbound updates based on the BGP autonomous system paths. Each filter is an access list based on regular expressions. To specify the access list filter, define an autonomous system path access list and apply it to updates to and from particular neighbors. See the "Regular Expressions" appendix in the *Cisco IOS Terminal Services Configuration Guide* for more information on forming regular expressions.

To configure BGP path filtering, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router# ip as-path access-list access-list-number {permit | deny} as-regexp`	Defines a BGP-related access list.
Step 2	`Router# router bgp as-number`	Enters router configuration mode.
Step 3	`Router(config-router)# neighbor {ip-address | peer-group-name} filter-list access-list-number {in | out}`	Establishes a BGP filter.

See the "BGP Path Filtering by Neighbor Examples" section at the end of this chapter for an example of BGP path filtering by neighbor.

Disabling Next Hop Processing on BGP Updates

You can configure the Cisco IOS software to disable next hop processing for BGP updates to a neighbor. Disabling next hop processing might be useful in nonmeshed networks such as Frame Relay or X.25, where BGP neighbors might not have direct access to all other neighbors on the same IP subnet. There are two ways to disable next hop processing:

- Provide a specific address to be used instead of the next hop address (manually configuring each address).
- Use a route map to specify that the address of the remote peer for matching inbound routes, or the local router for matching outbound routes (automatic method).

Disabling Next Hop Processing Using a Specific Address

To disable next hop processing and provide a specific address to be used instead of the next hop address, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor {ip-address | peer-group-name} next-hop-self`	Disables next hop processing on BGP updates to a neighbor.

Configuring this command causes the current router to advertise its peering address as the next hop for the specified neighbor. Therefore, other BGP neighbors will forward to it packets for that address. This configuration is useful in a nonmeshed environment because you know that a path exists from the present router to that address. In a fully meshed environment, this configuration is not useful because it will result in unnecessary extra hops and because there might be a direct access through the fully meshed cloud with fewer hops.

Disabling Next Hop Processing Using a Route Map

To override the inbound next hop setting for BGP routes and specify that the next hop of the matching routes is to be the IP address of the remote peer, or to set the peering address of the local router to be the next hop of the matching routes, use the **neighbor next-hop-self** router configuration command.

To configure the neighbor peering address to be used for the next hop address, use the following command in route map configuration mode:

Command	Purpose
`Router(config-route-map)# set ip next-hop ip-address [...ip-address] [peer-address]`	In an inbound route map of a BGP peer, sets the next hop of the matching routes to be the neighbor peering address, overriding any third-party next hops and allowing the same route map to be applied to multiple BGP peers to override third-party next hops. With an outbound route map of a BGP peer, sets the next hop of the received address to the peering address of the local router, disabling the next hop calculation. The next hop must be an adjacent router.

Configuring BGP Next Hop Propagation

The BGP Next Hop Propagation feature provides additional flexibility when designing and migrating networks. The BGP Next Hop Propagation feature allows a route reflector to modify the next hop attribute for a reflected route and allows BGP to send an update to an eBGP multihop peer with the next hop attribute unchanged.

Caution Incorrectly setting BGP attributes for a route reflector can cause inconsistent routing, routing loops, or a loss of connectivity. Setting BGP attributes for a route reflector should be attempted only by an experienced network operator.

The configuration of this feature in conjunction with the iBGP Multipath Load Sharing feature allows you to use an outbound route map to include BGP route reflectors in the forwarding path.

The BGP Next Hop Propagation feature allows you to perform the following tasks:

- Bring the route reflector into the forwarding path, which can be used with the iBGP Multipath Load Sharing feature to configure load balancing.
- Configure interprovider Multiprotocol Label Switching (MPLS) Virtual Private Networks (VPNs) by not modifying the next hop attribute when advertising routes to an eBGP peer.
- Turn off the next hop calculation for an eBGP peer. This feature is useful for configuring the end-to-end connection of a label-switched path.

To configure an eBGP multihop peer to propagate the next hop unchanged, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor ip-address next-hop-unchanged`	Configures the router to send BGP updates to BGP peers without modifying the next hop attribute. **Caution** This command should be configured only on route-reflector clients and not on a route reflector.

Configuring the BGP Version

By default, BGP sessions begin using BGP Version 4 and negotiating downward to earlier versions if necessary. To prevent negotiation and force the BGP version used to communicate with a neighbor, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor {ip-address | peer-group-name} version number`	Specifies the BGP version to use when communicating with a neighbor.

Configuring the MED Metric

BGP uses the MED metric as a hint to external neighbors about preferred paths. (The name of this metric for BGP Versions 2 and 3 is INTER_AS_METRIC.) To set the MED of the redistributed routes, Use the following command in router configuration mode. All the routes without a MED will also be set to this value.

Command	Purpose
`Router(config-router)# default-metric number`	Sets an MED.

Alternatively, you can set the MED using the **route-map** router configuration command. See the "BGP Route Map Examples" section at the end of this chapter for examples of using BGP route maps.

Configuring Advanced BGP Features

The tasks in this section are for configuring advanced BGP features.

Using Route Maps to Modify Updates

You can use a route map on a per-neighbor basis to filter updates and modify various attributes. A route map can be applied to either inbound or outbound updates. Only the routes that pass the route map are sent or accepted in updates.

On both the inbound and the outbound updates, we support matching based on autonomous system path, community, and network numbers. Autonomous system path matching requires the **as-path access-lis**t global configuration command, community based matching requires the **ip community-list** global configuration command and network-based matching requires the **ip access-list** global configuration command. To apply a route map to incoming and outgoing routes, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor {ip-address | peer-group-name} route-map map-name {in | out}`	Applies a route map to incoming or outgoing routes.

See the "BGP Route Map Examples" section at the end of this chapter for BGP route map examples.

Resetting eBGP Connections Immediately upon Link Failure

Normally, when a link between external neighbors goes down, the BGP session will not be reset immediately.To reset the eBGP session as soon as an interface goes down, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp fast-external-fallover`	Resets eBGP sessions automatically.

Configuring Aggregate Addresses

CIDR enables you to create aggregate routes (or *supernets*) to minimize the size of routing tables. You can configure aggregate routes in BGP either by redistributing an aggregate route into BGP or by using the BGP Conditional Aggregation feature. An aggregate address will be added to the BGP table if at least one more specific entry is in the BGP table.

To create an aggregate address in the routing table, use the following commands in router configuration mode:

Command	Purpose
`Router(config-router)# aggregate-address address mask`	Creates an aggregate entry in the BGP routing table.
`Router(config-router)# aggregate-address address mask as-set`	Generates autonomous system set path information.
`Router(config-router)# aggregate-address address-mask summary-only`	Advertises summary addresses only.
`Router(config-router)# aggregate-address address mask suppress-map map-name`	Suppresses selected, more specific routes.
`Router(config-router)# aggregate-address address mask advertise-map map-name`	Generates an aggregate based on conditions specified by the route map.
`Router(config-router)# aggregate-address address mask attribute-map map-name`	Generates an aggregate with attributes specified in the route map.

See the "BGP Aggregate Route Examples" section at the end of this chapter for examples of using BGP aggregate routes.

Disabling Automatic Summarization of Network Numbers

In BGP Version 3, when a subnet is redistributed from an IGP into BGP, only the network route is injected into the BGP table. By default, this automatic summarization is enabled. To disable automatic network number summarization, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no auto-summary`	Disables automatic network summarization.

Configuring BGP Community Filtering

BGP supports transit policies via controlled distribution of routing information. The distribution of routing information is based on one of the following three values:

- IP address (see the "Configuring BGP Route Filtering by Neighbor" section earlier in this chapter).
- The value of the autonomous system path attribute (see the "Configuring BGP Path Filtering by Neighbor" section earlier in this chapter).
- The value of the communities attribute (as described in this section).

The *communities* attribute is a way to group destinations into communities and apply routing decisions based on the communities. This method simplifies the configuration of a BGP speaker that controls distribution of routing information.

A *community* is a group of destinations that share some common attribute. Each destination can belong to multiple communities. Autonomous system administrators can define to which communities a destination belongs. By default, all destinations belong to the general Internet community. The community is carried as the communities attribute.

The communities attribute is an optional, transitive, global attribute in the numerical range from 1 to 4,294,967,200. Along with Internet community, there are a few predefined, well-known communities, as follows:

- internet—Advertise this route to the Internet community. All routers belong to it.
- no-export—Do not advertise this route to eBGP peers.
- no-advertise—Do not advertise this route to any peer (internal or external).
- local-as—Do not advertise this route to peers outside the local autonomous system. This route will not be advertised to other autonomous systems or sub-autonomous systems when confederations are configured.

Based on the community, you can control which routing information to accept, prefer, or distribute to other neighbors. A BGP speaker can set, append, or modify the community of a route when you learn, advertise, or redistribute routes. When routes are aggregated, the resulting aggregate has a communities attribute that contains all communities from all the initial routes.

You can use community lists to create groups of communities to use in a match clause of a route map. Just like an access list, a series of community lists can be created. Statements are checked until a match is found. As soon as one statement is satisfied, the test is concluded.

To create a community list, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip community-list` *community-list-number* {**permit** | **deny**} *community-number*	Creates a community list.

To set the communities attribute and match clauses based on communities, see the **match community-list** and **set community** route map configuration commands in the "Redistribute Routing Information" section in the "Configuring IP Routing Protocol-Independent Features" chapter.

By default, no communities attribute is sent to a neighbor. To specify that the communities attribute to be sent to the neighbor at an IP address, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor` {*ip-address* | *peer-group-name*} **send-community [both |standard |extended]**	Specifies that the communities attribute be sent to the neighbor at this IP address. Both standard and extended communities can be specified with the both keyword. Only standard or only extended can be specified with the standard and extended keywords.

To remove communities from the community attribute of an inbound or outbound update using a route map to filter and determine the communities to be deleted, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# set comm-list` *community-list-number* **delete**	Removes communities in a community attribute that match a standard or extended community list.

Specifying the Format for the Community

A BGP community is displayed in a two-part format 2 bytes long in the **show ip bgp community** EXEC command output, and wherever communities are displayed in the router configuration, such as router maps and community lists. In the most recent version of the RFC for BGP, a community is of the form AA:NN, where the first part is the autonomous system number and the second part is a 2-byte number. The Cisco default community format is in the format NNAA.

To display BGP communities in the new format, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip bgp-community new-format`	Displays and parses BGP communities in the format AA:NN.

Configuring BGP Conditional Advertisement

BGP advertises routes from its routing table to external peers (peers in different autonomous systems) by default. The BGP Conditional Advertisement feature provides additional control of route advertisement depending on the existence of other prefixes in the BGP table. Normally, routes are propagated regardless of the existence of a different path. The BGP Conditional Advertisement feature uses the non-exist-map and the advertise-map to track routes by the route prefix. If a route prefix is not present in the non-exist-map, the route specified by the advertise-map is announced. The announced route is installed to the BGP routing table as a locally originated route and will behave as a locally originated route. The announced route will be originated by BGP only if the corresponding route exists in the BGP table. After the prefix is locally originated by BGP, BGP will advertise the prefix to internal and external peers. If the route prefix is present, the route in the advertise-map is not announced.

Conditional advertisement can be useful in a multihomed network, in which some prefixes are to be advertised to one of the providers, only if information from the other provider is missing. This condition would indicate a failure in the peering session, or partial reachability.

If the same information is advertised to all providers in a multihomed environment, the information is duplicated in the global BGP table. When the BGP Conditional Advertisement feature is used, only partial routes are advertised to each provider, and the size of the global BGP table is not increased with redundant information. The administrator can also guarantee the path that inbound traffic will follow because only specific paths are advertised to providers.

Note The conditional BGP announcements are sent in addition to the normal announcements that a BGP router sends to its peers.

Note Autonomous system path list information cannot be used for conditional advertisement because the IP routing table does not contain autonomous system path information.

BGP Conditional Advertisement Configuration Task List

See the following section for configuration tasks for the BGP Conditional Advertisement feature. Each task in the list indicates if the task is optional or required.

- Configure the route-maps that will be used in conjunction with the advertise-map and the non-exist-map. This step may include the configuration of access-lists or prefix-lists. (Required)
- Configure the router to run BGP. (Required)
- Configure the advertise-map and the non-exist-map with the **neighbor advertise-map non-exist-map** router configuration command. (Required)
- Verify that the BGP Condition Advertisement feature has been configured with the **show ip bgp neighbor** command. (Optional)

Conditional Advertisement of a Set of Routes

To conditionally advertise a set of routes, use the following commands beginning in router configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp as-number`	Configures the router to run a BGP process.
Step 2	`Router(config-router)# neighbor ip-address remote-as as-number`	Specifies the peer that should receive conditional advertisement for a given set routes.
Step 3	`Router(config-router)# neighbor ip-address advertise-map map1 non-exist-map map2`	Configures the advertise-map and non-exist map for the BGP Conditional Advertisement feature.

See the "BGP Conditional Advertisement Configuration Examples" section at the end of this chapter for an example configuration of BGP conditional advertisement.

Verifying BGP Conditional Advertisement

To verify that the BGP Condition Advertisement feature has been configured, use the **show ip bgp neighbor** command. The **show ip bgp neighbor EXEC** command will show the status of the BGP Conditional Advertisement feature as initialized or uninitialized. The following example shows output from the **show ip bgp neighbor EXEC** command:

```
router# show ip bgp neigbor 172.16.1.1
BGP neighbor is 172.16.1.1,  remote AS 65200, internal link
 Description:link to boston as 65200
  BGP version 4, remote router ID 10.1.1.1
  BGP state = Established, up for 01:04:30
  Last read 00:00:30, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh:advertised and received
    Address family IPv4 Unicast:advertised and received
  Received 83 messages, 0 notifications, 0 in queue
  Sent 78 messages, 0 notifications, 0 in queue
  Route refresh request:received 0, sent 0
  Minimum time between advertisement runs is 5 seconds

 For address family:IPv4 Unicast
  BGP table version 18, neighbor version 18
  Index 2, Offset 0, Mask 0x4
```

```
Inbound soft reconfiguration allowed
NEXT_HOP is always this router
Community attribute sent to this neighbor
Condition-map old-route, Advertise-map new-route, status:Uninitialized
2 accepted prefixes consume 72 bytes
Prefix advertised 7, suppressed 0, withdrawn 4

Connections established 1; dropped 0
Last reset 01:05:29, due to Soft reconfig change
```

BGP Conditional Advertisement Troubleshooting Tips

This section provides troubleshooting information for the BGP conditional advertisement feature.

The BGP Conditional Advertisement feature is based on the nonexistence of a prefix and the advertisement of another. Normally, only two problems can occur:

- The tracked prefix exists, but the conditional advertisement occurs.
- The tracked prefix does not exist, and the conditional advertisement does not occur.

The same method of troubleshooting is used for both problems:

- Verify the existence (or not) of the tracked prefix in the BGP table with the **show ip bgp EXEC** command.
- Verify the advertisement (or not) of the other prefix using the **show ip bgp neighbor advertised-routes EXEC** command.

The user needs to ensure that all of the characteristics specified in the route maps match the routes in the BGP table.

Configuring a Routing Domain Confederation

One way to reduce the iBGP mesh is to divide an autonomous system into multiple subautonomous systems and group them into a single confederation. To the outside world, the confederation looks like a single autonomous system. Each autonomous system is fully meshed within itself, and has a few connections to other autonomous systems in the same confederation. Even though the peers in different autonomous systems have eBGP sessions, they exchange routing information as if they were iBGP peers. Specifically, the next hop, MED, and local preference information is preserved. This feature allows the you to retain a single IGP for all of the autonomous systems.

To configure a BGP confederation, you must specify a confederation identifier. To the outside world, the group of autonomous systems will look like a single autonomous system with the confederation identifier as the autonomous system number. To configure a BGP confederation identifier, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp confederation identifier` *as-number*	Configures a BGP confederation.

In order to treat the neighbors from other autonomous systems within the confederation as special eBGP peers, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp confederation peers` *as-number* `[as-number]`	Specifies the autonomous systems that belong to the confederation.

See the "BGP Community with Route Maps Examples" section at the end of this chapter for an example configuration of several peers in a confederation.

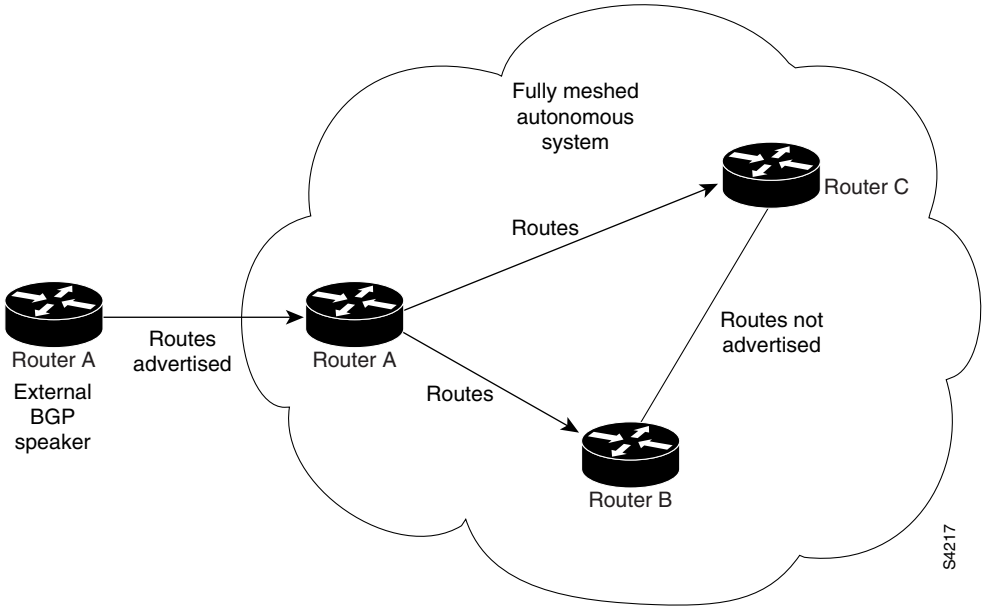
For an alternative way to reduce the iBGP mesh, see the next section, "Configuring a Route Reflector."

Configuring a Route Reflector

BGP requires that all iBGP speakers be fully meshed. However, this requirement does not scale well when there are many iBGP speakers. Instead of configuring a confederation, another way to reduce the iBGP mesh is to configure a *route reflector*.

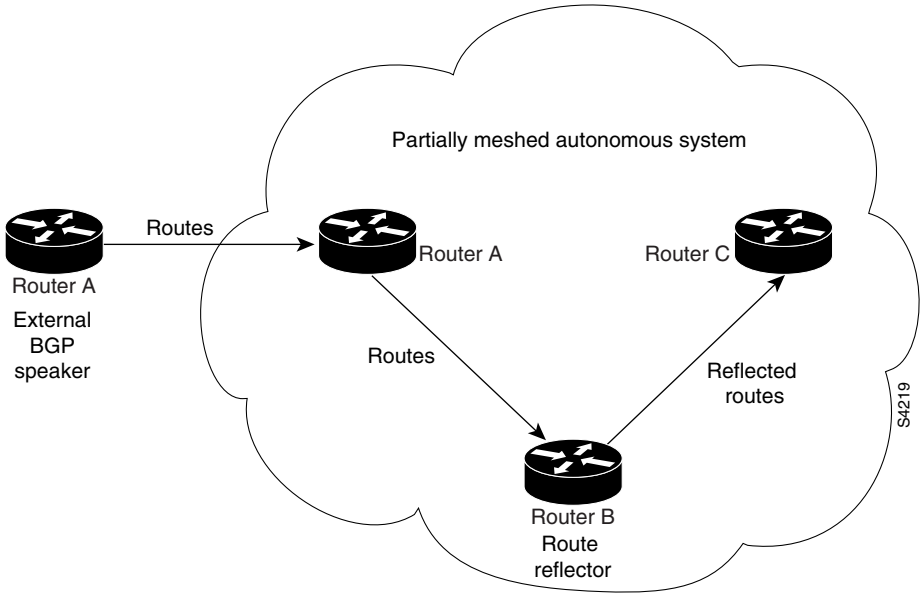
Figure 55 illustrates a simple iBGP configuration with three iBGP speakers (Routers A, B, and C). Without route reflectors, when Router A receives a route from an external neighbor, it must advertise it to both routers B and C. Routers B and C do not readvertise the iBGP learned route to other iBGP speakers because the routers do not pass on routes learned from internal neighbors to other internal neighbors, thus preventing a routing information loop.

Figure 55 Three Fully Meshed iBGP Speakers



With route reflectors, all iBGP speakers need not be fully meshed because there is a method to pass learned routes to neighbors. In this model, an iBGP peer is configured to be a route reflector responsible for passing iBGP learned routes to a set of iBGP neighbors. In Figure 56, Router B is configured as a route reflector. When the route reflector receives routes advertised from Router A, it advertises them to Router C, and vice versa. This scheme eliminates the need for the iBGP session between Routers A and C.

Figure 56 Simple BGP Model with a Route Reflector



The internal peers of the route reflector are divided into two groups: client peers and all the other routers in the autonomous system (nonclient peers). A route reflector reflects routes between these two groups. The route reflector and its client peers form a *cluster*. The nonclient peers must be fully meshed with each other, but the client peers need not be fully meshed. The clients in the cluster do not communicate with iBGP speakers outside their cluster.

Figure 57 More Complex BGP Route Reflector Model

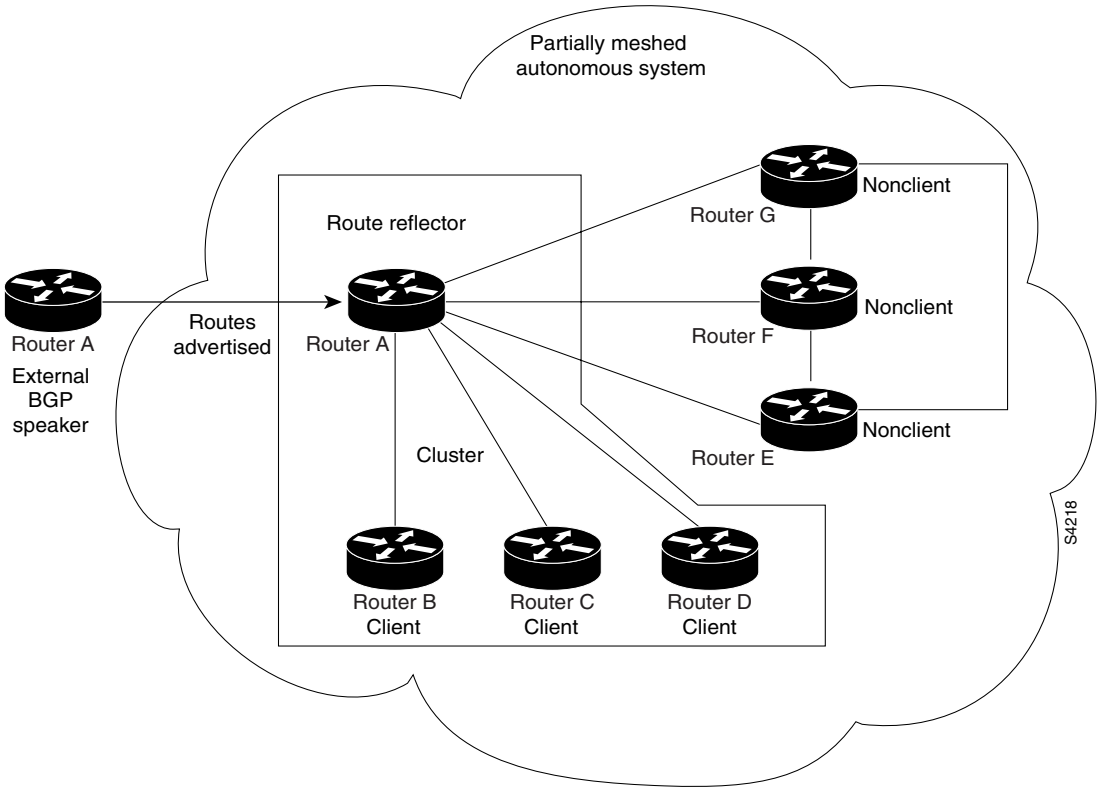


Figure 57 illustrates a more complex route reflector scheme. Router A is the route reflector in a cluster with routers B, C, and D. Routers E, F, and G are fully meshed, nonclient routers.

When the route reflector receives an advertised route, depending on the neighbor, it takes the following actions:

- A route from an external BGP speaker is advertised to all clients and nonclient peers.
- A route from a nonclient peer is advertised to all clients.
- A route from a client is advertised to all clients and nonclient peers. Hence, the clients need not be fully meshed.

To configure a route reflector and its clients, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor` *ip-address* | *peer-group-name* **route-reflector-client**	Configures the local router as a BGP route reflector and the specified neighbor as a client.

Along with route reflector-aware BGP speakers, it is possible to have BGP speakers that do not understand the concept of route reflectors. They can be members of either client or nonclient groups allowing a easy and gradual migration from the old BGP model to the route reflector model. Initially, you could create a single cluster with a route reflector and a few clients. All the other iBGP speakers could be nonclient peers to the route reflector and then more clusters could be created gradually.

An autonomous system can have multiple route reflectors. A route reflector treats other route reflectors just like other iBGP speakers. A route reflector can be configured to have other route reflectors in a client group or nonclient group. In a simple configuration, the backbone could be divided into many clusters. Each route reflector would be configured with other route reflectors as nonclient peers (thus, all the route reflectors will be fully meshed). The clients are configured to maintain iBGP sessions with only the route reflector in their cluster.

Usually a cluster of clients will have a single route reflector. In that case, the cluster is identified by the router ID of the route reflector. To increase redundancy and avoid a single point of failure, a cluster might have more than one route reflector. In this case, all route reflectors in the cluster must be configured with the 4-byte cluster ID so that a route reflector can recognize updates from route reflectors in the same cluster. All the route reflectors serving a cluster should be fully meshed and all of them should have identical sets of client and nonclient peers.

If the cluster has more than one route reflector, configure the cluster ID by using the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp cluster-id` *cluster-id*	Configures the cluster ID.

Use the **show ip bgp** EXEC command to display the originator ID and the cluster-list attributes.

By default, the clients of a route reflector are not required to be fully meshed and the routes from a client are reflected to other clients. However, if the clients are fully meshed, the route reflector need not reflect routes to clients.

To disable client-to-client route reflection, use the **no bgp client-to-client reflection** command in router configuration mode:

Command	Purpose
`Router(config-router)# no bgp client-to-client reflection`	Disables client-to-client route reflection.

As the iBGP learned routes are reflected, routing information may loop. The route reflector model has the following mechanisms to avoid routing loops:

- Originator ID is an optional, nontransitive BGP attribute. It is a 4-byte attributed created by a route reflector. The attribute carries the router ID of the originator of the route in the local autonomous system. Therefore, if a misconfiguration causes routing information to come back to the originator, the information is ignored.
- Cluster-list is an optional, nontransitive BGP attribute. It is a sequence of cluster IDs that the route has passed. When a route reflector reflects a route from its clients to nonclient peers, and vice versa, it appends the local cluster ID to the cluster-list. If the cluster-list is empty, a new cluster-list is created. Using this attribute, a route reflector can identify if routing information is looped back to the same cluster due to misconfiguration. If the local cluster ID is found in the cluster-list, the advertisement is ignored.
- Use **set** clauses in outbound route maps to modify attributes, possibly creating routing loops. To avoid this behavior, **set** clauses of outbound route maps are ignored for routes reflected to iBGP peers.

Configuring BGP Peer Groups

Often, in a BGP speaker, many neighbors are configured with the same update policies (that is, the same outbound route maps, distribute lists, filter lists, update source, and so on). Neighbors with the same update policies can be grouped into peer groups to simplify configuration and, more importantly, to make updating more efficient. When you have many peers, this approach is highly recommended.

The three steps to configure a BGP peer group, described in the following sections, are as follows:

1. Creating the Peer Group
2. Assigning Options to the Peer Group
3. Making Neighbors Members of the Peer Group

You can disable a BGP peer or peer group without removing all the configuration information using the **neighbor shutdown** router configuration command.

Creating the Peer Group

To create a BGP peer group, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor` *peer-group-name* `peer-group`	Creates a BGP peer group.

Assigning Options to the Peer Group

After you create a peer group, you configure the peer group with **neighbor** commands. By default, members of the peer group inherit all the configuration options of the peer group. Members can also be configured to override the options that do not affect outbound updates.

Peer group members will always inherit the following attributes: minimum-advertisement-interval, next-hop-self, out-route-map, out-filter-list, out-dist-list, remote-as (if configured), version, and update-source. All the peer group members will inherit changes made to the peer group.

To assign configuration options to an individual neighbor, specify any of the following commands using the IP address. To assign the options to a peer group, specify any of the commands using the peer group name. Use the following commands in router configuration mode as needed.

Command	Purpose
`Router(config-router)# neighbor {ip-address | peer-group-name} remote-as as-number`	Specifies a BGP neighbor.
`Router(config-router)# neighbor {ip-address | peer-group-name} description text`	Associates a description with a neighbor.
`Router(config-router)# neighbor {ip-address | peer-group-name} default-originate [route-map map-name]`	Allows a BGP speaker (the local router) to send the default route 0.0.0.0 to a neighbor for use as a default route.
`Router(config-router)# neighbor {ip-address | peer-group-name} send-community`	Specifies that the communities attribute be sent to the neighbor at this IP address.
`Router(config-router)# neighbor {ip-address | peer-group-name} update-source interface-type`	Allows iBGP sessions to use any operational interface for TCP connections.
`Router(config-router)# neighbor {ip-address | peer-group-name} ebgp-multihop`	Allows BGP sessions, even when the neighbor is not on a directly connected segment. The multihop session is not established if the only route to the address of the multihop peer is the default route (0.0.0.0).
`Router(config-router)# neighbor {ip-address | peer-group-name} advertisement-interval seconds`	Sets the minimum interval between sending BGP routing updates.
`Router(config-router)# neighbor {ip-address | peer-group-name} maximum-prefix maximum [threshold] [warning-only]`	Limits the number of prefixes allowed from a neighbor.
`Router(config-router)# neighbor {ip-address | peer-group-name} weight weight`	Specifies a weight for all routes from a neighbor.
`Router(config-router)# neighbor {ip-address | peer-group-name} distribute-list {access-list-number | access-list-name} {in | out}`	Filters BGP routing updates to and from neighbors, as specified in an access list.
`Router(config-router)# neighbor {ip-address | peer-group-name} filter-list access-list-number {in | out | weight weight}`	Establishes a BGP filter.
`Router(config-router)# neighbor {ip-address | peer-group-name} next-hop-self`	Disables next hop processing on the BGP updates to a neighbor.
`Router(config-router)# neighbor {ip-address | peer-group-name} version value`	Specifies the BGP version to use when communicating with a neighbor.

Command	Purpose
`Router(config-router)# neighbor {ip-address | peer-group-name} password string`	Invokes MD5 authentication on a TCP connection to a BGP peer. You can enter a case-sensitive password of up to 25 characters. The string can contain any alphanumeric characters, including spaces. A password cannot be configured in the number-space-anything format. The space after the number causes problems. You can also use any combination of the following symbolic characters along with alphanumeric characters: ` ~ ! @ # $ % ^ & * ( ) - _ = + | \ }] { [" ' : ; / > < . , ? **Caution** If the authentication string is configured incorrectly, the BGP peering session will not be established. We recommend that you enter the authentication string carefully and verify that the peering session is established after authentication is configured.
`Router(config-router)# neighbor {ip-address | peer-group-name} route-map map-name {in | out}`	Applies a route map to incoming or outgoing routes.
`Router(config-router)# neighbor {ip-address | peer-group-name} soft-reconfiguration inbound`	Configures the software to start storing received updates. This command requires at least one keyword. Currently the only keyword available is **inbound**, so the use of inbound is not optional.

If a peer group is not configured with a remote-as attribute, the members can be configured with the **neighbor remote-as** router configuration command. This command allows you to create peer groups containing eBGP neighbors.

You can customize inbound policies for peer group members (using, for example, a distribute list, route map, or filter list) because one identical copy of an update is sent to every member of a group. Therefore, neighbor options related to outgoing updates cannot be customized for peer group members.

External BGP peers normally must reside on a directly connected network. Sometimes it is useful to relax this restriction in order to test BGP; do so by specifying the **neighbor ebgp-multihop** router configuration command.

Note To avoid the accidental creation of loops through oscillating routes, the multihop session will not be established if the only route to the address of the multihop peer is the default route (0.0.0.0).

Members of a peer group can pass routes from one member of the peer group to another. For example, if router B is peering with routers A and C, router B can pass routes from router A to router C.

For iBGP, you might want to allow your BGP connections to stay up regardless of which interface is used to reach a neighbor. To enable this configuration, you first configure a *loopback* interface and assign it an IP address. Next, configure the BGP update source to be the loopback interface. Finally, configure your neighbor to use the address on the loopback interface. Now the iBGP session will be up as long as there is a route, regardless of any interface.

You can set the minimum interval of time between BGP routing updates.

Configuring MD5 Authentication for BGP Peering Sessions

You can configure MD5 authentication between two BGP peers, meaning that each segment sent on the TCP connection between the peers is verified. MD5 authentication must be configured with the same password on both BGP peers; otherwise, the connection between them will not be made. Configuring MD5 authentication causes the Cisco IOS software to generate and check the MD5 digest of every segment sent on the TCP connection. If authentication is invoked and a segment fails authentication, then an error message will be displayed in the console.

When configuring MD5 authentication, you can enter a case-sensitive password of up to 25 characters. The string can contain any alphanumeric characters, including spaces. A password cannot be configured in the number-space-anything format. The space after the number can cause authentication to fail. You can also use any combination of the following symbolic characters along with alphanumeric characters:

` ~ ! @ # $ % ^ & * ( ) - _ = + | \ }] { [“ ‘ : ; / > < . , ?

Caution If the authentication string is configured incorrectly, the BGP peering session will not be established. We recommend that you enter the authentication string carefully and verify that the peering session is established after authentication is configured.

Old Behavior

In previous versions of Cisco IOS software, configuring MD5 authentication for a BGP peering session was generally considered to be difficult because the initial configuration and any subsequent MD5 configuration changes required the BGP neighbor to be reset.

New Behavior

This behavior has been changed in current versions of Cisco IOS software. CSCdx23494 introduced a change to MD5 authentication for BGP peering sessions. The BGP peering session does not need to be reset to maintain or establish the peering session for initial configuration or after the MD5 configuration has been changed. However, the configuration must be completed on both the local and remote BGP peer before the BGP hold timer expires. If the hold down timer expires before the MD5 configuration has been completed on both BGP peers, the BGP session will time out.

When the password has been configured, the MD5 key is applied to the TCP session immediately. If one peer is configured before the other, the TCP segments will be discarded on both the local and remote peers due to an authentication failure. The peer that is configured with the password will print an error message in the console similar to the following:

```
00:03:07: %TCP-6-BADAUTH: No MD5 digest from 10.0.0.2(179) to 10.0.0.1(11000)
```

The time period in which the password must changed is typically the life time of a stale BGP session. When the password or MD5 key is configured, incoming tcp segments will only be accepted if the key is known. If the key is unknown on both the remote and local peer, the TCP segments will be dropped, and the BGP session will time out when the holddown timer expires.

If the BGP session has been preconfigured with a hold time of 0 seconds, no keepalive messages will be sent. The BGP session will stay up until one of the peers, on either side, tries to transmit a message (For example, a prefix update).

Note Configuring a new timer value for the holddown timer will only take effect after the session has been reset. So, it is not possible to change the configuration of the holddown timer to avoid resetting the BGP session.

See the "BGP Peer Group Examples" at the end of this chapter for an example of enabling MD5 authentication.

BGP through PIX Firewalls

When configuring BGP peers with MD5 authentication that pass through a PIX firewall you must also disable the TCP random sequence number feature on the PIX firewall because this feature will prevent the BGP peers from successfully negotiating a connection. The BGP neighbor authentication fails because the PIX firewall changes the TCP sequence number for IP packets before it forwards them. When the BGP peer receiving the authentication request runs the MD5 algorithm it will detect that the TCP sequence number has been changed and reject the authentication request. To prevent the TCP sequence number change, use the **nonrandomseq** keyword in the PIX configuration for the static route configured to allow the BGP connection through the firewall. The non random sequence feature on the PIX firewall prevents the PIX firewall software from changing the sequence number.

Here is an example of the static command configuration on the PIX with the **nonrandomseq** keyword:

```
static (inside, outside) 10.0.0.0 10.0.0.0 netmask 255.0.0.0 norandomseq
```

Making Neighbors Members of the Peer Group

To configure a BGP neighbor to be a member of a BGP peer group, use the following command in router configuration mode, using the same peer group name:

Command	Purpose
`Router(config-router)# neighbor` *ip-address* **peer-group** *peer-group-name*	Makes a BGP neighbor a member of the peer group.

See the "BGP Peer Group Examples" section at the end of this chapter for examples of iBGP and eBGP peer groups.

Disabling a Peer or Peer Group

To disable an existing BGP neighbor or neighbor peer group, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor` {*ip-address* | *peer-group-name*} **shutdown**	Shuts down or disables a BGP neighbor or peer group.

To enable a previously existing neighbor or neighbor peer group that had been disabled using the **neighbor shutdown** router configuration command, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# no neighbor` {*ip-address* | *peer-group-name*} **shutdown**	Enables a BGP neighbor or peer group.

Indicating Backdoor Routes

You can indicate which networks are reachable by using a *backdoor* route that the border router should use. A backdoor network is treated as a local network, except that it is not advertised. To configure backdoor routes, use the **network backdoor** command, beginning in router configuration mode:

Command	Purpose
`Router(config-router)# network ip-address backdoor`	Indicates reachable networks through backdoor routes.

Modifying Parameters While Updating the IP Routing Table

By default, when a BGP route is put into the IP routing table, the MED is converted to an IP route metric, the BGP next hop is used as the next hop for the IP route, and the tag is not set. However, you can use a route map to perform mapping. To modify metric and tag information when the IP routing table is updated with BGP learned routes, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# table-map map-name`	Applies a route map to routes when updating the IP routing table.

Setting Administrative Distance

Administrative distance is a measure of the preference of different routing protocols. BGP uses three different administrative distances: external, internal, and local. Routes learned through external BGP are given the external distance, routes learned with iBGP are given the internal distance, and routes that are part of this autonomous system are given the local distance. To assign a BGP administrative distance, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# distance bgp external-distance internal-distance local-distance`	Assigns a BGP administrative distance.

Changing the administrative distance of BGP routes is considered dangerous and generally is not recommended. The external distance should be lower than any other dynamic routing protocol, and the internal and local distances should be higher than any other dynamic routing protocol.

Adjusting BGP Timers

BGP uses certain timers to control periodic activities such as the sending of keepalive messages and the interval after not receiving a keepalive message after which the Cisco IOS software declares a peer dead. By default, the keepalive timer is 60 seconds, and the hold-time timer is 180 seconds.You can adjust these timers. When a connection is started, BGP will negotiate the hold time with the neighbor. The smaller of the two hold times will be chosen. The keepalive timer is then set based on the negotiated hold time and the configured keepalive time.

To adjust BGP timers for all neighbors, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# timers bgp keepalive holdtime`	Adjusts BGP timers for all neighbors.

To adjust BTP keepalive and hold-time timers for a specific neighbor, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# neighbor [ip-address | peer-group-name] timers keepalive holdtime`	Sets the keepalive and hold-time timers (in seconds) for the specified peer or peer group.

Note The timers configured for a specific neighbor or peer group override the timers configured for all BGP neighbors using the **timers bgp** router configuration command.

To clear the timers for a BGP neighbor or peer group, use the **no** form of the **neighbor timers** command.

Changing the Default Local Preference Value

You can define a particular path as more preferable or less preferable than other paths by changing the default local preference value of 100. To assign a different default local preference value, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp default local-preference value`	Changes the default local preference value.

You can use route maps to change the default local preference of specific paths. See the "BGP Route Map Examples" section at the end of this chapter for examples when used with BGP route maps.

Redistributing Network 0.0.0.0

By default, you are not allowed to redistribute network 0.0.0.0. To permit the redistribution of network 0.0.0.0, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# default-information originate`	Allows the redistribution of network 0.0.0.0 into BGP.

Configuring the Router to Consider a Missing MED as Worst Path

To configure the router to consider a path with a missing MED attribute as the worst path, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp bestpath med missing-as-worst`	Configures the router to consider a missing MED as having a value of infinity, making the path without a MED value the least desirable path.

Selecting Path Based on MEDs from Other Autonomous Systems

The MED is one of the parameters that is considered when selecting the best path among many alternative paths. The path with a lower MED is preferred over a path with a higher MED.

By default, during the best path selection process, MED comparison is done only among paths from the same autonomous system. You can allow comparison of MEDs among paths regardless of the autonomous system from which the paths are received. To do so, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp always-compare-med`	Allows the comparison of MEDs for paths from neighbors in different autonomous systems.

Configuring the Router to Use the MED to Choose a Path from Subautonomous System Paths

To configure the router to consider the MED value in choosing a path, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp bestpath med confed`	Configures the router to consider the MED in choosing a path from among those advertised by different subautonomous systems within a confederation.

The comparison between MEDs is only made if there are no external autonomous systems in the path (an external autonomous system is an autonomous system that is not within the confederation). If there is an external autonomous system in the path, then the external MED is passed transparently through the confederation, and the comparison is not made.

The following example compares route A with these paths:

```
path= 65000 65004, med=2
path= 65001 65004, med=3
path= 65002 65004, med=4
path= 65003 1, med=1
```

In this case, path 1 would be chosen if the **bgp bestpath med confed** router configuration command is enabled. The fourth path has a lower MED, but it is not involved in the MED comparison because there is an external autonomous system is in this path.

Configuring the Router to Use the MED to Choose a Path in a Confederation

To configure the router to use the MED to select the best path from among paths advertised by a single subautonomous system within a confederation, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp deterministic med`	Configures the router to compare the MED variable when choosing among routes advertised by different peers in the same autonomous system.

Note If the **bgp always-compare-med** router configuration command is enabled, all paths are fully comparable, including those from other autonomous systems in the confederation, even if the **bgp deterministic med** command is also enabled.

Configuring Route Dampening

Route dampening is a BGP feature designed to minimize the propagation of flapping routes across an internetwork. A route is considered to be flapping when it is repeatedly available, then unavailable, then available, then unavailable, and so on.

For example, consider a network with three BGP autonomous systems: autonomous system 1, autonomous system 2, and autonomous system 3. Suppose the route to network A in autonomous system 1 flaps (it becomes unavailable). Under circumstances without route dampening, the eBGP neighbor of autonomous system 1 to autonomous system 2 sends a withdraw message to autonomous system 2. The border router in autonomous system 2, in turn, propagates the withdraw message to autonomous system 3. When the route to network A reappears, autonomous system 1 sends an advertisement message to autonomous system 2, which sends it to autonomous system 3. If the route to network A repeatedly becomes unavailable, then available, many withdrawal and advertisement messages are sent. This is a problem in an internetwork connected to the Internet because a route flap in the Internet backbone usually involves many routes.

Note No penalty is applied to a BGP peer reset when route dampening is enabled. Although the reset withdraws the route, no penalty is applied in this instance, even if route flap dampening is enabled.

Minimizing Flapping

The route dampening feature minimizes the flapping problem as follows. Suppose again that the route to network A flaps. The router in autonomous system 2 (where route dampening is enabled) assigns network A a penalty of 1000 and moves it to history state. The router in autonomous system 2 continues

to advertise the status of the route to neighbors. The penalties are cumulative. When the route flaps so often that the penalty exceeds a configurable suppress limit, the router stops advertising the route to network A, regardless of how many times it flaps. Thus, the route is dampened.

The penalty placed on network A is decayed until the reuse limit is reached, upon which the route is once again advertised. At half of the reuse limit, the dampening information for the route to network A is removed.

Understanding Route Dampening Terms

The following terms are used when describing route dampening:

- Flap—A route is available, then unavailable, or vice versa.
- History state—After a route flaps once, it is assigned a penalty and put into history state, meaning the router does not have the best path, based on historical information.
- Penalty—Each time a route flaps, the router configured for route dampening in another autonomous system assigns the route a penalty of 1000. Penalties are cumulative. The penalty for the route is stored in the BGP routing table until the penalty exceeds the suppress limit. At that point, the route state changes from history to damp.
- Damp state—In this state, the route has flapped so often that the router will not advertise this route to BGP neighbors.
- Suppress limit—A route is suppressed when its penalty exceeds this limit. The default value is 2000.
- Half-life—Once the route has been assigned a penalty, the penalty is decreased by half after the half-life period (which is 15 minutes by default). The process of reducing the penalty happens every 5 seconds.
- Reuse limit—As the penalty for a flapping route decreases and falls below this reuse limit, the route is unsuppressed. That is, the route is added back to the BGP table and once again used for forwarding. The default reuse limit is 750. The process of unsuppressing routes occurs at 10-second increments. Every 10 seconds, the router finds out which routes are now unsuppressed and advertises them to the world.
- Maximum suppress limit—This value is the maximum amount of time a route can be suppressed. The default value is four times the half-life.

The routes external to an autonomous system learned via iBGP are not dampened. This policy prevent the iBGP peers from having a higher penalty for routes external to the autonomous system.

Enabling Route Dampening

To enable BGP route dampening, use the following command in address family or router configuration mode:

Command	Purpose
`Router(config)# bgp dampening`	Enables BGP route dampening.

To change the default values of various dampening factors, use the following command in address family or router configuration mode:

Command	Purpose
`Router(config)# bgp dampening half-life reuse suppress max-suppress [route-map map-name]`	Changes the default values of route dampening factors.

Monitoring and Maintaining BGP Route Dampening

You can monitor the flaps of all the paths that are flapping. The statistics will be deleted once the route is not suppressed and is stable for at least one half-life. To display flap statistics, use the following commands in EXEC mode as needed:

Command	Purpose
`Router# show ip bgp flap-statistics`	Displays BGP flap statistics for all paths.
`Router# show ip bgp flap-statistics regexp regexp`	Displays BGP flap statistics for all paths that match the regular expression.
`Router# show ip bgp flap-statistics filter-list access-list`	Displays BGP flap statistics for all paths that pass the filter.
`Router# show ip bgp flap-statistics ip-address mask`	Displays BGP flap statistics for a single entry.
`Router# show ip bgp flap-statistics ip-address mask longer-prefix`	Displays BGP flap statistics for more specific entries.

To clear BGP flap statistics (thus making it less likely that the route will be dampened), use the following commands in EXEC mode as needed:

Command	Purpose
`Router# clear ip bgp flap-statistics`	Clears BGP flap statistics for all routes.
`Router# clear ip bgp flap-statistics regexp regexp`	Clears BGP flap statistics for all paths that match the regular expression.
`Router# clear ip bgp flap-statistics filter-list list`	Clears BGP flap statistics for all paths that pass the filter.
`Router# clear ip bgp flap-statistics ip-address mask`	Clears BGP flap statistics for a single entry.
`Router# clear ip bgp ip-address flap-statistics`	Clears BGP flap statistics for all paths from a neighbor.

Note The flap statistics for a route are also cleared when a BGP peer is reset. Although the reset withdraws the route, there is no penalty applied in this instance, even if route flap dampening is enabled.

Once a route is dampened, you can display BGP route dampening information, including the time remaining before the dampened routes will be unsuppressed. To display the information, use the following command in EXEC mode:

Command	Purpose
`Router# show ip bgp dampened-paths`	Displays the dampened routes, including the time remaining before they will be unsuppressed.

You can clear BGP route dampening information and unsuppress any suppressed routes by using the following command in EXEC mode:

Command	Purpose
`Router# clear ip bgp dampening [ip-address network-mask]`	Clears route dampening information and unsuppresses the suppressed routes.

Monitoring and Maintaining BGP

You can remove all contents of a particular cache, table, or database. You also can display specific statistics. The following sections describe each of these tasks.

Clearing Caches, Tables, and Databases

You can remove all contents of a particular cache, table, or database. Clearing a cache, table, or database can become necessary when the contents of the particular structure have become, or are suspected to be, invalid.

To clear caches, tables, and databases for BGP, use the following commands in EXEC mode, as needed:

Command	Purpose
`Router# clear ip bgp neighbor-address`	Resets a particular BGP connection.
`Router# clear ip bgp *`	Resets all BGP connections.
`Router# clear ip bgp peer-group tag`	Removes all members of a BGP peer group.

Displaying System and Network Statistics

You can display specific statistics such as the contents of BGP routing tables, caches, and databases. Information provided can be used to determine resource utilization and solve network problems. You can also display information about node reachability and discover the routing path that the packets of your device are taking through the network.

To display various routing statistics, use the following commands in EXEC mode, as needed:

Command	Purpose
`Router# show ip bgp prefix`	Displays peer groups and peers not in peer groups to which the prefix has been advertised. Also displays prefix attributes such as the next hop and the local prefix.
`Router# show ip bgp cidr-only`	Displays all BGP routes that contain subnet and supernet network masks.
`Router# show ip bgp community community-number [exact]`	Displays routes that belong to the specified communities.
`Router# show ip bgp community-list community-list-number [exact]`	Displays routes that are permitted by the community list.
`Router# show ip bgp filter-list access-list-number`	Displays routes that are matched by the specified autonomous system path access list.
`Router# show ip bgp inconsistent-as`	Displays the routes with inconsistent originating autonomous systems.
`Router# show ip bgp regexp regexp`	Displays the routes that have an autonomous system path that matches the specified regular expression entered on the command line.
`Router# show ip bgp`	Displays the contents of the BGP routing table.
`Router# show ip bgp neighbors [neighbor-address]`	Displays detailed information on the BGP and TCP connections to individual neighbors.
`Router# show ip bgp neighbors [address] [received-routes | routes | advertised-routes | paths regexp | dampened-routes]`	Displays routes learned from a particular BGP neighbor.
`Router# show ip bgp paths`	Displays all BGP paths in the database.
`Router# show ip bgp peer-group [tag] [summary]`	Displays information about BGP peer groups.
`Router# show ip bgp summary`	Displays the status of all BGP connections.

Logging Changes in Neighbor Status

To enable the logging of messages generated when a BGP neighbor resets, comes up, or goes down, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# bgp log-neighbor-changes`	Logs messages generated when a BGP neighbor goes up or down, or resets

BGP Configuration Examples

The following sections provide BGP configuration examples:

- BGP Route Map Examples
- BGP Neighbor Configuration Examples

- BGP Prefix List Filtering Examples
- BGP Soft Reset Examples
- BGP Synchronization Examples
- BGP Path Filtering by Neighbor Examples
- BGP Aggregate Route Examples
- BGP Community with Route Maps Examples
- BGP Conditional Advertisement Configuration Examples
- BGP Confederation Examples
- BGP Peer Group Examples
- TCP MD5 Authentication for BGP Examples

BGP Route Map Examples

The following example shows how you can use route maps to modify incoming data from a neighbor. Any route received from 140.222.1.1 that matches the filter parameters set in autonomous system access list 200 will have its weight set to 200 and its local preference set to 250, and it will be accepted.

```
router bgp 100
!
 neighbor 140.222.1.1 route-map FIX-WEIGHT in
 neighbor 140.222.1.1 remote-as 1
!
ip as-path access-list 200 permit ^690$
ip as-path access-list 200 permit ^1800
!
route-map FIX-WEIGHT permit 10
 match as-path 200
 set local-preference 250
 set weight200
```

In the following example, the route map named freddy marks all paths originating from autonomous system 690 with an MED metric attribute of 127. The second permit clause is required so that routes not matching autonomous system path list 1 will still be sent to neighbor 1.1.1.1.

```
router bgp 100
 neighbor 1.1.1.1 route-map freddy out
!
ip as-path access-list 1 permit ^690_
ip as-path access-list 2 permit .*
!
route-map freddy permit 10
 match as-path 1
 set metric 127
!
route-map freddy permit 20
 match as-path 2
```

The following example shows how you can use route maps to modify redistributed information from the IP forwarding table:

```
router bgp 100
 redistribute igrp 109 route-map igrp2bgp
!
route-map igrp2bgp
 match ip address 1
```

```
 set local-preference 25
 set metric 127
 set weight 30000
 set next-hop 192.92.68.24
 set origin igp
!
access-list 1 permit 131.108.0.0 0.0.255.255
access-list 1 permit 160.89.0.0 0.0.255.255
access-list 1 permit 198.112.0.0 0.0.127.255
```

It is proper behavior to not accept any autonomous system path not matching the **match** clause of the route map. This behavior means that you will not set the metric and the Cisco IOS software will not accept the route. However, you can configure the software to accept autonomous system paths not matched in the **match** clause of the **route-map** router configuration command by using multiple maps of the same name, some without accompanying **set** commands.

```
route-map fnord permit 10
 match as-path 1
 set local-preference 5
!
route-map fnord permit 20
 match as-path 2
```

The following example shows how you can use route maps in a reverse operation to set the route tag (as defined by the BGP/OSPF interaction document, RFC 1403) when exporting routes from BGP into the main IP routing table:

```
router bgp 100
 table-map set_ospf_tag
!
route-map set_ospf_tag
 match as-path 1
 set automatic-tag
!
ip as-path access-list 1 permit .*
```

The following example shows how the route map named set-as-path is applied to outbound updates to the neighbor 200.69.232.70. The route map will prepend the autonomous system path “100 100” to routes that pass access list 1. The second part of the route map is to permit the advertisement of other routes.

```
router bgp 100
 network 171.60.0.0
 network 172.60.0.0
 neighbor 200.69.232.70 remote-as 200
 neighbor 200.69.232.70 route-map set-as-path out
!
route-map set-as-path 10 permit
 match address 1
 set as-path prepend 100 100
!
route-map set-as-path 20 permit
 match address 2
!
access-list 1 permit 171.60.0.0 0.0.255.255
access-list 1 permit 172.60.0.0 0.0.255.255
!
access-list 2 permit 0.0.0.0 255.255.255.255
```

Inbound route maps could perform prefix-based matching and set various parameters of the update. Inbound prefix matching is available in addition to autonomous system path and community list matching. The following example shows how the **set local-preference** route-map configuration command sets the local preference of the inbound prefix 140.10.0.0/16 to 120:

```
!
router bgp 100
 network 131.108.0.0
 neighbor 131.108.1.1 remote-as 200
 neighbor 131.108.1.1 route-map set-local-pref in
!
route-map set-local-pref permit 10
 match ip address 2
 set local preference 120
!
route-map set-local-pref permit 20
!
access-list 2 permit 140.10.0.0 0.0.255.255
access-list 2 deny any
```

The following examples show how to ensure that traffic from one router on a shared LAN will always be passed through a second router, rather than being sent directly to a third router on the same LAN.

Routers A, B, and C connect to the same LAN. Router A peers with router B, and router B peers with router C. Router B sends traffic over the routes of router A to router C, but wants to make sure that all traffic from router C to router A goes through router B, rather than directly from router C to router A over the shared LAN. This configuration can be useful for traffic accounting purposes or to satisfy the peering agreement between router C and router B. You can achieve this configuration by using the **set ip next-hop** route-map configuration command as shown in the following two examples.

Example one applies an inbound route map on the BGP session of router C with router B.

Router A Configuration

```
router bgp 100
 neighbor 1.1.1.2 remote-as 200
```

Router B Configuration

```
router bgp 200
 neighbor 1.1.1.1 remote-as 100
 neighbor 1.1.1.3 remote-as 300
```

Router C Configuration

```
router bgp 300
 neighbor 1.1.1.2 remote-as 200
 neighbor 1.1.1.2 route-map set-peer-address in

route-map set-peer-address permit 10
 set ip next-hop peer-address
```

The following example applies an outbound route map on the BGP session of router B with router C:

Router A Configuration

```
router bgp 100
 neighbor 1.1.1.2 remote-as 200
```

Router B Configuration

```
router bgp 200
 neighbor 1.1.1.1 remote-as 100
```

```
 neighbor 1.1.1.3 remote-as 300
 neighbor 1.1.1.3 route-map set-peer-address out

route-map set-peer-address permit 10
 set ip next-hop peer-address
```

Router C Configuration

```
router bgp 300
 neighbor 1.1.1.2 remote-as 200
```

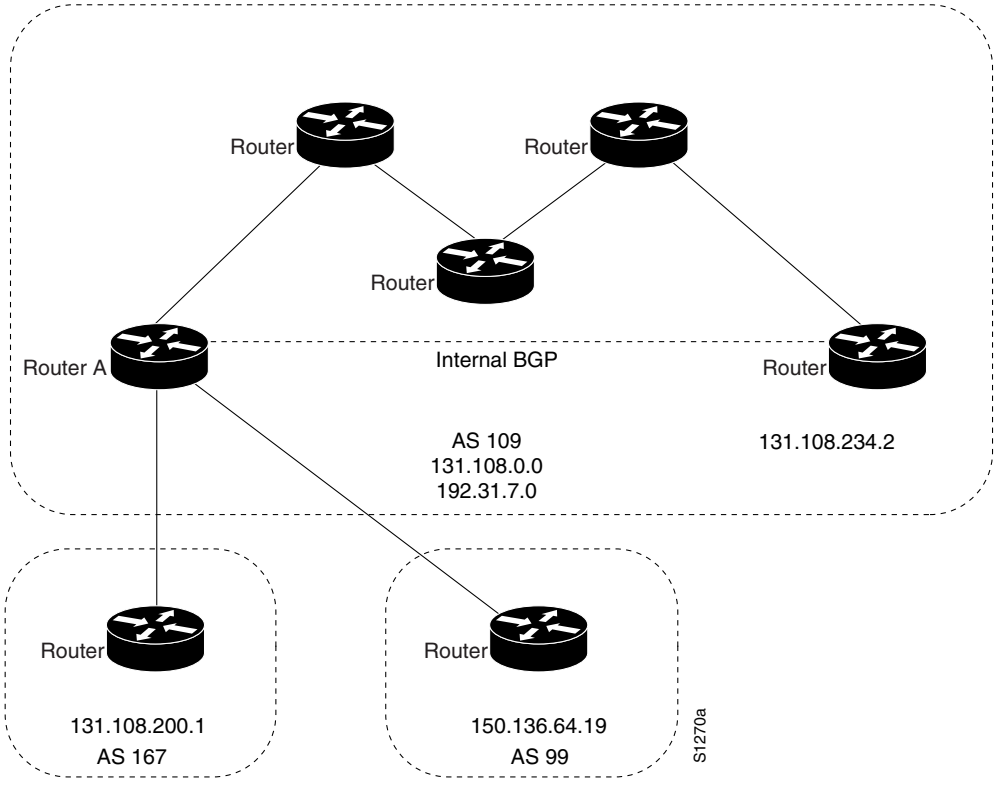
BGP Neighbor Configuration Examples

The following example shows how BGP neighbors on an autonomous system are configured to share information. In the example, a BGP router is assigned to autonomous system 109, and two networks are listed as originating in the autonomous system. Then the addresses of three remote routers (and their autonomous systems) are listed. The router being configured will share information about networks 131.108.0.0 and 192.31.7.0 with the neighbor routers. The first router listed is in a different autonomous system; the second **neighbor remote-as** router configuration command specifies an internal neighbor (with the same autonomous system number) at address 131.108.234.2; and the third **neighbor remote-as** router configuration command specifies a neighbor on a different autonomous system.

```
router bgp 109
 network 131.108.0.0
 network 192.31.7.0
 neighbor 131.108.200.1 remote-as 167
 neighbor 131.108.234.2 remote-as 109
 neighbor 150.136.64.19 remote-as 99
```

In Figure 58, Router A is being configured. The iBGP neighbor is not directly linked to Router A. External neighbors (in autonomous system 167 and autonomous system 99) must be linked directly to Router A.

Figure 58 Assigning Internal and External BGP Neighbors



BGP Prefix List Filtering Examples

The following examples show route filtering using a single prefix list and a group of prefixes, and how to add or delete an individual entry from a prefix list.

Route Filtering Configuration Example Using a Single Prefix List

The following example shows how a prefix list denies the default route 0.0.0.0/0:

```
ip prefix-list abc deny 0.0.0.0/0
```

The following example shows how a prefix list permits a route that matches the prefix 35.0.0.0/8:

```
ip prefix-list abc permit 35.0.0.0/8
```

The following example shows how to configure the BGP process so that it only accept prefixes with a prefix length of /8 to /24:

```
router bgp
version 2
network 101.20.20.0
distribute-list prefix max24 in
!
ip prefix-list max24 seq 5 permit 0.0.0.0/0 ge 8 le 24
```

The following example configuration shows how to conditionally originate a default route (0.0.0.0/0) in RIP when a prefix 10.1.1.0/24 exists in the routing table:

```
ip prefix-list cond permit 10.1.1.0/24
!
route-map default-condition permit 10
match ip address prefix-list cond
!
router rip
default-information originate route-map default-condition
```

The following example shows how to configure BGP to accept routing updates from 192.1.1.1 only, besides filtering on the prefix length:

```
router bgp
distribute-list prefix max24 gateway allowlist in
!
ip prefix-list allowlist seq 5 permit 192.1.1.1/32
!
```

The following example shows how to direct the BGP process to filter incoming updates to the prefix using name1, and match the gateway (next hop) of the prefix being updated to the prefix list name2, on the Ethernet interface 0:

```
router bgp 103
distribute-list prefix name1 gateway name2 in ethernet 0.
```

Route Filtering Configuration Example Specifying a Group of Prefixes

The following example shows how to configure BGP to permit routes with a prefix length up to 24 in network 192/8:

```
ip prefix-list abc permit 192.0.0.0/8 le 24
```

The following example shows how to configure BGP to deny routes with a prefix length greater than in 25 in 192/8:

```
ip prefix-list abc deny 192.0.0.0/8 ge 25
```

The following example shows how to configure BGP to permit routes with a prefix length greater than 8 and less than 24 in all address space:

```
ip prefix-list abc permit 0.0.0.0/0 ge 8 le 24
```

The following example shows how to configure BGP to deny routes with a prefix length greater than 25 in all address space:

```
ip prefix-list abc deny 0.0.0.0/0 ge 25
```

The following example shows how to configure BGP to deny all routes in 10/8, because any route in the Class A network 10.0.0.0/8 is denied if its mask is less than or equal to 32 bits:

```
ip prefix-list abc deny 10.0.0.0/8 le 32
```

The following example shows how to configure BGP to deny routes with a mask greater than 25 in 204.70.1/24:

```
ip prefix-list abc deny 204.70.1.0/24 ge 25
```

The following example shows how to configure BGP to permit all routes:

```
ip prefix-list abc permit 0.0.0.0/0 le 32
```

Added or Deleted Prefix List Entries Examples

You can add or delete individual entries in a prefix list if a prefix list has the following initial configuration:

```
ip prefix-list abc deny 0.0.0.0/0 le 7
ip prefix-list abc deny 0.0.0.0/0 ge 25
ip prefix-list abc permit 35.0.0.0/8
ip prefix-list abc permit 204.70.0.0/15
```

The following example shows how to delete an entry from the prefix list so that 204.70.0.0 is not permitted, and add a new entry that permits 198.0.0.0/8:

```
no ip prefix-list abc permit 204.70.0.0/15
ip prefix-list abc permit 198.0.0.0/8
```

The new configuration is as follows:

```
ip prefix-list abc deny 0.0.0.0/0 le 7
ip prefix-list abc deny 0.0.0.0/0 ge 25
ip prefix-list abc permit 35.0.0.0/8
ip prefix-list abc permit 198.0.0.0/8
```

BGP Soft Reset Examples

The following examples show two ways to reset the connection for BGP peer 131.108.1.1.

Dynamic Inbound Soft Reset Example

The following examples shows the **clear ip bgp 131.108.1.1 soft in** EXEC command used to initiate a dynamic soft reconfiguration in the BGP peer 131.108.1.1. This command requires that the peer support the route refresh capability.

```
clear ip bgp 131.108.1.1 soft in
```

Inbound Soft Reset Using Stored Information Example

The following example shows how to enable inbound soft reconfiguration for the neighbor 131.108.1.1. All the updates received from this neighbor will be stored unmodified, regardless of the inbound policy. When inbound soft reconfiguration is performed later, the stored information will be used to generate a new set of inbound updates.

```
router bgp 100
 neighbor 131.108.1.1 remote-as 200
 neighbor 131.108.1.1 soft-reconfiguration inbound
```

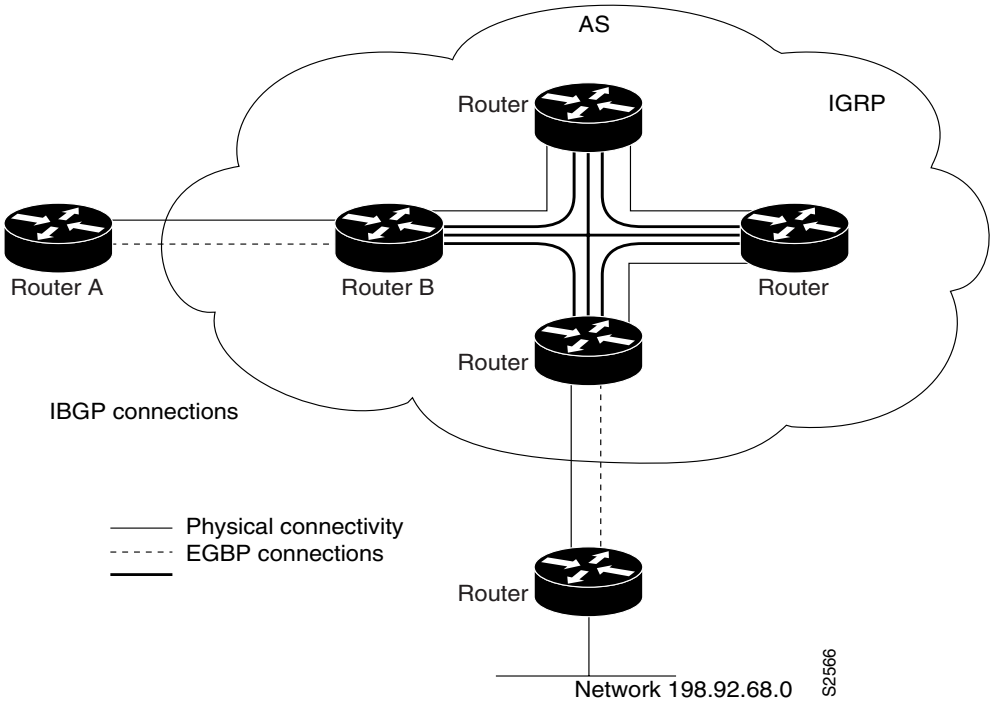
The following example clears the session with the neighbor 131.108.1.1.

```
clear ip bgp 131.108.1.1 soft in
```

BGP Synchronization Examples

The example shown in Figure 59 shows how to use the **no synchronization** router configuration command. In the figure, synchronization is on, and Router B does not advertise network 198.92.68.0 to Router A until an IGRP route for network 198.92.68.0 exists. If you specify the **no synchronization** router configuration command, Router B advertises network 198.92.68.0 as soon as possible. However, because routing information still must be sent to interior peers, you must configure a full iBGP mesh.

Figure 59 BGP Synchronization Configuration



BGP Path Filtering by Neighbor Examples

The following example shows BGP path filtering by neighbor. Only the routes that pass autonomous system path access list 2 will be sent to 193.1.12.10. Similarly, only routes passing access list 3 will be accepted from 193.1.12.10.

```
router bgp 200
 neighbor 193.1.12.10 remote-as 100
 neighbor 193.1.12.10 filter-list 1 out
 neighbor 193.1.12.10 filter-list 2 in
ip as-path access-list 1 permit _109_
ip as-path access-list 2 permit _200$
ip as-path access-list 2 permit ^100$
ip as-path access-list 3 deny _690$
ip as-path access-list 3 permit .*
```

BGP Aggregate Route Examples

The following examples show how you can use aggregate routes in BGP either by redistributing an aggregate route into BGP or by using the BGP Conditional Aggregate routing feature.

In the following example, the **redistribute static** router configuration command is used to redistribute aggregate route 193.0.0.0:

```
ip route 193.0.0.0 255.0.0.0 null 0
!
router bgp 100
 redistribute static
```

The following configuration shows how to create an aggregate entry in the BGP routing table when at least one specific route falls into the specified range. The aggregate route will be advertised as coming from your autonomous system and has the atomic aggregate attribute set to show that information might be missing. (By default, atomic aggregate is set unless you use the **as-set** keyword in the **aggregate-address** router configuration command.)

```
router bgp 100
 aggregate-address 193.0.0.0 255.0.0.0
```

The following example shows how to create an aggregate entry using the same rules as in the previous example, but the path advertised for this route will be an AS_SET consisting of all elements contained in all paths that are being summarized:

```
router bgp 100
 aggregate-address 193.0.0.0 255.0.0.0 as-set
```

The following example shows how to create the aggregate route for 193.0.0.0 and also suppress advertisements of more specific routes to all neighbors:

```
router bgp 100
 aggregate-address 193.0.0.0 255.0.0.0 summary-only
```

BGP Community with Route Maps Examples

This section contains three examples of the use of BGP communities with route maps, and two examples that also contain confederation configurations. For an example of how to configure a BGP confederation, see the section "BGP Confederation Examples" in this chapter.

The first example shows how the route map named set-community is applied to the outbound updates to the neighbor 171.69.232.50. The routes that pass access list 1 have the special community attribute value no-export. The remaining routes are advertised normally. This special community value automatically prevents the advertisement of those routes by the BGP speakers in autonomous system 200.

```
router bgp 100
 neighbor 171.69.232.50 remote-as 200
 neighbor 171.69.232.50 send-community
 neighbor 171.69.232.50 route-map set-community out
!
route-map set-community 10 permit
 match address 1
 set community no-export
!
route-map set-community 20 permit
 match address 2
```

The second example shows how the route map named set-community is applied to the outbound updates to neighbor 171.69.232.90. All the routes that originate from autonomous system 70 have the community values 200 200 added to their already existing values. All other routes are advertised as normal.

```
route-map bgp 200
 neighbor 171.69.232.90 remote-as 100
 neighbor 171.69.232.90 send-community
 neighbor 171.69.232.90 route-map set-community out
!
route-map set-community 10 permit
 match as-path 1
 set community 200 200 additive
!
route-map set-community 20 permit
!
ip as-path access-list 1 permit 70$
ip as-path access-list 2 permit .*
```

The third example shows how community-based matching is used to selectively set MED and local preference for routes from neighbor 171.69.232.55. All the routes that match community list 1 get the MED set to 8000, including any routes that have the communities 100 200 300 or 900 901. These routes could have other community values also.

All the routes that pass community list 2 get the local preference set to 500. This includes the routes that have community values 88 or 90. If they belong to any other community, they will not be matched by community list 2.

All the routes that match community list 3 get the local preference set to 50. Community list 3 will match all the routes because all the routes are members of the Internet community. Thus, all the remaining routes from neighbor 171.69.232.55 get a local preference 50.

```
router bgp 200
 neighbor 171.69.232.55 remote-as 100
 neighbor 171.69.232.55 route-map filter-on-community in
!
route-map filter-on-community 10 permit
 match community 1
 set metric 8000
!
route-map filter-on-community 20 permit
 match community 2 exact-match
 set local-preference 500
!
route-map filter-on-community 30 permit
 match community 3
 set local-preference 50
!
ip community-list 1 permit 100 200 300
ip community-list 1 permit 900 901
!
ip community-list 2 permit 88
ip community-list 2 permit 90
!
ip community-list 3 permit internet
```

The next two examples show how BGP community attributes are used with BGP confederation configurations to filter routes.

The next example shows how the route map named set-community is applied to the outbound updates to neighbor 171.69.232.50 and the local-as community attribute is used to filter the routes. The routes that pass access list 1 have the special community attribute value local-as. The remaining routes are advertised normally. This special community value automatically prevents the advertisement of those routes by the BGP speakers outside autonomous system 200.

```
router bgp 65000
 network 1.0.0.0 route-map set-community
 bgp confederation identifier 200
 bgp confederation peers 65001
 neighbor 171.69.232.50 remote-as 100
 neighbor 171.69.233.2 remote-as 65001
!
route-map set-community permit 10
 match ip address 1
 set community local-as
!
```

The following example shows how to use the local-as community attribute to filter the routes. Confederation 100 contains three autonomous systems: 100, 200, and 300. For network 1.0.0.0, the route map named set-local-as specifies that the advertised routes have the community attribute local-as. These routes are not advertised to any eBGP peer outside the local autonomous system. For network 2.0.0.0, the route map named set-no-export specifies that the routes advertised have the community attribute no-export.

A route between router 6500 and router 65001 does not cross the boundary between autonomous systems within the confederation. A route between subautonomous systems for which router 65000 is the controlling router does not cross the boundary between the confederation and an external autonomous system, and also does not cross the boundary between subautonomous systems within the local autonomous system. A route to from router 65000 to router 65001 would not be acceptable for network 1.0.0.0 because it crosses the boundary between subautonomous systems within the confederation.

```
router bgp 65001
 bgp confederation identifier 200
 bgp confederation peer 65000
 network 2.0.0.0 route-map  set-community
 neighbor 171.69.233.1 remote-as 65000
route-map set-community permit 10
 set community no-export
```

BGP Conditional Advertisement Configuration Examples

This section provides a configuration example of the BGP Conditional Advertisement feature. In the following example, the *ip-address* argument refers to the IP address of the neighbor, and the *map1-name* and *map2-name* arguments, refer to the names of the route maps:

neighbor{*ip-address*} **advertise-map** {*map1-name*} **non-exist-map** {*map2-name*}

no neighbor{*ip-address*} **advertise-map** {*map1-name*} **non-exist-map** {*map2-name*}

The route map associated with the non-exist-map specifies the prefix that the BGP speaker tracks. The route map associated with the advertise map specifies the prefix that is advertised when the prefix in the non-exist-map no longer exists. The prefix tracked by the BGP speaker must be present in the BGP table for the conditional advertisement not to take place. In the following example, the router advertises 172.16.0.0/16 to its neighbor only if 192.168.7.0/24 is not present in the IP routing table.

To conditionally advertise a set of routes, use the following commands in router configuration mode:

```
ip prefix-list BLUE permit 172.16.0.0
ip prefix-list RED permit 192.168.7.0
!
route-map map1-name permit 10
 match ip address prefix-list BLUE
!
route-map map2-name permit 10
 match ip address prefix-list RED
!
router bgp 100
 neighbor 10.89.2.33 remote-as 2051
 neighbor 10.89.2.33 advertise-map map1-name non-exist-map map2-name
!
```

BGP Confederation Examples

The following is a sample configuration that shows several peers in a confederation. The confederation consists of three internal autonomous systems with autonomous system numbers 6001, 6002, and 6003. To the BGP speakers outside the confederation, the confederation looks like a normal autonomous system with autonomous system number 60000 (specified via the **bgp confederation identifier** router configuration command).

In a BGP speaker in autonomous system 6001, the **bgp confederation peers** router configuration command marks the peers from autonomous systems 6002 and 6003 as special eBGP peers. Hence peers 171.69.232.55 and 171.69.232.56 will get the local preference, next hop, and MED unmodified in the updates. The router at 160.69.69.1 is a normal eBGP speaker and the updates received by it from this peer will be just like a normal eBGP update from a peer in autonomous system 60000.

```
router bgp 6001
 bgp confederation identifier 60000
 bgp confederation peers 6002 6003
 neighbor 171.69.232.55 remote-as 6002
 neighbor 171.69.232.56 remote-as 6003
 neighbor 160.69.69.1 remote-as 777
```

In a BGP speaker in autonomous system 6002, the peers from autonomous systems 6001 and 6003 are configured as special eBGP peers. 170.70.70.1 is a normal iBGP peer and 199.99.99.2 is a normal eBGP peer from autonomous system 700.

```
router bgp 6002
 bgp confederation identifier 60000
 bgp confederation peers 6001 6003
 neighbor 170.70.70.1 remote-as 6002
 neighbor 171.69.232.57 remote-as 6001
 neighbor 171.69.232.56 remote-as 6003
 neighbor 199.99.99.2 remote-as 700
```

In a BGP speaker in autonomous system 6003, the peers from autonomous systems 6001 and 6002 are configured as special eBGP peers. 200.200.200.200 is a normal eBGP peer from autonomous system 701.

```
router bgp 6003
 bgp confederation identifier 60000
 bgp confederation peers 6001 6002
 neighbor 171.69.232.57 remote-as 6001
 neighbor 171.69.232.55 remote-as 6002
 neighbor 200.200.200.200 remote-as 701
```

The following is a part of the configuration from the BGP speaker 200.200.200.205 from autonomous system 701 in the same example. Neighbor 171.69.232.56 is configured as a normal eBGP speaker from autonomous system 60000. The internal division of the autonomous system into multiple autonomous systems is not known to the peers external to the confederation.

```
router bgp 701
 neighbor 171.69.232.56 remote-as 60000
 neighbor 200.200.200.205 remote-as 701
```

For examples of how the BGP **set-community** route-map configuration command can be used with a confederation configuration, see the last two examples in the section"BGP Community with Route Maps Examples" in this chapter.

BGP Peer Group Examples

This section contains an iBGP peer group example and an eBGP peer group example.

iBGP Peer Group Example

The following example shows how the peer group named internal configures the members of the peer group to be iBGP neighbors. By definition, this is an iBGP peer group because the **router bgp** global configuration command and the **neighbor remote-as** router configuration command indicate the same autonomous system (in this case, autonomous system 100). All the peer group members use loopback 0 as the update source and use set-med as the outbound route map. The example also shows that, except for the neighbor at address 171.69.232.55, all the neighbors have filter list 2 as the inbound filter list.

```
router bgp 100
 neighbor internal peer-group
 neighbor internal remote-as 100
 neighbor internal update-source loopback 0
 neighbor internal route-map set-med out
 neighbor internal filter-list 1 out
 neighbor internal filter-list 2 in
 neighbor 171.69.232.53 peer-group internal
 neighbor 171.69.232.54 peer-group internal
 neighbor 171.69.232.55 peer-group internal
 neighbor 171.69.232.55 filter-list 3 in
```

eBGP Peer Group Example

The following example shows how the peer group named external-peers is defined without the **neighbor remote-as** router configuration command, making it an eBGP peer group. Each member of the peer group is configured with its respective autonomous system number separately. Thus, the peer group consists of members from autonomous systems 200, 300, and 400. All the peer group members have set-metric route map as an outbound route map and filter list 99 as an outbound filter list. Except for neighbor 171.69.232.110, all have 101 as the inbound filter list.

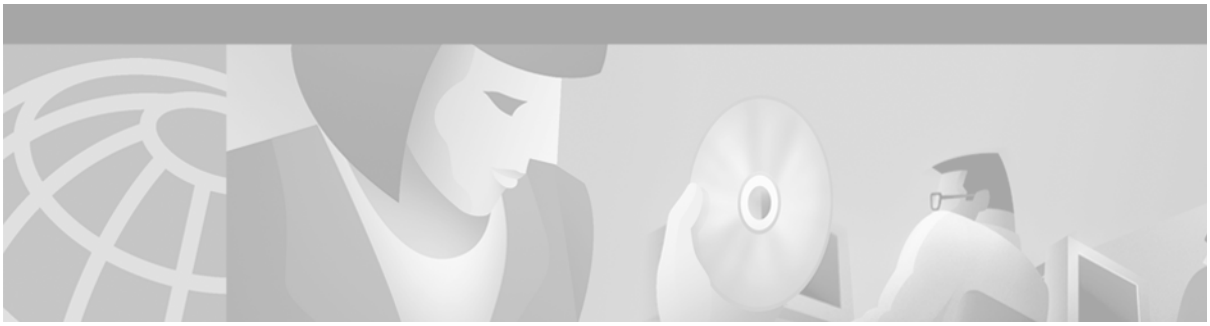
```
router bgp 100
 neighbor external-peers peer-group
 neighbor external-peers route-map set-metric out
 neighbor external-peers filter-list 99 out
 neighbor external-peers filter-list 101 in
 neighbor 171.69.232.90 remote-as 200
 neighbor 171.69.232.90 peer-group external-peers
 neighbor 171.69.232.100 remote-as 300
 neighbor 171.69.232.100 peer-group external-peers
 neighbor 171.69.232.110 remote-as 400
```

```
 neighbor 171.69.232.110 peer-group external-peers
 neighbor 171.69.232.110 filter-list 400 in
```

TCP MD5 Authentication for BGP Examples

The following example enables the authentication feature between this router and the BGP neighbor at 10.108.1.1. The password that must also be configured for the neighbor is *bla4u00=2nkq*.The remote peer must be configured before the holddown timer expires.

```
router bgp 109
 neighbor 10.108.1.1 password bla4u00=2nkq
```



Configuring Multiprotocol BGP Extensions for IP Multicast

This chapter describes the multiprotocol Border Gateway Protocol (BGP) based upon RFC 2283, *Multiprotocol Extensions for BGP-4*. For a complete description of the multiprotocol BGP commands in this chapter, refer to the "Multiprotocol BGP Extensions for IP Multicast Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols*. To locate documentation for other commands that appear in this chapter, use the command reference master index, or search online. For BGP configuration information and examples, refer to the "Configuring BGP" chapter of the *Cisco IOS IP Configuration Guide*. For BGP command descriptions, refer to the "BGP Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols*.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

An extension of BGP, multiprotocol BGP offers the following benefits:

- A network can support incongruent unicast and multicast topologies.
- A network can support congruent unicast and multicast topologies that have different policies (BGP filtering configurations).
- A network can carry routing information for multiple network layer protocol address families (for example, IP Version 4 or VPN Version 4) as specified in RFC 1700, *Assigned Numbers*.
- A network that is backward compatible—routers that support the multiprotocol extensions can interoperate with routers that do not support the extensions.
- All of the routing policy capabilities of BGP can be applied to multiprotocol BGP.
- All of the BGP commands can be used with multiprotocol BGP.

You should be familiar with BGP and IP multicast routing before you attempt to configure multiprotocol BGP. For IP multicast configuration information and examples, refer to the "IP Multicast" part of this document and *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*.

Multiprotocol BGP is an enhanced BGP that carries routing information for multiple network layer protocols and IP multicast routes. BGP carries two sets of routes, one set for unicast routing and one set for multicast routing. The routes associated with multicast routing are used by the Protocol Independent Multicast (PIM) feature to build data distribution trees.

Multiprotocol BGP is useful when you want a link dedicated to multicast traffic, perhaps to limit which resources are used for which traffic. Perhaps you want all multicast traffic exchanged at one network access point (NAP). Multiprotocol BGP allows you to have a unicast routing topology different from a multicast routing topology. Thus, you have more control over your network and resources.

In BGP, the only way to perform interdomain multicast routing was to use the BGP infrastructure that was in place for unicast routing. If those routers were not multicast-capable, or there were differing policies where you wanted multicast traffic to flow, multicast routing could not be supported without multiprotocol BGP.

Note It is possible to configure BGP peers that exchange both unicast and multicast network layer reachability information (NLRI), but you cannot connect multiprotocol BGP clouds with a BGP cloud. That is, you cannot redistribute multiprotocol BGP routes into BGP.

Figure 60 illustrates a simple example of unicast and multicast topologies that are incongruent, and therefore are not possible without multiprotocol BGP.

Autonomous systems 100, 200, and 300 are each connected to two NAPs that are FDDI rings. One is used for unicast peering (and therefore the exchanging of unicast traffic). The Multicast Friendly Interconnect (MFI) ring is used for multicast peering (and therefore the exchanging of multicast traffic). Each router is unicast- and multicast-capable.

Figure 60 Incongruent Unicast and Multicast Routes

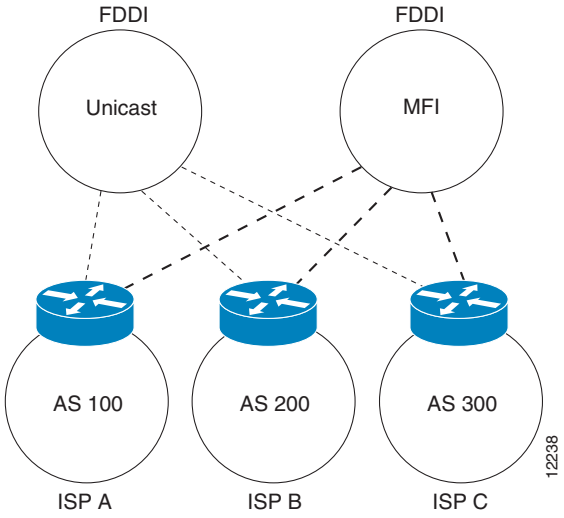


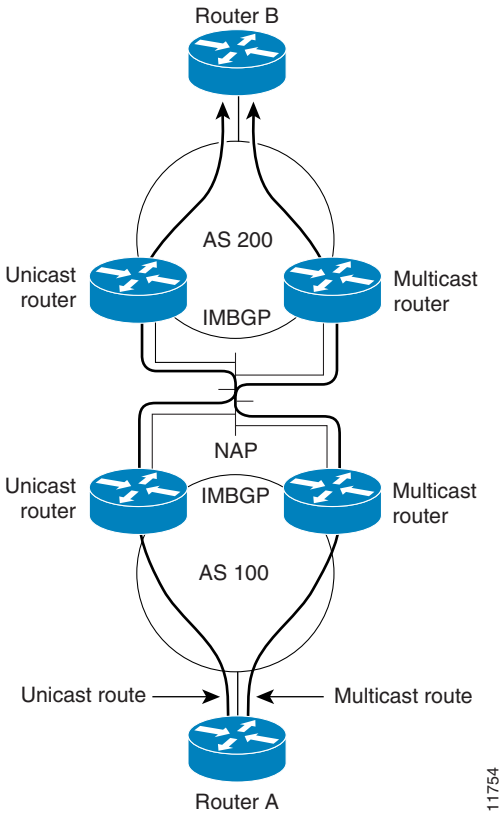
Figure 61 is a topology of unicast-only routers and multicast-only routers. The two routers on the left are unicast-only routers (that is, they do not support or are not configured to perform multicast routing). The two routers on the right are multicast-only routers. Routers A and B support both unicast and multicast routing. The unicast-only and multicast-only routers are connected to a single NAP.

In Figure 61, only unicast traffic can travel from Router A to the unicast routers to Router B and back. Multicast traffic could not flow on that path, so another routing table is required. Multicast traffic uses the path from Router A to the multicast routers to Router B and back.

Figure 61 illustrates a multiprotocol BGP environment with a separate unicast route and multicast route from Router A to Router B. Multiprotocol BGP allows these routes to be noncongruent. Both of the autonomous systems must be configured for internal multiprotocol BGP (IMBGP) in the figure.

A multicast routing protocol, such as PIM, uses the multicast BGP database to perform Reverse Path Forwarding (RPF) lookups for multicast-capable sources. Thus, packets can be sent and accepted on the multicast topology but not on the unicast topology.

Figure 61 Multicast BGP Environment



Multiprotocol BGP Configuration Task List

To configure multiprotocol BGP, perform the following tasks described in the following sections. Each section in the list is identified as either required or optional.

- Understanding NLRI Keywords and Address Families (Required)
- Configuring a Multiprotocol BGP Peer (Required)
- Configuring a Multiprotocol BGP Peer Group (Optional)
- Advertising Routes into Multiprotocol BGP (Required)
- Configuring Route Maps for Multiprotocol BGP Prefixes (Optional)
- Redistributing Prefixes into Multiprotocol BGP (Required)
- Configuring DVMRP Interoperability with Multiprotocol BGP (Optional)
- Configuring a Multiprotocol BGP Route Reflector (Optional)
- Configuring Aggregate Multiprotocol BGP Addresses (Optional)
- Verifying Multiprotocol BGP Configuration and Operation (Optional)

Understanding NLRI Keywords and Address Families

Multiprotocol BGP was introduced in Cisco IOS Release 11.1(20)CC and Cisco IOS Release 12.0(2)S prior to it being integrated into Cisco IOS Release 12.1. In Cisco IOS Release 11.1(20)CC and later releases and Cisco IOS Release 12.0(2)S and later releases, the Cisco IOS software uses NLRI keywords to enable multiprotocol BGP over a BGP session and to populate unicast BGP prefixes in the unicast database and multicast BGP prefixes in the multicast database. In Cisco IOS Release 12.1, the Cisco IOS software uses separate address families to enable multiprotocol BGP over a BGP session and to populate unicast BGP prefixes in the unicast database and multicast BGP prefixes in the multicast database.

Cisco IOS Release 12.1 does not support the NLRI keywords. However, for backward compatibility, the NLRI keyword configuration of a Cisco router is automatically converted to an address family configuration when a router is upgraded to Cisco IOS Release 12.1. The following example shows an NLRI keyword configuration for a Cisco router that is running Cisco IOS Release 12.0(8)S:

```
router bgp 5
 no synchronization
 network 172.16.214.0 mask 255.255.255.0 nlri unicast multicast
 neighbor 172.16.214.34 remote-as 5
 neighbor 172.16.214.38 remote-as 2 nlri unicast multicast
 neighbor 172.16.214.42 remote-as 5
 neighbor 172.16.214.59 remote-as 5
 no auto-summary
```

The following example shows the resulting address family configuration after the same router is upgraded to Cisco IOS Release 12.1:

```
router bgp 5
 no synchronization
 network 172.16.214.0 mask 255.255.255.0
 neighbor 172.16.214.34 remote-as 5
  neighbor 172.16.214.38 remote-as 2
 neighbor 172.16.214.42 remote-as 5
 neighbor 172.16.214.59 remote-as 5
 no auto-summary
```

Note Although supported in Cisco IOS Release 12.1, the following sections do not explain how to configure the BGP-4 extensions for Virtual Private Network (VPN) address family prefixes. Configuring VPN address family prefixes will be explained in a later release of the *Cisco IOS IP Configuration Guide* and the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols*.

Configuring a Multiprotocol BGP Peer

To configure multiprotocol BGP between two routers, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp autonomous-system`	Configures a BGP routing process and places the router in router configuration mode.
Step 2	`Router(config-router)# neighbor ip-address remote-as autonomous-system-number`	Adds the IP address of the neighbor in the remote autonomous system to the multiprotocol BGP neighbor table of the local router.

	Command	Purpose
Step 3	`Router(config-router)# address-family ipv4 multicast`	Specifies the IPv4 address family type and places the router in address family configuration mode.
Step 4	`Router(config-router-af)# neighbor {ip-address | peer-group-name} activate`	Enables the neighbor to exchange prefixes for the specified family type with the local router.

Note By default, neighbors that are defined using the **neighbor remote-as** command in router configuration mode exchange only unicast address prefixes. To exchange other address prefix types, such as multicast and VPNv4, neighbors must also be activated using the **neighbor activate** command in address family configuration mode, as shown.

See the "Multiprotocol BGP Peer Examples" section for multiprotocol BGP peer configuration examples.

Configuring a Multiprotocol BGP Peer Group

To configure a peer group to perform multiprotocol BGP routing, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp autonomous-system`	Configures a BGP routing process and places the router in router configuration mode.
Step 2	`Router(config-router)# neighbor peer-group-name peer-group`	Creates a multiprotocol BGP peer group.
Step 3	`Router(config-router)# neighbor ip-address remote-as autonomous-system-number`	Adds the IP address of the neighbor in the remote autonomous system to the multiprotocol BGP neighbor table of the local router.
Step 4	`Router(config-router)# neighbor ip-address peer-group peer-group-name`	Assigns the IP address of a BGP neighbor to a peer group.
Step 5	`Router(config-router)# address-family ipv4 multicast`	Specifies the IP Version 4 address family type and places the router in address family configuration mode.
Step 6	`Router(config-router-af)# neighbor peer-group-name activate`	Enables the peer group to exchange prefixes for the specified family type with the neighbor and the local router.
Step 7	`Router(config-router-af)# neighbor ip-address peer-group peer-group-name`	Assigns the IP address of a BGP neighbor to a peer group.

Note By default, neighbors that are defined using the **neighbor remote-as** command in router configuration mode exchange only unicast address prefixes. To exchange other address prefix types, such as multicast and VPNv4, neighbors must also be activated using the **neighbor activate** command in address family configuration mode, as shown.

Note Peer groups that are defined in router configuration mode using the **neighbor peer-group** command exchange only unicast address prefixes by default. To exchange other address prefix types, such as multicast, peer groups must be defined in address family configuration mode using the **neighbor activate** command, as shown.

Members of a peer group automatically inherit the address prefix configuration of the peer group.

Refer to the section "Configure BGP Peer Groups" of the "Configuring BGP" chapter in the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* for information and instructions on assigning options to the peer group and making a BGP or multiprotocol BGP neighbor a member of the peer group.

See the "Multiprotocol BGP Peer Group Examples" section for an example of configuring multiprotocol BGP peer groups.

Advertising Routes into Multiprotocol BGP

To advertise (inject) a network number and mask into multiprotocol BGP, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp autonomous-system`	Configures a BGP routing process and places the router in router configuration mode.
Step 2	`Router(config-router)# address-family ipv4 multicast`	Specifies the IP Version 4 address family type and places the router in address family configuration mode.
Step 3	`Router(config-router-af)# network network-number [mask network-mask]`	Advertises (injects) this network number and mask into the multicast BGP database. (The routes must first be found in the unicast forwarding table.) Specifically, the network number and mask are injected into the multicast database for the address family specified in the previous step. Routes are tagged from the specified network as "local origin."

Note Networks that are defined in router configuration mode using the **network** command are injected into the unicast database by default. To inject a network into another database, such as the multicast database, the network must be defined in address family configuration mode using the **network** command, as shown.

To redistribute Distance Vector Multicast Routing Protocol (DVMRP) routes into multiprotocol BGP, see the "Redistributing DVMRP Routes into Multiprotocol BGP" section. See the "Multiprotocol BGP Network Advertisement Examples" section for multiprotocol BGP network advertisement configuration examples.

Configuring Route Maps for Multiprotocol BGP Prefixes

To configure a route map for multiprotocol BGP prefixes, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp autonomous-system`	Configures a BGP routing process and places the router in router configuration mode.
Step 2	`Router(config-router)# neighbor ip-address remote-as autonomous-system-number`	Adds the IP address of the neighbor in the remote autonomous system to the multiprotocol BGP neighbor table of the local router.
Step 3	`Router(config-router)# address-family ipv4 multicast`	Specifies the IP Version 4 address family type and places the router in address family configuration mode.
Step 4	`Router(config-router-af)# neighbor ip-address activate`	Enables the address family for the neighbor in the remote autonomous system.
Step 5	`Router(config-router-af)# neighbor ip-address route-map route-map-name {in | out}`	Applies a route map to incoming or outgoing routes.
Step 6	`Router(config)# route-map map-tag [permit | deny] [sequence-number]`	Defines a route map.
Step 7	`Router(config-route-map)# match ip-address access-list-number`	Distributes any routes that have a destination network number address permitted by a standard or extended access list, or performs policy routing on packets.

Note By default, neighbors that are defined using the **neighbor remote-as** command in router configuration mode exchange only unicast address prefixes. To exchange other address prefix types, such as multicast and VPNv4, neighbors must also be activated using the **neighbor activate** command in address family configuration mode, as shown.

Note Route maps that are applied in router configuration mode using the **neighbor route-map** command are applied to unicast address prefixes by default. Route maps for other address families, such as multicast, must be applied in address family configuration mode using the **neighbor route-map** command, as shown. The route maps are applied either as the inbound or outbound routing policy for neighbors under each address family. Configuring separate route maps under each address family simplifies managing complicated or different policies for each address family.

See the "Multiprotocol BGP Route Map Examples" section for multiprotocol BGP route map configuration examples.

Redistributing Prefixes into Multiprotocol BGP

Redistribution is the process of injecting prefixes from one routing protocol into another routing protocol. The tasks in this section explain how to inject prefixes from a routing protocol into multiprotocol BGP. Specifically, prefixes that are redistributed into multiprotocol BGP using the **redistribute** command are injected into the unicast database, the multicast database, or both.

To inject prefixes from a routing protocol into multiprotocol BGP, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp autonomous-system`	Configures a BGP routing process and places the router in router configuration mode.
Step 2	`Router(config-router)# address-family ipv4 multicast`	Specifies the IP Version 4 address family type and places the router in address family configuration mode.
Step 3	`Router(config-router-a)# redistribute protocol [process-id] [route-map map-name]`	Specifies the routing protocol from which prefixes should be redistributed into multiprotocol BGP. Issue the exit command two times to return to global configuration mode.
Step 4	`Router(config)# route-map map-tag [permit | deny] [sequence-number]`	Defines a route map and places the router in route map configuration mode. Follow this step with a **match** command.
Step 5	`Router(config-route-map)# match ip-address access-list-number`	Distributes any prefixes that have a destination network number address permitted by a standard or extended access list, or performs policy routing on packets.

Note Route maps that are applied in router configuration mode using the **redistribute route-map** command are applied to unicast address prefixes by default. Route maps for other address families, such as multicast, must be applied in address family configuration mode using the **redistribute route-map** command, as shown.

See the "Multiprotocol BGP Route Redistribute Examples" section for multiprotocol BGP route redistribution configuration examples.

Configuring DVMRP Interoperability with Multiprotocol BGP

Cisco multicast routers using PIM can interoperate with non-Cisco multicast routers that use DVMRP.

PIM routers dynamically discover DVMRP multicast routers on attached networks. Once a DVMRP neighbor has been discovered, the router caches DVMRP routes that the neighbor sends. Those routes describe sources in a DVMRP cloud that want their packets to be received by receivers outside of this routing domain. Multiprotocol BGP allows the source prefixes of those sources to be known outside of the routing domain.

The router periodically sends DVMRP report messages advertising the unicast sources reachable in the PIM domain.

Redistributing Multiprotocol BGP Routes into DVMRP

By default, no multiprotocol BGP routes are redistributed into DVMRP. However, you can configure all multiprotocol BGP routes to be redistributed into DVMRP with a specified metric. Furthermore, to redistribute only certain multiprotocol BGP routes into DVMRP, you can configure the metric and

subject it to route map conditions. If you supply a route map, you can specify various match criteria options for the multiprotocol BGP routes. If the route passes the route map, then the route is redistributed into DVMRP.

If there are multicast sources in other routing domains that are known via multiprotocol BGP and there are receivers in a DVMRP cloud, they will want to receive packets from those sources. Therefore, you need to redistribute the multiprotocol BGP prefix routes into DVMRP. This will be the scenario when distributing multiprotocol BGP prefixes into the MBONE.

To redistribute multiprotocol BGP routes into DVMRP, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp metric` *metric* [**route-map** *map-name*] **mbgp**	Redistributes multiprotocol BGP routes into DVMRP with a specified metric. An optional route map controls which routes are redistributed; otherwise, all multiprotocol BGP routes are redistributed.

Redistributing DVMRP Routes into Multiprotocol BGP

If there are multicast sources in a DVMRP routing domain that need to reach receivers in multiprotocol BGP routing domains, you need to redistribute DVMRP prefixes into multiprotocol BGP. If you supply a route map, you can also use the **set** route-map configuration commands to specify various BGP attribute settings.

To redistribute DVMRP prefixes into multiprotocol BGP, use the following command in address family configuration mode:

Command	Purpose
`Router(config-router-af)# redistribute dvmrp` [**route-map** *map-name*]	Redistributes DVMRP routes into multiprotocol BGP.

To redistribute DVMRP prefixes into multiprotocol BGP, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# redistribute dvmrp` [**route-map** *map-name*]	Redistributes DVMRP routes into multiprotocol BGP.

See the "Multiprotocol BGP Route Redistribute Examples" section for an example of redistributing DVMRP routers into a multiprotocol BGP routing domain.

Configuring a Multiprotocol BGP Route Reflector

To configure a local router as a route reflector of multiprotocol BGP prefixes, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp autonomous-system`	Configures a BGP routing process and places the router in router configuration mode.
Step 2	`Router(config-router)# neighbor ip-address remote-as autonomous-system-number`	Adds the IP address of the neighbor in the remote autonomous system to the multiprotocol BGP neighbor table of the local router.
Step 3	`Router(config-router)# address-family ipv4 multicast`	Specifies the IP Version 4 address family type and places the router in address family configuration mode.
Step 4	`Router(config-router-af)# neighbor ip-address activate`	Enables the specified address family for the neighbor in the remote autonomous system.
Step 5	`Router(config-router-af)# neighbor ip-address route-reflector-client`	Configures the router as a route reflector of prefixes for the specified address family type and configures the specified neighbor as its client.

Note By default, neighbors that are defined using the **neighbor remote-as** command in router configuration mode exchange only unicast address prefixes. To exchange other address prefix types, such as multicast and VPNv4, neighbors must also be activated using the **neighbor activate** command in address family configuration mode, as shown.

Note Route reflectors and clients (neighbors or internal BGP peer groups) that are defined in router configuration mode using the **neighbor route-reflector-client** command reflect unicast address prefixes to and from those clients by default. To reflect prefixes for other address families, such as multicast, define the reflectors and clients in address family configuration mode using the **neighbor route-reflector-client** command, as shown.

See the "Multiprotocol BGP Route Reflector Examples" section for multiprotocol BGP route reflector configuration examples.

Configuring Aggregate Multiprotocol BGP Addresses

The tasks in this section explain how to configure an aggregate address for multiprotocol BGP. Specifically, the tasks in this section explain how to inject an aggregate address into the multicast database, the unicast database, or both.

To configure an aggregate address for multiprotocol BGP, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router bgp autonomous-system`	Configures a BGP routing process and places the router in router configuration mode.
Step 2	`Router(config-router)# address-family ipv4 multicast`	Specifies the IP Version 4 address family type and places the router in address family configuration mode.
Step 3	`Router(config-router-af)# aggregate-address address mask [as-set] [summary-only] [suppress-map map-name] [advertise-map map-name] [attribute-map map-name]`	Configures an aggregate address with various options.

Note Aggregate addresses that are defined in router configuration mode using the **aggregate-address as-set** command are injected into the unicast database by default. To enter an aggregate address in another database, such as the multicast database, the aggregate address must be defined in address family configuration mode using the **aggregate-address as-set** command, as shown.

See the "Aggregate Multiprotocol BGP Address Examples" section for aggregate multiprotocol BGP address configuration examples.

Verifying Multiprotocol BGP Configuration and Operation

To verify multiprotocol BGP configuration and operation, perform the following steps:

Step 1 Enter the **show ip bgp ipv4 multicast** EXEC command to display information related to the multicast database:

```
Router# show ip bgp ipv4 multicast

MBGP table version is 6, local router ID is 192.168.200.66
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network          Next Hop            Metric LocPrf Weight Path
*> 10.0.20.16/28     0.0.0.0                  0      0 32768 i
*> 10.0.35.16/28     0.0.0.0                  0      0 32768 i
*> 10.0.36.0/28      0.0.0.0                  0      0 32768 i
*> 10.0.48.16/28     0.0.0.0                  0      0 32768 i
*> 10.2.0.0/16       0.0.0.0                  0      0 32768 i
*> 10.2.1.0/24       0.0.0.0                  0      0 32768 i
*> 10.2.2.0/24       0.0.0.0                  0      0 32768 i
*> 10.2.3.0/24       0.0.0.0                  0      0 32768 i
*> 10.2.7.0/24       0.0.0.0                  0      0 32768 i
*> 10.2.8.0/24       0.0.0.0                  0      0 32768 i
*> 10.2.10.0/24      0.0.0.0                  0      0 32768 i
*> 10.2.11.0/24      0.0.0.0                  0      0 32768 i
*> 10.2.12.0/24      0.0.0.0                  0      0 32768 i
*> 10.2.13.0/24      0.0.0.0                  0      0 32768 i
```

Note For a description of each output display field, refer to the **show ip bgp ipv4 multicast** command in the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*.

Step 2 Enter the **show ip bgp ipv4 multicast summary** EXEC command to display a summary of multicast database information:

```
Router# show ip bgp ipv4 multicast summary

BGP router identifier 10.0.33.34, local AS number 34
BGP table version is 5, main routing table version 1
4 network entries and 6 paths using 604 bytes of memory
5 BGP path attribute entries using 260 bytes of memory
1 BGP AS-PATH entries using 24 bytes of memory
2 BGP community entries using 48 bytes of memory
2 BGP route-map cache entries using 32 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP activity 8/28 prefixes, 12/0 paths, scan interval 15 secs

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.0.33.35      4    35     624     624        5    0    0 10:13:46        3
```

Step 3 Enter the **debug ip mbgp dampening** EXEC command to log the route flap dampening activity:

```
Router# debug ip mbgp dampening

BGP: charge penalty for 173.19.0.0/16 path 49 with halflife-time 15 reuse/suppress
750/2000
BGP: flapped 1 times since 00:00:00. New penalty is 1000
BGP: charge penalty for 173.19.0.0/16 path 19 49 with halflife-time 15 reuse/suppress
750/2000
BGP: flapped 1 times since 00:00:00. New penalty is 1000
```

Step 4 Enter the **debug ip mbgp updates** EXEC command to log the multiprotocol BGP-related information passed in BGP Update messages:

```
Router# debug ip mbgp updates

BGP: NEXT_HOP part 1 net 200.10.202.0/24, neigh 171.69.233.49, next 171.69.233.34
BGP: 171.69.233.49 send UPDATE 200.10.202.0/24, next 171.69.233.34, metric 0, path 33 34
19 49 109 65000 297 1239 1800 3597
BGP: NEXT_HOP part 1 net 200.10.228.0/22, neigh 171.69.233.49, next 171.69.233.34
BGP: 171.69.233.49 rcv UPDATE about 222.2.2.0/24, next hop 171.69.233.49, path 49 109
metric 0
BGP: 171.69.233.49 rcv UPDATE about 131.103.0.0/16, next hop 171.69.233.49, path 49 109
metric 0
BGP: 171.69.233.49 rcv UPDATE about 206.205.242.0/24, next hop 171.69.233.49, path 49 109
metric 0
```

Step 5 Enter the **show ip mpacket quality** EXEC command to display the quality of Real-Time Transport Protocol (RTP) data based on packets captured in the IP multicast cache header buffer:

```
Router# show ip mpacket 224.2.163.188 quality

Calculating RTP data quality for 224.2.163.188
  Session: UO Presents KKNU New Country
  Source: 128.223.83.27 (sand.uoregon.edu), Port: 23824
    Packets received: 83, lost: 5, loss percentage: 5.6%
    Packets misordered: 7, average loss gap: 0
```

Multiprotocol BGP Configuration Examples

This section provides the following multiprotocol BGP configuration examples:

- Multiprotocol BGP Peer Examples
- Multiprotocol BGP Peer Group Examples
- Multiprotocol BGP Network Advertisement Examples
- Multiprotocol BGP Route Map Examples
- Multiprotocol BGP Route Redistribute Examples
- Multiprotocol BGP Route Reflector Examples
- Aggregate Multiprotocol BGP Address Examples

Multiprotocol BGP Peer Examples

The following example shows how to use an address family to configure a neighbor as both unicast and multicast-capable:

```
router bgp 50000
 address-family ipv4 unicast
  neighbor 10.1.1.1 activate

router bgp 50000
 address-family ipv4 multicast
  neighbor 10.1.1.1 activate
```

Multiprotocol BGP Peer Group Examples

The following example shows how to use an address family to configure a peer group so that all members of the peer group are both unicast and multicast-capable:

```
router bgp 50000
 neighbor 10.1.1.1 remote-as 1
 neighbor 12.2.2.2 remote-as 1
 address-family ipv4 unicast
  neighbor mygroup peer-group
  neighbor 10.1.1.1 peer-group mygroup
  neighbor 12.2.2.2 peer-group mygroup

router bgp 50000
 neighbor 10.1.1.1 remote-as 1
 neighbor 12.2.2.2 remote-as 1
 address-family ipv4 multicast
  neighbor mygroup peer-group
  neighbor 10.1.1.1 peer-group mygroup
  neighbor 12.2.2.2 peer-group mygroup
```

Note The **neighbor activate** command is not required in this configuration because peer groups are activated automatically as peer group configuration parameters are applied.

Multiprotocol BGP Network Advertisement Examples

The following examples show how to use an address family to inject a network number and mask into the unicast database and the multicast database:

```
router bgp 100
 address-family ipv4 unicast
  network 10.0.0.0 mask 255.0.0.0

router bgp 100
 address-family ipv4 multicast
  network 10.0.0.0 mask 255.0.0.0
```

Multiprotocol BGP Route Map Examples

The following example shows how to use an address family to configure BGP so that any unicast and multicast routes from neighbor 10.1.1.1 are accepted if they match access list 1:

```
router bgp 50000
 neighbor 10.1.1.1 remote-as 1
 address-family ipv4 unicast
  neighbor 10.1.1.1 route-map filter-some-multicast in

router bgp 50000
 neighbor 10.1.1.1 remote-as 1
 address-family ipv4 multicast
  neighbor 10.1.1.1 route-map filter-some-multicast in
  neighbor 10.1.1.1 activate

route-map filter-some-multicast
 match ip address 1
```

Multiprotocol BGP Route Redistribute Examples

The following example shows how to use an address family to redistribute DVMRP routes that match access list 1 into the multicast database and the unicast database of the local router:

```
router bgp 50000
 address-family ipv4 unicast
  redistribute dvmrp route-map dvmrp-into-mbgp

router bgp 50000
 address-family ipv4 multicast
  redistribute dvmrp route-map dvmrp-into-mbgp

route-map dvmrp-into-mbgp
 match ip address 1
```

Multiprotocol BGP Route Reflector Examples

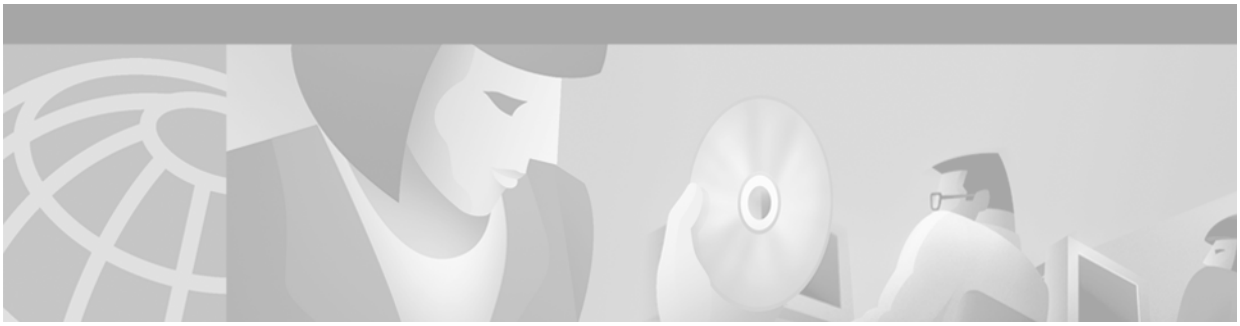
The following example shows how to use an address family to configure internal BGP peer 10.1.1.1 as a route reflector client for both unicast and multicast prefixes:

```
router bgp 50000
 address-family ipv4 unicast
  neighbor 10.1.1.1 activate
  neighbor 10.1.1.1 route-reflector-client

router bgp 50000
 address-family ipv4 multicast
  neighbor 10.1.1.1 activate
  neighbor 10.1.1.1 route-reflector-client
```

Aggregate Multiprotocol BGP Address Examples

The following example shows how to use an address family to configure an aggregate multiprotocol BGP address entry in both the unicast database and the multicast database:

```
router bgp 50000
 address-family ipv4 unicast
  aggregate-address 172.16.0.0 255.0.0.0 as-set

router bgp 50000
 address-family ipv4 multicast
  aggregate-address 172.16.0.0 255.0.0.0 as-set
```



Configuring IP Routing Protocol-Independent Features

This chapter describes how to configure IP routing protocol-independent features. For a complete description of the IP routing protocol-independent commands in this chapter, refer to the "IP Routing Protocol-Independent Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* publication. To locate documentation of other commands in this chapter, use the command reference master index, or search online.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter in this book.

Protocol-Independent Feature Task List

Previous chapters addressed configurations of specific routing protocols. To configure optional protocol-independent features, perform any of the tasks described in the following sections:

- Using Variable-Length Subnet Masks (Optional)
- Configuring Static Routes (Optional)
- Specifying Default Routes (Optional)
- Changing the Maximum Number of Paths (Optional)
- Configuring Multi-Interface Load Splitting (Optional)
- Redistributing Routing Information (Optional)
- Filtering Routing Information (Optional)
- Enabling Policy Routing (PBR) (Optional)
- Managing Authentication Keys (Optional)
- Monitoring and Maintaining the IP Network (Optional)

See the section "IP Routing Protocol-Independent Configuration Examples" at the end of this chapter for configuration examples.

Using Variable-Length Subnet Masks

Enhanced IGRP (EIGRP), Intermediate System-to-Intermediate System (IS-IS) Interdomain Routing Protocol, Open Shortest Path First (OSPF), Routing Information Protocol (RIP) Version 2, and static routes support variable-length subnet masks (VLSMs). With VLSMs, you can use different masks for the same network number on different interfaces, which allows you to conserve IP addresses and more efficiently use available address space. However, using VLSMs also presents address assignment challenges for the network administrator and ongoing administrative challenges.

Refer to RFC 1219 for detailed information about VLSMs and how to correctly assign addresses.

Note Consider your decision to use VLSMs carefully. You can easily make mistakes in address assignments and you will generally find it more difficult to monitor your network using VLSMs.

Note The best way to implement VLSMs is to keep your existing numbering plan in place and gradually migrate some networks to VLSMs to recover address space. See the "Variable-Length Subnet Mask Example" section at the end of this chapter for an example of using VLSMs.

Configuring Static Routes

Static routes are user-defined routes that cause packets moving between a source and a destination to take a specified path. Static routes can be important if the Cisco IOS software cannot build a route to a particular destination. They are useful for specifying a gateway of last resort to which all unroutable packets will be sent.

To configure a static route, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip route prefix mask {ip-address | interface-type interface-number} [distance] [tag tag] [permanent]`	Establishes a static route.

See the "Overriding Static Routes with Dynamic Protocols Example" section at the end of this chapter for an example of configuring static routes.

The software remembers static routes until you remove them (using the **no** form of the **ip route** global configuration command). However, you can override static routes with dynamic routing information through prudent assignment of administrative distance values. Each dynamic routing protocol has a default administrative distance, as listed in Table 9. If you would like a static route to be overridden by information from a dynamic routing protocol, simply ensure that the administrative distance of the static route is higher than that of the dynamic protocol.

Table 9 Dynamic Routing Protocol Default Administrative Distances

Route Source	Default Distance
Connected interface	0
Static route	1

Table 9 Dynamic Routing Protocol Default Administrative Distances (continued)

Route Source	Default Distance
Enhanced IGRP (EIGRP) summary route	5
Exterior Border Gateway Protocol (BGP)	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
EIGRP external route	170
Interior BGP	200
Unknown	255

Static routes that point to an interface will be advertised via RIP, IGRP, and other dynamic routing protocols, regardless of whether **redistribute static** router configuration commands were specified for those routing protocols. These static routes are advertised because static routes that point to an interface are considered in the routing table to be connected and hence lose their static nature. However, if you define a static route to an interface that is not one of the networks defined in a **network** command, no dynamic routing protocols will advertise the route unless a **redistribute static** command is specified for these protocols.

When an interface goes down, all static routes through that interface are removed from the IP routing table. Also, when the software can no longer find a valid next hop for the address specified as the address of the forwarding router in a static route, the static route is removed from the IP routing table.

Specifying Default Routes

A router might not be able to determine the routes to all other networks. To provide complete routing capability, the common practice is to use some routers as *smart routers* and give the remaining routers default routes to the smart router. (Smart routers have routing table information for the entire internetwork.) These default routes can be passed along dynamically, or can be configured into the individual routers.

Most dynamic interior routing protocols include a mechanism for causing a smart router to generate dynamic default information that is then passed along to other routers.

Specifying a Default Network

If a router has a directly connected interface onto the specified default network, the dynamic routing protocols running on that device will generate or source a default route. In the case of RIP, the router will advertise the pseudonetwork 0.0.0.0. In the case of IGRP, the network itself is advertised and flagged as an exterior route.

A router that is generating the default for a network also may need a default of its own. One way a router can generate its own default is to specify a static route to the network 0.0.0.0 through the appropriate device.

To define a static route to a network as the static default route, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip default-network network-number`	Specifies a default network.

Understanding Gateway of Last Resort

When default information is being passed along through a dynamic routing protocol, no further configuration is required. The system periodically scans its routing table to choose the optimal default network as its default route. In the case of RIP, there is only one choice, network 0.0.0.0. In the case of IGRP, there might be several networks that can be candidates for the system default. The Cisco IOS software uses both administrative distance and metric information to determine the default route (gateway of last resort). The selected default route appears in the gateway of last resort display of the **show ip route** EXEC command.

If dynamic default information is not being passed to the software, candidates for the default route are specified with the **ip default-network** global configuration command. In this usage, the **ip default-network** command takes an unconnected network as an argument. If this network appears in the routing table from any source (dynamic or static), it is flagged as a candidate default route and is a possible choice as the default route.

If the router has no interface on the default network, but does have a route to it, it considers this network as a candidate default path. The route candidates are examined and the best one is chosen, based on administrative distance and metric. The gateway to the best default path becomes the gateway of last resort.

Changing the Maximum Number of Paths

By default, most IP routing protocols install a maximum of four parallel routes in a routing table. Static routes always install six routes. The exception is BGP, which by default allows only one path to a destination.

The range of maximum paths is one to six paths. To change the maximum number of parallel paths allowed, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# maximum-paths maximum`	Configures the maximum number of parallel paths allowed in a routing table.

Configuring Multi-Interface Load Splitting

Multi-interface load splitting allows you to efficiently control traffic that travels across multiple interfaces to the same destination. The **traffic-share min** router configuration command specifies that if multiple paths are available to the same destination, only paths with the minimum metric will be installed in the routing table. The number of paths allowed is never more than six. For dynamic routing

protocols, the number of paths is controlled by the **maximum-paths** router configuration command. The static route source can always install six paths. If more paths are available, the extra paths are discarded. If some installed paths are removed from the routing table, pending routes are added automatically.

When the **traffic-share min** command is used with the **across-interfaces** keyword, an attempt is made to use as many different interfaces as possible to forward traffic to the same destination. When the maximum path limit has been reached and a new path is installed, the router compares the installed paths. For example, if path X references the same interface as path Y and the new path uses a different interface, path X is removed and the new path is installed.

To configure traffic that is distributed among multiple routes of unequal cost for equal cost paths across multiple interfaces, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# traffic-share min {across-interfaces}`	Configures multi-interface load splitting across different interfaces with equal cost paths.

Redistributing Routing Information

In addition to running multiple routing protocols simultaneously, the Cisco IOS software can redistribute information from one routing protocol to another. For example, you can instruct the software to readvertise IGRP-derived routes using RIP, or to readvertise static routes using the IGRP protocol. Redistributing information from one routing protocol to another applies to all of the IP-based routing protocols.

You also can conditionally control the redistribution of routes between routing domains by defining a method known as *route maps* between the two domains.

The following four tables list tasks associated with route redistribution. Although redistribution is a protocol-independent feature, some of the **match** and **set** commands are specific to a particular protocol.

To define a route map for redistribution, use the following command in global configuration mode:

Command	Purpose
`Router(config)# route-map map-tag [permit | deny] [sequence-number]`	Defines any route maps needed to control redistribution.

One or more **match** commands and one or more **set** commands typically follow a **route-map** global configuration command. If there are no **match** commands, then everything matches. If there are no **set** commands, nothing is done (other than the match). Therefore, you need at least one **match** or **set** command.

To define conditions for redistributing routes from one routing protocol into another, use at least one of the following commands in route-map configuration mode, as needed:

Command	Purpose
`Router(config-route-map)# match as-path path-list-number`	Matches a BGP autonomous system path access list.
`Router(config-route-map)# match community-list community-list-number [exact]`	Matches a BGP community list.

Command	Purpose
`Router(config-route-map)# match ip address {access-list-number | access-list-name} [...access-list-number | ...access-list-name]`	Matches a standard access list.
`Router(config-route-map)# match metric metric-value`	Matches the specified metric.
`Router(config-route-map)# match ip next-hop {access-list-number | access-list-name} [access-list-number | access-list-name]`	Matches a next-hop router address passed by one of the access lists specified.
`Router(config-route-map)# match tag tag-value [tag-value]`	Matches the specified tag value.
`Router(config-route-map)# match interface interface-type interface-number [interface-type interface-number]`	Matches the specified next hop route out one of the interfaces specified.
`Router(config-route-map)# match ip route-source {access-list-number | access-list-name} [access-list-number | access-list-name]`	Matches the address specified by the specified advertised access lists.
`Router(config-route-map)# match route-type {local | internal | external [type-1 | type-2] | level-1 | level-2}`	Matches the specified route type.

One or more **match** commands and one or more **set** commands should follow a **route-map** router configuration command. To define conditions for redistributing routes from one routing protocol into another, use at least one of the following commands in route-map configuration mode as needed:

Command	Purpose
`Router(config-route-map)# set community {community-number [additive]} | none`	Sets the communities attribute.
`Router(config-route-map)# set dampening halflife reuse suppress max-suppress-time`	Sets BGP route dampening factors.
`Router(config-route-map)# set local-preference number-value`	Assigns a value to a local BGP path.
`Router(config-route-map)# set weight weight`	Specifies the BGP weight for the routing table.
`Router(config-route-map)# set origin {igp | egp as-number | incomplete}`	Sets the BGP origin code.
`Router(config-route-map)# set as-path {tag | prepend as-path-string}`	Modifies the BGP autonomous system path.
`Router(config-route-map)# set next-hop next-hop`	Specifies the address of the next hop.
`Router(config-route-map)# set automatic-tag`	Enables automatic computing of the tag table.
`Router(config-route-map)# set level {level-1 | level-2 | level-1-2 | stub-area | backbone}`	Specifies the areas in which to import routes.
`Router(config-route-map)# set metric metric-value`	Sets the metric value to give the redistributed routes (for any protocol except IGRP or Enhanced IGRP [EIGRP]).
`Router(config-route-map)# set metric bandwidth delay reliability loading mtu`	Sets the metric value to give the redistributed routes (for IGRP or EIGRP only).
`Router(config-route-map)# set metric-type {internal | external | type-1 | type-2}`	Sets the metric type to give redistributed routes.

Command	Purpose
`Router(config-route-map)# set metric-type internal`	Sets the Multi Exit Discriminator (MED) value on prefixes advertised to Exterior BGP neighbor to match the Interior Gateway Protocol (IGP) metric of the next hop.
`Router(config-route-map)# set tag tag-value`	Sets the tag value to associate with the redistributed routes.

See the "BGP Route Map Examples" section in the "Configuring BGP" chapter for examples of BGP route maps. See the "BGP Community with Route Maps Examples" section in the "Configuring BGP" chapter for examples of BGP communities and route maps.

To distribute routes from one routing domain into another and to control route redistribution, use the following commands in router configuration mode:

	Command	Purpose
Step 1	`Router(config-router)# redistribute protocol [process-id] {level-1 | level-1-2 | level-2} [metric metric-value] [metric-type type-value] [match internal | external type-value] [tag tag-value] [route-map map-tag] [subnets]`	Redistributes routes from one routing protocol to another routing protocol.
Step 2	`Router(config-router)# default-metric number`	Causes the current routing protocol to use the same metric value for all redistributed routes (BGP, OSPF, RIP).
Step 3	`Router(config-router)# default-metric bandwidth delay reliability loading mtu`	Causes the IGRP or Enhanced IGRP (EIGRP) routing protocol to use the same metric value for all non-IGRP redistributed routes.
Step 4	`Router(config-router)# no default-information {in | out}`	Disables the redistribution of default information between IGRP processes, which is enabled by default.

The metrics of one routing protocol do not necessarily translate into the metrics of another. For example, the RIP metric is a hop count and the IGRP metric is a combination of five quantities. In such situations, an artificial metric is assigned to the redistributed route. Because of this unavoidable tampering with dynamic information, carelessly exchanging routing information between different routing protocols can create routing loops, which can seriously degrade network operation.

Understanding Supported Metric Translations

This section describes supported automatic metric translations between the routing protocols. The following descriptions assume that you have not defined a default redistribution metric that replaces metric conversions:

- RIP can automatically redistribute static routes. It assigns static routes a metric of 1 (directly connected).
- BGP does not normally send metrics in its routing updates.

- IGRP can automatically redistribute static routes and information from other IGRP-routed autonomous systems. IGRP assigns static routes a metric that identifies them as directly connected. IGRP does not change the metrics of routes derived from IGRP updates from other autonomous systems.
- Note that any protocol can redistribute other routing protocols if a default metric is in effect.

Filtering Routing Information

To filter routing protocol information performing the tasks in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional:

- Preventing Routing Updates Through an Interface (Required)
- Controlling the Advertising of Routes in Routing Updates (Optional)
- Controlling the Processing of Routing Updates (Optional)
- Filtering Sources of Routing Information (Optional)

Note When routes are redistributed between OSPF processes, no OSPF metrics are preserved.

Preventing Routing Updates Through an Interface

To prevent other routers on a local network from learning about routes dynamically, you can keep routing update messages from being sent through a router interface. Keeping routing update messages from being sent through a router interface prevents other systems on the interface from learning about routes dynamically. This feature applies to all IP-based routing protocols except BGP.

OSPF and IS-IS behave somewhat differently. In OSPF, the interface address you specify as passive appears as a stub network in the OSPF domain. OSPF routing information is neither sent nor received through the specified router interface. In IS-IS, the specified IP addresses are advertised without actually running IS-IS on those interfaces.

To prevent routing updates through a specified interface, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# passive-interface` *interface-type interface-number*	Suppresses the sending of routing updates through the specified interface.

See the "Passive Interface Examples" section at the end of this chapter for examples of configuring passive interfaces.

Configuring Default Passive Interfaces

In Internet service provider (ISP) and large enterprise networks, many of the distribution routers have more than 200 interfaces. Before the introduction of the Default Passive Interface feature, there were two possibilities for obtaining routing information from these interfaces:

- Configure a routing protocol such as OSPF on the backbone interfaces and redistribute connected interfaces.
- Configure the routing protocol on all interfaces and manually set most of them as passive.

Network managers may not always be able to summarize type 5 link-state advertisements (LSAs) at the router level where redistribution occurs, as in the first possibility. Thus, a large number of type 5 LSAs can be flooded over the domain.

In the second possibility, large type 1 LSAs might be flooded into the area. The Area Border Router (ABR) creates type 3 LSAs, one for each type 1 LSA, and floods them to the backbone. It is possible, however, to have unique summarization at the ABR level, which will inject only one summary route into the backbone, thereby reducing processing overhead.

The prior solution to this problem was to configure the routing protocol on all interfaces and manually set the **passive-interface** router configuration command on the interfaces where adjacency was not desired. But in some networks, this solution meant coding 200 or more passive interface statements. With the Default Passive Interface feature, this problem is solved by allowing all interfaces to be set as passive by default using a single **passive-interface default** command, then configuring individual interfaces where adjacencies are desired using the **no passive-interface** command.

Thus, the Default Passive Interface feature simplifies the configuration of distribution routers and allows the network manager to obtain routing information from the interfaces in large ISP and enterprise networks.

To set all interfaces as passive by default and then activate only those interfaces that need to have adjacencies set, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# router protocol`	Configures the routing protocol on the network.
Step 2	`Router(config-router)# passive-interface default`	Sets all interfaces as passive by default.
Step 3	`Router(config-router)# no passive-interface interface-type`	Activates only those interfaces that need to have adjacencies set.
Step 4	`Router(config-router)# network network-address [options]`	Specifies the list of networks for the routing process. The *network-address* argument is an IP address written in dotted decimal notation—172.24.101.14, for example.

See the section "Default Passive Interface Example" at the end of this chapter for an example of a default passive interface.

To verify that interfaces on your network have been set to passive, you could enter a network monitoring command such as the **show ip ospf interface** EXEC command, or you could verify the interfaces you enabled as active using a command such as the **show ip interface** EXEC command.

Controlling the Advertising of Routes in Routing Updates

To prevent other routers from learning one or more routes, you can suppress routes from being advertised in routing updates. Suppressing routes in route updates prevents other routers from learning the interpretation of a particular device of one or more routes. You cannot specify an interface name in OSPF. When used for OSPF, this feature applies only to external routes.

To suppress routes from being advertised in routing updates, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# distribute-list {access-list-number | access-list-name} out [interface-name | routing-process | as-number]`	Permits or denies routes from being advertised in routing updates depending upon the action listed in the access list.

Controlling the Processing of Routing Updates

You might want to avoid processing certain routes listed in incoming updates. This feature does not apply to OSPF or IS-IS. To suppress routes in incoming updates, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# distribute-list {access-list-number | access-list-name} in [interface-type interface-number]`	Suppresses routes listed in updates from being processed.

Filtering Sources of Routing Information

Filtering sources of routing information prioritizes routing information from different sources, because some pieces of routing information may be more accurate than others. An *administrative distance* is a rating of the trustworthiness of a routing information source, such as an individual router or a group of routers. In a large network, some routing protocols and some routers can be more reliable than others as sources of routing information. Also, when multiple routing processes are running in the same router for IP, it is possible for the same route to be advertised by more than one routing process. By specifying administrative distance values, you enable the router to intelligently discriminate between sources of routing information. The router will always pick the route whose routing protocol has the lowest administrative distance.

To filter sources of routing information, use the following command in router configuration mode:

Command	Purpose
`Router(config-router)# distance {ip-address {wildcard-mask}} [ip-standard-list] [ip-extended]`	Filters on routing information sources.

There are no general guidelines for assigning administrative distances because each network has its own requirements. You must determine a reasonable matrix of administrative distances for the network as a whole. Table 9 shows the default administrative distance for various routing information sources.

For example, consider a router using IGRP and RIP. Suppose you trust the IGRP-derived routing information more than the RIP-derived routing information. In this example, because the default IGRP administrative distance is lower than the default RIP administrative distance, the router uses the IGRP-derived information and ignores the RIP-derived information. However, if you lose the source of the IGRP-derived information (because of a power shutdown in another building, for example), the router uses the RIP-derived information until the IGRP-derived information reappears.

For an example of filtering on sources of routing information, see the section "Administrative Distance Examples" later in this chapter.

Note You also can use administrative distance to rate the routing information from routers running the same routing protocol. This application is generally discouraged if you are unfamiliar with this particular use of administrative distance, because it can result in inconsistent routing information, including forwarding loops.

Note The weight of a route can no longer be set with the **distance** command. To set the weight for a route, use a route-map.

Enabling Policy Routing (PBR)

Policy routing (or "policy-based routing" [PBR]) is a more flexible mechanism for routing packets than destination routing. It is a process whereby the router puts packets through a route map before routing them. The route map determines which packets are routed to which router next. You might enable policy routing if you want certain packets to be routed some way other than the obvious shortest path. Possible applications for policy routing are to provide equal access, protocol-sensitive routing, source-sensitive routing, routing based on interactive versus batch traffic, and routing based on dedicated links.

To enable policy routing, you must identify which route map to use for policy routing and create the route map. The route map itself specifies the match criteria and the resulting action if all of the match clauses are met. These steps are described in the following task tables.

To enable policy routing on an interface, indicate which route map the router should use by using the following command in interface configuration mode. A packet arriving on the specified interface will be subject to policy routing except when its destination IP address is the same as the IP address of the router's interface. This command disables fast switching of all packets arriving on this interface.

Command	Purpose
`Router(config-if)# ip policy route-map map-tag`	Identifies the route map to use for policy routing.

To define the route map to be used for policy routing, use the following command in global configuration mode:

Command	Purpose
`Router(config)# route-map map-tag [permit | deny] [sequence-number]`	Defines a route map to control where packets are output.

To define the criteria by which packets are examined to learn if they will be policy-routed, use either one or both of the following commands in route-map configuration mode. No match clause in the route map indicates all packets.

Command	Purpose
`Router(config-route-map)# match length minimum-length maximum-length`	Matches the Level 3 length of the packet.
`Router(config-route-map)# match ip address {access-list-number | access-list-name} [access-list-number | access-list-name]`	Matches the destination IP address that is permitted by one or more standard or extended access lists.

To set the precedence and specify where the packets that pass the match criteria are output, use the following commands in route-map configuration mode:

	Command	Purpose
Step 1	`Router(config-route-map)# set ip precedence number | name`	Sets the precedence value in the IP header.
Step 2	`Router(config-route-map)# set ip next-hop ip-address [ip-address]`	Specifies the next hop to which to route the packet. (It must be an adjacent router).
Step 3	`Router(config-route-map)# set interface interface-type interface-number [... interface-type interface-number]`	Specifies the output interface for the packet.
Step 4	`Router(config-route-map)# set ip default next-hop ip-address [ip-address]`	Specifies the next hop to which to route the packet, if there is no explicit route for this destination. **Note** Like the **set ip next-hop** command, the **set ip default next-hop** command needs to specify an adjacent router.
Step 5	`Router(config-route-map)# set default interface interface-type interface-number [... interface-type interface-number]`	Specifies the output interface for the packet, if there is no explicit route for this destination.

Note The **set ip next-hop** and **set ip default next-hop** are similar commands but have a different order of operations. Configuring the **set ip next-hop** command causes the system to use policy routing first and then use the routing table. Configuring the **set ip default next-hop** causes the system to use the routing table first and then policy route the specified next hop.

The precedence setting in the IP header determines whether, during times of high traffic, the packets will be treated with more or less precedence than other packets. By default, the Cisco IOS software leaves this value untouched; the header remains with the precedence value it had.

The precedence bits in the IP header can be set in the router when policy routing is enabled. When the packets containing those headers arrive at another router, the packets are ordered for transmission according to the precedence set, if the queueing feature is enabled. The router does not honor the precedence bits if queueing is not enabled; the packets are sent in FIFO order.

You can change the precedence setting, using either a number or name. The names came from RFC 791, but are evolving. You can enable other features that use the values in the **set ip precedence** route-map configuration command to determine precedence. Table 10 lists the possible numbers and their corresponding name, from least important to most important.

Table 10 IP Precedence Values

Number	Name
0	routine
1	priority
2	immediate
3	flash
4	flash-override
5	critical
6	internet
7	network

The **set** commands can be used with each other. They are evaluated in the order shown in the previous task table. A usable next hop implies an interface. Once the local router finds a next hop and a usable interface, it routes the packet.

Preverifying Next-Hop Availability

If the router is policy routing packets to the next hop and the next hop happens to be down, the router will try unsuccessfully to use Address Resolution Protocol (ARP) for the next hop (which is down). This behavior will continue forever.

To prevent this situation, you can configure the router to first verify that the next hops of the route map are CDP neighbors of the router before routing to that next hop.

This task is optional because some media or encapsulations do not support CDP, or it may not be a Cisco device that is sending the router traffic

To configure the route-map policy to verify that the next hop is available before the router attempts to route traffic to it, use the following command in route-map configuration mode:

Command	Purpose
`Router(config-route-map)# set ip next-hop verify-availability`	Causes the router to confirm that the next hop, specified in the route map configuration, are active and available. • This command relies on CDP to determine if the next hop is an active CDP neighbor. • If this command is not used, and the next hop is not available, the traffic will remain forever unrouted. • If this command is used, and the next hop is not a CDP neighbor, the router looks to the subsequent next hop, if there is one. If a subsequent next-hop is not defined, the packets simply are not policy routed

The **set ip next-hop verify-availability** has the following restrictions:

- It can cause some performance degradation due to CDP database lookup overhead per packet.
- CDP must be enabled on the interface.

- The directly connected next hop must be a Cisco device with CDP enabled.
- It is not supported for use in conjunction with dCEF, due to the dependency of the CDP neighbor database.

If you want to selectively verify availability of only some next hops, you can configure different route-map entries (under the same route map name) with different criteria (using access list matching or packet size matching), and use the **set ip next-hop verify-availability** configuration command selectively.

Displaying Route-Map Policy Information

To display the cache entries in the policy route cache, use the **show ip cache policy** EXEC command.

To display the route map Inter Processor Communication (IPC) message statistics in the Route Processor (RP) or Versatile Interface Processor (VIP), use the following command in EXEC mode:

Command	Purpose
`Router# show route-map ipc`	Displays the route map IPC message statistics in the RP or VIP.

If you want policy routing to be fast switched, see the following section "Enabling Fast-Switched Policy Routing."

See the "Policy Routing Example" section at the end of this chapter for an example of policy routing.

Note For new policy-based routing (PBR) features in 12.4, see the following modules:

- PBR Support for Multiple Tracking Options
- PBR Recursive Next Hop

Enabling Fast-Switched Policy Routing

IP policy routing can now be fast switched. Prior to fast-switched policy routing, policy routing could only be process switched, which meant that on most platforms, the switching rate was approximately 1000 to 10,000 packets per second. Such rates were not fast enough for many applications. Users that need policy routing to occur at faster speeds can now implement policy routing without slowing down the router.

Fast-switched policy routing supports all of the **match** commands and most of the **set** commands, except for the following restrictions:

- The **set ip default** command is not supported.
- The **set interface** command is supported only over point-to-point links, unless a route cache entry exists using the same interface specified in the **set interface** command in the route map. Also, at the process level, the routing table is consulted to determine if the interface is on a reasonable path to the destination. During fast switching, the software does not make this check. Instead, if the packet matches, the software blindly forwards the packet to the specified interface.

Policy routing must be configured before you configure fast-switched policy routing. Fast switching of policy routing is disabled by default. To have policy routing be fast switched, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip route-cache policy`	Enables fast switching of policy routing.

Enabling Local Policy Routing

Packets that are generated by the router are not normally policy routed. To enable local policy routing for such packets, indicate which route map the router should use by using the following command in global configuration mode. All packets originating on the router will then be subject to local policy routing.

Command	Purpose
`Router(config)# ip local policy route-map map-tag`	Identifies the route map to use for local policy routing.

Use the **show ip local policy** EXEC command to display the route map used for local policy routing, if one exists.

Managing Authentication Keys

Key management is a method of controlling authentication keys used by routing protocols. Not all protocols can use key management. Authentication keys are available for Director Response Protocol (DRP) Agent, Enhanced IGRP (EIGRP), and RIP Version 2.

Before you manage authentication keys, authentication must be enabled. See the appropriate protocol chapter to learn how to enable authentication for that protocol.

To manage authentication keys, define a key chain, identify the keys that belong to the key chain, and specify how long each key is valid. Each key has its own key identifier (specified with the **key chain** configuration command), which is stored locally. The combination of the key identifier and the interface associated with the message uniquely identifies the authentication algorithm and Message Digest 5 (MD5) authentication key in use.

You can configure multiple keys with lifetimes. Only one authentication packet is sent, regardless of how many valid keys exist. The software examines the key numbers in order from lowest to highest, and uses the first valid key it encounters. The lifetimes allow for overlap during key changes. Note that the router must know the time. Refer to the Network Time Protocol (NTP) and calendar commands in the "Performing Basic System Management" chapter of the *Cisco IOS Configuration Fundamentals Configuration Guide*.

To manage authentication keys, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)#key chain name-of-chain`	Identifies a key chain.
Step 2	`Router(config-keychain)# key number`	Identifies the key number in key chain configuration mode.
Step 3	`Router(config-keychain-key)# key-string text`	Identifies the key string in key chain configuration mode.

	Command	Purpose
Step 4	`Router(config-keychain-key)# accept-lifetime start-time {infinite | end-time | duration seconds}]`	Specifies the time period during which the key can be received.
Step 5	`Router(config-keychain-key)# send-lifetime start-time {infinite | end-time | duration seconds}`	Specifies the time period during which the key can be sent.

Use the **show key chain** EXEC command to display key chain information. For examples of key management, see the "Key Management Examples" section at the end of this chapter.

Monitoring and Maintaining the IP Network

You can remove all contents of a particular cache, table, or database. You also can display specific statistics. The following sections describe each of these tasks.

Clearing Routes from the IP Routing Table

You can remove all contents of a particular table. Clearing a table can become necessary when the contents of the particular structure have become, or are suspected to be, invalid.

To clear one or more routes from the IP routing table, use the following command in EXEC mode:

Command	Purpose
`Router# clear ip route {network [mask] | *}`	Clears one or more routes from the IP routing table.

Displaying System and Network Statistics

You can display specific statistics such as the contents of IP routing tables, caches, and databases. Information provided can be used to determine resource utilization and solve network problems. You can also display information about node reachability and discover the routing path packets leaving your device are taking through the network.

To display various routing statistics, use the following commands in EXEC mode, as needed:

Command	Purpose
`Router# show ip cache policy`	Displays the cache entries in the policy route cache.
`Router# show ip local policy`	Displays the local policy route map if one exists.
`Router# show ip policy`	Displays policy route maps.
`Router# show ip protocols`	Displays the parameters and current state of the active routing protocol process.
`Router# show ip route [address [mask] [longer-prefixes]] | [protocol [process-id]]`	Displays the current state of the routing table.
`Router# show ip route summary`	Displays the current state of the routing table in summary form.
`Router# show ip route supernets-only`	Displays supernets.

Command	Purpose
Router# **show key chain** [*name-of-chain*]	Displays authentication key information.
Router# **show route-map** [*map-name*]	Displays all route maps configured or only the one specified.

IP Routing Protocol-Independent Configuration Examples

The following sections provide routing protocol-independent configuration examples:

- Variable-Length Subnet Mask Example
- Overriding Static Routes with Dynamic Protocols Example
- Administrative Distance Examples
- Static Routing Redistribution Example
- IGRP Redistribution Example
- RIP and IGRP Redistribution Example
- EIGRP Redistribution Examples
- RIP and EIGRP Redistribution Examples
- OSPF Routing and Route Redistribution Examples
- Default Metric Values Redistribution Example
- Policy Routing (Route Map) Examples
- Passive Interface Examples
- Policy Routing Example
- Key Management Examples

Variable-Length Subnet Mask Example

In the following example, a 14-bit subnet mask is used, leaving two bits of address space reserved for serial line host addresses. There is sufficient host address space for two host endpoints on a point-to-point serial link.

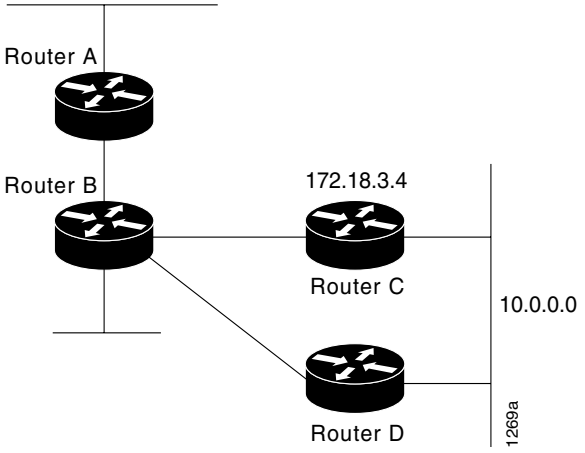
```
interface ethernet 0
 ip address 172.17.1.1 255.255.255.0
! 8 bits of host address space reserved for ethernets

interface serial 0
 ip address 172.17.254.1 255.255.255.252
! 2 bits of address space reserved for serial lines

! Router is configured for OSPF and assigned AS 1
router ospf 1
! Specifies the network directly connected to the router
 network 172.17.0.0 0.0.255.255 area 0.0.0.0
```

Overriding Static Routes with Dynamic Protocols Example

In the following example, packets for network 10.0.0.0 from Router B (where the static route is installed) will be routed through 172.18.3.4 if a route with an administrative distance less than 110 is not available. Figure 62 illustrates this example. The route learned by a protocol with an administrative distance of less than 110 might cause Router B to send traffic destined for network 10.0.0.0 via the alternate path—through Router D.

```
ip route 10.0.0.0 255.0.0.0 172.18.3.4 110
```

Figure 62 Overriding Static Routes



Administrative Distance Examples

In the following example, the **router igrp** global configuration command sets up IGRP routing in autonomous system 1. The **network** router configuration commands specify IGRP routing on networks 192.168.7.0 and 172.16.0.0. The first **distance** router configuration command sets the default administrative distance to 255, which instructs the router to ignore all routing updates from routers for which an explicit distance has not been set. The second **distance** command sets the administrative distance to 90 for all routers on the Class C network 192.168.7.0. The third **distance** command sets the administrative distance to 120 for the router with the address 172.16.1.3.

```
router igrp 1
 network 192.168.7.0
 network 172.16.0.0
 distance 255
 distance 90 192.168.7.0 0.0.0.255
 distance 120 172.16.1.3 0.0.0.0
```

The following example assigns the router with the address 192.168.7.18 an administrative distance of 100 and all other routers on subnet 192.168.7.0 an administrative distance of 200:

```
 distance 100 192.168.7.18 0.0.0.0
 distance 200 192.168.7.0 0.0.0.255
```

However, if you reverse the order of these two commands, all routers on subnet 192.168.7.0 are assigned an administrative distance of 200, including the router at address 192.168.7.18:

```
 distance 200 192.168.7.0 0.0.0.255
 distance 100 192.168.7.18 0.0.0.0
```

Assigning administrative distances is a problem unique to each network and is done in response to the greatest perceived threats to the connected network. Even when general guidelines exist, the network manager must ultimately determine a reasonable matrix of administrative distances for the network as a whole.

In the following example, the distance value for IP routes learned is 90. Preference is given to these IP routes rather than routes with the default administrative distance value of 110.

```
router isis
 distance 90 ip
```

Static Routing Redistribution Example

In the example that follows, three static routes are specified, two of which are to be advertised. The static routes are created by specifying the **redistribute static** router configuration command and then specifying an access list that allows only those two networks to be passed to the IGRP process. Any redistributed static routes should be sourced by a single router to minimize the likelihood of creating a routing loop.

```
ip route 192.168.2.0 255.255.255.0 192.168.7.65
ip route 192.168.5.0 255.255.255.0 192.168.7.65
ip route 172.16.0.0 255.255.255.0 192.168.7.65
access-list 3 permit 192.168.2.0
access-list 3 permit 192.168.5.0
!
router igrp 1
 network 192.168.7.0
 default-metric 10000 100 255 1 1500
 redistribute static
 distribute-list 3 out static
```

IGRP Redistribution Example

Each IGRP routing process can provide routing information to only one autonomous system; the Cisco IOS software must run a separate IGRP process and maintain a separate routing database for each autonomous system that it services. However, you can transfer routing information between these routing databases.

Suppose that the router has one IGRP routing process for network 10.0.0.0 in autonomous system 71 and another IGRP routing process for network 192.168.7.0 in autonomous system 1, as the following commands specify:

```
router igrp 71
 network 10.0.0.0
router igrp 1
 network 192.168.7.0
```

To transfer a route to 192.168.7.0 into autonomous system 71 (without passing any other information about autonomous system 1), use the command in the following example:

```
router igrp 71
 redistribute igrp 1
 distribute-list 3 out igrp 1
access-list 3 permit 192.168.7.0
```

RIP and IGRP Redistribution Example

Consider a WAN at a university that uses RIP as an interior routing protocol. Assume that the university wants to connect its WAN to a regional network, 172.16.0.0, which uses IGRP as the routing protocol. The goal in this case is to advertise the networks in the university network to the routers on the regional network. The commands for the interconnecting router are listed in the example that follows:

```
router igrp 1
 network 172.16.0.0
 redistribute rip
 default-metric 10000 100 255 1 1500
 distribute-list 10 out rip
```

In this example, the **router** global configuration command starts an IGRP routing process. The **network** router configuration command specifies that network 172.16.0.0 (the regional network) is to receive IGRP routing information. The **redistribute** router configuration command specifies that RIP-derived routing information be advertised in the routing updates. The **default-metric** router configuration command assigns an IGRP metric to all RIP-derived routes. The **distribute-list** router configuration command instructs the Cisco IOS software to use access list 10 (not defined in this example) to limit the number of entries in each outgoing update. The access list prevents unauthorized advertising of university routes to the regional network.

EIGRP Redistribution Examples

Each Enhanced IGRP (EIGRP) routing process provides routing information to only one autonomous system. The Cisco IOS software must run a separate EIGRP process and maintain a separate routing database for each autonomous system that it services. However, you can transfer routing information between these routing databases.

Suppose that the software has one EIGRP routing process for network 10.0.0.0 in autonomous system 71 and another EIGRP routing process for network 192.168.7.0 in autonomous system 1, as the following commands specify:

```
router eigrp 71
 network 10.0.0.0
router eigrp 1
 network 192.168.7.0
```

To transfer a route from 192.168.7.0 into autonomous system 71 (without passing any other information about autonomous system 1), use the command in the following example:

```
router eigrp 71
 redistribute eigrp 1 route-map 1-to-71
 route-map 1-to-71 permit
 match ip address 3
 set metric 10000 100 1 255 1500
access-list 3 permit 192.168.7.0
```

The following example is an alternative way to transfer a route to 192.168.7.0 into autonomous system 71. Unlike the previous configuration, this one does not allow you to arbitrarily set the metric.

```
router eigrp 71
 redistribute eigrp 1
 distribute-list 3 out eigrp 1
access-list 3 permit 192.168.7.0
```

RIP and EIGRP Redistribution Examples

This section provides a simple RIP redistribution example and a complex redistribution example between Enhanced IGRP (EIGRP) and BGP.

Simple Redistribution Example

Consider a WAN at a university that uses RIP as an interior routing protocol. Assume that the university wants to connect its WAN to a regional network, 172.16.0.0, which uses Enhanced IGRP (EIGRP) as the routing protocol. The goal in this case is to advertise the networks in the university network to the routers on the regional network. The commands for the interconnecting router are listed in the example that follows:

```
router eigrp 1
 network 172.16.0.0
 redistribute rip
 default-metric 10000 100 255 1 1500
 distribute-list 10 out rip
```

In this example, the **router** global configuration command starts an EIGRP routing process. The **network** router configuration command specifies that network 172.16.0.0 (the regional network) is to send and receive EIGRP routing information. The **redistribute** router configuration command specifies that RIP-derived routing information be advertised in the routing updates. The **default-metric** router configuration command assigns an EIGRP metric to all RIP-derived routes. The **distribute-list** router configuration command instructs the Cisco IOS software to use access list 10 (not defined in this example) to limit the entries in each outgoing update. The access list prevents unauthorized advertising of university routes to the regional network.

Complex Redistribution Example

The most complex redistribution case is one in which *mutual* redistribution is required between an IGP (in this case EIGRP) and BGP.

Suppose that BGP is running on a router somewhere else in autonomous system 50000 and that the BGP routes are injected into EIGRP routing process 1. You must use filters to ensure that the proper routes are advertised. The example configuration for router R1 illustrates use of access filters and a distribution list to filter routes advertised to BGP neighbors. This example also illustrates configuration commands for redistribution between BGP and EIGRP.

```
! Configuration for router R1:
router bgp 50000
 network 172.18.0.0
 neighbor 192.168.10.1 remote-as 2
 neighbor 192.168.10.15 remote-as 1
 neighbor 192.168.10.24 remote-as 3
 redistribute eigrp 1
 distribute-list 1 out eigrp 1
!
! All networks that should be advertised from R1 are controlled with access lists:
!
access-list 1 permit 172.18.0.0
access-list 1 permit 172.16.0.0
access-list 1 permit 172.17.0.0
!
router eigrp 1
 network 172.18.0.0
 network 192.168.10.0
```

```
 redistribute bgp 50000
```

OSPF Routing and Route Redistribution Examples

OSPF typically requires coordination among many internal routers, ABRs, and Autonomous System Boundary Routers (ASBRs). At a minimum, OSPF-based routers can be configured with all default parameter values, with no authentication, and with interfaces assigned to areas. Three types of examples follow:

- The first examples are simple configurations illustrating basic OSPF commands.
- The second example illustrates a configuration for an internal router, ABR, and ASBRs within a single, arbitrarily assigned, OSPF autonomous system.
- The third example illustrates a more complex configuration and the application of various tools available for controlling OSPF-based routing environments.

Basic OSPF Configuration Examples

The following example illustrates a simple OSPF configuration that enables OSPF routing process 9000, attaches Ethernet interface 0 to area 0.0.0.0, and redistributes RIP into OSPF and OSPF into RIP:

```
interface ethernet 0
 ip address 172.16.1.1 255.255.255.0
 ip ospf cost 1
!
interface ethernet 1
 ip address 172.17.1.1 255.255.255.0
!
router ospf 9000
 network 172.16.0.0 0.0.255.255 area 0.0.0.0
 redistribute rip metric 1 subnets
!
router rip
 network 172.17.0.0
 redistribute ospf 9000
 default-metric 1
```

The following example illustrates the assignment of four area IDs to four IP address ranges. In the example, OSPF routing process 1 is initialized, and four OSPF areas are defined: 10.9.50.0, 2, 3, and 0. Areas 10.9.50.0, 2, and 3 mask specific address ranges, whereas area 0 enables OSPF for *all other* networks.

```
router ospf 1
 network 172.16.20.0 0.0.0.255 area 10.9.50.0
 network 172.16.0.0 0.0.255.255 area 2
 network 172.17.10.0 0.0.0.255 area 3
 network 0.0.0.0 255.255.255.255 area 0
!
! Ethernet interface 0 is in area 10.9.50.0:
interface ethernet 0
 ip address 172.16.20.5 255.255.255.0
!
! Ethernet interface 1 is in area 2:
interface ethernet 1
 ip address 172.16.1.5 255.255.255.0
!
! Ethernet interface 2 is in area 2:
interface ethernet 2
 ip address 172.17.2.5 255.255.255.0
```

```
!
! Ethernet interface 3 is in area 3:
interface ethernet 3
 ip address 172.18.10.5 255.255.255.0
!
! Ethernet interface 4 is in area 0:
interface ethernet 4
 ip address 172.19.1.1 255.255.255.0
!
! Ethernet interface 5 is in area 0:
interface ethernet 5
 ip address 10.1.0.1 255.255.0.0
```

Each **network** router configuration command is evaluated sequentially, so the specific order of these commands in the configuration is important. The Cisco IOS software sequentially evaluates the address/wildcard-mask pair for each interface. See the "IP Routing Protocols Commands" chapter of the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols* publication for more information.

Consider the first **network** command. Area ID 10.9.50.0 is configured for the interface on which subnet 172.18.20.0 is located. Assume that a match is determined for Ethernet interface 0. Ethernet interface 0 is attached to Area 10.9.50.0 only.

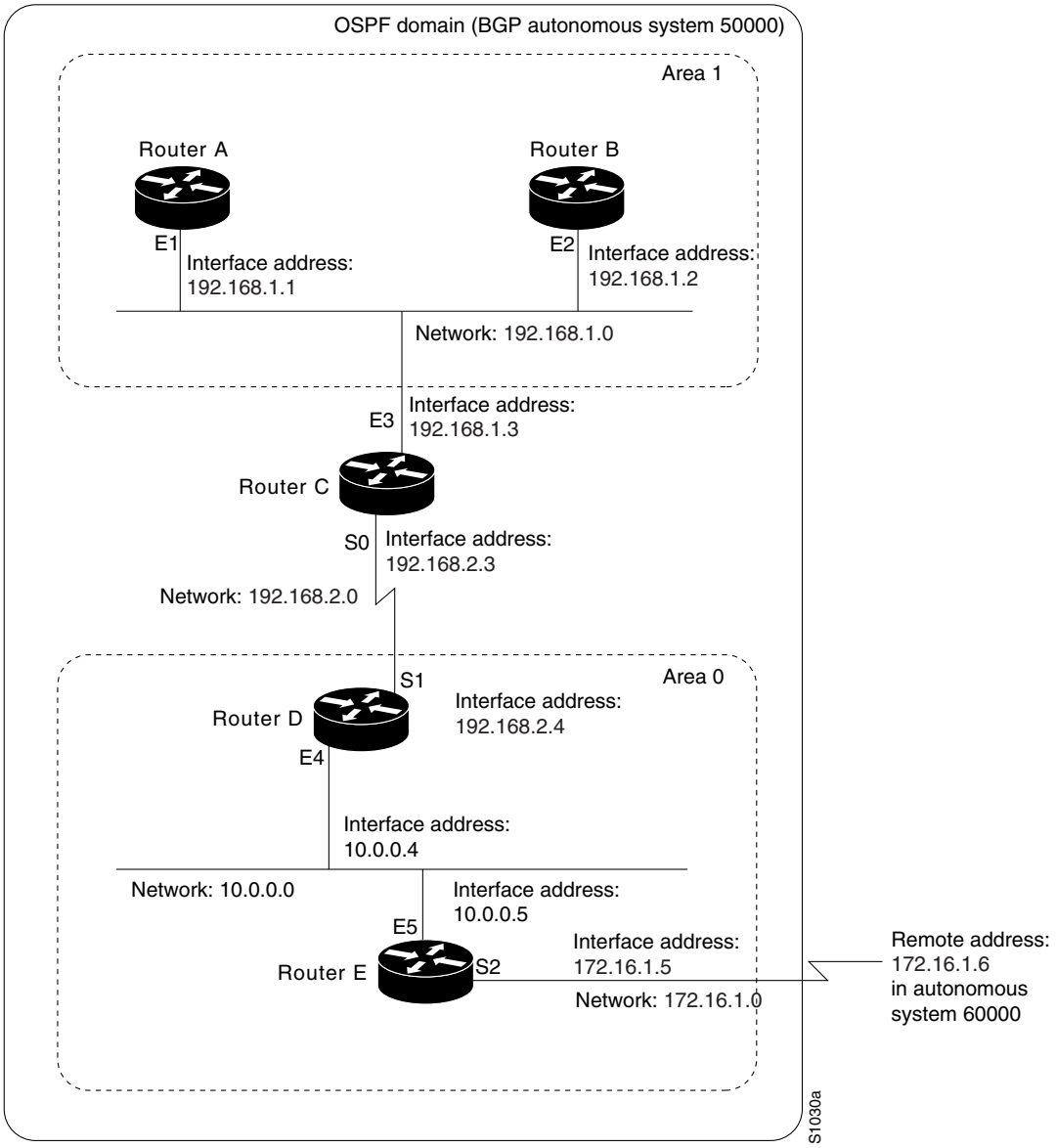
The second **network** command is evaluated next. For Area 2, the same process is then applied to all interfaces (except Ethernet interface 0). Assume that a match is determined for Ethernet interface 1. OSPF is then enabled for that interface and Ethernet 1 is attached to Area 2.

This process of attaching interfaces to OSPF areas continues for all **network** commands. Note that the last **network** command in this example is a special case. With this command, all available interfaces (not explicitly attached to another area) are attached to Area 0.

Internal Router, ABR, and ASBRs Configuration Example

Figure 63 provides a general network map that illustrates a sample configuration for several routers within a single OSPF autonomous system.

Figure 63 Example OSPF Autonomous System Network Map



In this configuration, five routers are configured in OSPF autonomous system 1:

- Router A and Router B are both internal routers within area 1.
- Router C is an OSPF ABR. Note that for Router C, area 1 is assigned to E3 and Area 0 is assigned to S0.
- Router D is an internal router in area 0 (backbone area). In this case, both **network** router configuration commands specify the same area (area 0, or the backbone area).
- Router E is an OSPF ASBR. Note that BGP routes are redistributed into OSPF and that these routes are advertised by OSPF.

Note It is not necessary to include definitions of all areas in an OSPF autonomous system in the configuration of all routers in the autonomous system. You must define only the *directly* connected areas. In the example that follows, routes in Area 0 are learned by the routers in area 1 (Router A and Router B) when the ABR (Router C) injects summary LSAs into area 1.

Autonomous system 60000 is connected to the outside world via the BGP link to the external peer at IP address 172.16.1.6.

Following is the example configuration for the general network map shown in Figure 63.

Router A Configuration—Internal Router

```
interface ethernet 1
 ip address 192.168.1.1 255.255.255.0

router ospf 1
 network 192.168.1.0 0.0.0.255 area 1
```

Router B Configuration—Internal Router

```
interface ethernet 2
 ip address 192.168.1.2 255.255.255.0

router ospf 1
 network 192.168.1.0 0.0.0.255 area 1
```

Router C Configuration—ABR

```
interface ethernet 3
 ip address 192.168.1.3 255.255.255.0

interface serial 0
 ip address 192.168.2.3 255.255.255.0

router ospf 1
 network 192.168.1.0 0.0.0.255 area 1
 network 192.168.2.0 0.0.0.255 area 0
```

Router D Configuration—Internal Router

```
interface ethernet 4
 ip address 10.0.0.4 255.0.0.0

interface serial 1
 ip address 192.168.2.4 255.255.255.0

router ospf 1
 network 192.168.2.0 0.0.0.255 area 0
 network 10.0.0.0 0.255.255.255 area 0
```

Router E Configuration—ASBR

```
interface ethernet 5
 ip address 10.0.0.5 255.0.0.0

interface serial 2
 ip address 172.16.1.5 255.255.0.0

router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
 redistribute bgp 50000 metric 1 metric-type 1
```

```
router bgp 50000
 network 192.168.0.0
 network 10.0.0.0
 neighbor 172.16.1.6 remote-as 60000
```

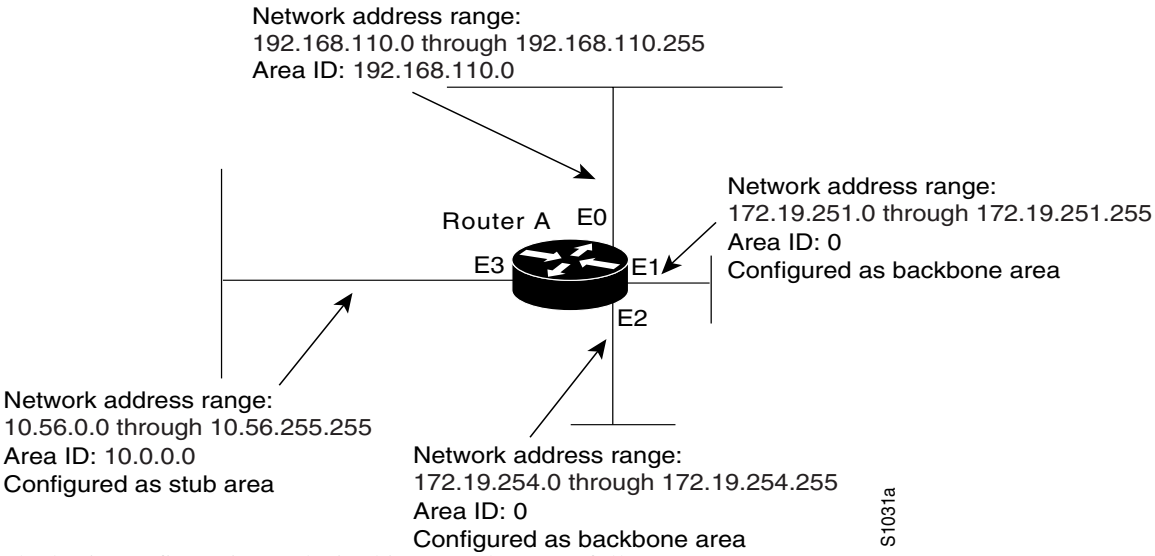
Complex OSPF Configuration Example

The following example configuration accomplishes several tasks in setting up an ABR. These tasks can be split into two general categories:

- Basic OSPF configuration
- Route redistribution

The specific tasks outlined in this configuration are detailed briefly in the following descriptions. Figure 64 illustrates the network address ranges and area assignments for the interfaces.

Figure 64 Interface and Area Specifications for OSPF Configuration Example



The basic configuration tasks in this example are as follows:

- Configure address ranges for Ethernet interface 0 through Ethernet interface 3.
- Enable OSPF on each interface.
- Set up an OSPF authentication password for each area and network.
- Assign link-state metrics and other OSPF interface configuration options.
- Create a *stub area* with area ID 10.0.0.0. (Note that the **authentication** and **stub** options of the **area** router configuration command are specified with separate **area** command entries, but they can be merged into a single **area** command.)
- Specify the backbone area (area 0).

Configuration tasks associated with redistribution are as follows:

- Redistribute IGRP and RIP into OSPF with various options set (including **metric-type**, **metric**, **tag**, and **subnet**).
- Redistribute IGRP and OSPF into RIP.

The following is an example OSPF configuration:

```
interface ethernet 0
 ip address 192.168.110.201 255.255.255.0
 ip ospf authentication-key abcdefgh
 ip ospf cost 10
!
interface ethernet 1
 ip address 172.19.251.201 255.255.255.0
 ip ospf authentication-key ijklmnop
 ip ospf cost 20
 ip ospf retransmit-interval 10
 ip ospf transmit-delay 2
 ip ospf priority 4
!
interface ethernet 2
 ip address 172.19.254.201 255.255.255.0
 ip ospf authentication-key abcdefgh
 ip ospf cost 10
!
interface ethernet 3
 ip address 10.0.0.201 255.255.0.0
 ip ospf authentication-key ijklmnop
 ip ospf cost 20
 ip ospf dead-interval 80
```

In the following configuration, OSPF is on network 172.19.0.0:

```
router ospf 1
 network 10.0.0.0 0.255.255.255 area 10.0.0.0
 network 192.168.110.0 0.0.0.255 area 192.168.110.0
 network 172.19.0.0 0.0.255.255 area 0
 area 0 authentication
 area 10.0.0.0 stub
 area 10.0.0.0 authentication
 area 10.0.0.0 default-cost 20
 area 192.168.110.0 authentication
 area 10.0.0.0 range 10.0.0.0 255.0.0.0
 area 192.168.110.0 range 192.168.110.0 255.255.255.0
 area 0 range 172.19.251.0 255.255.255.0
 area 0 range 172.19.254.0 255.255.255.0

 redistribute igrp 200 metric-type 2 metric 1 tag 200 subnets
 redistribute rip metric-type 2 metric 1 tag 200
```

In the following configuration IGRP autonomous system 1 is on 172.19.0.0:

```
router igrp 1
 network 172.19.0.0
!
! RIP for 192.168.110.0
!
router rip
 network 192.168.110.0
 redistribute igrp 1 metric 1
 redistribute ospf 201 metric 1
```

Default Metric Values Redistribution Example

The following example shows a router in autonomous system 1 using both RIP and IGRP. The example advertises IGRP-derived routes using RIP and assigns the IGRP-derived routes a RIP metric of 10.

```
router rip
 default-metric 10
 redistribute igrp 1
```

Policy Routing (Route Map) Examples

The examples in this section illustrate the use of redistribution, with and without route maps. Examples from both the IP and Connectionless Network Service (CLNS) routing protocols are given.

The following example redistributes all OSPF routes into IGRP:

```
router igrp 1
 redistribute ospf 110
```

The following example redistributes RIP routes with a hop count equal to 1 into OSPF. These routes will be redistributed into OSPF as external LSAs with a metric of 5, metric a type of type 1, and a tag equal to 1.

```
router ospf 1
 redistribute rip route-map rip-to-ospf
!
route-map rip-to-ospf permit
 match metric 1
 set metric 5
 set metric-type type1
 set tag 1
```

The following example redistributes OSPF learned routes with tag 7 as a RIP metric of 15:

```
router rip
 redistribute ospf 1 route-map 5
!
route-map 5 permit
 match tag 7
 set metric 15
```

The following example redistributes OSPF intra-area and interarea routes with next hop routers on serial interface 0 into BGP with an INTER_AS metric of 5:

```
router bgp 50000
 redistribute ospf 1 route-map 10
!
route-map 10 permit
 match route-type internal
 match interface serial 0
 set metric 5
```

The following example redistributes two types of routes into the integrated IS-IS routing table (supporting both IP and CLNS). The first type is OSPF external IP routes with tag 5; these routes are inserted into Level 2 IS-IS link-state packets (LSPs) with a metric of 5. The second type is ISO-IGRP derived CLNS prefix routes that match CLNS access list 2000; these routes will be redistributed into IS-IS as Level 2 LSPs with a metric of 30.

```
router isis
 redistribute ospf 1 route-map 2
```

```
 redistribute iso-igrp nsfnet route-map 3
!
route-map 2 permit
 match route-type external
 match tag 5
 set metric 5
 set level level-2
!
route-map 3 permit
 match address 2000
 set metric 30
```

With the following configuration, OSPF external routes with tags 1, 2, 3, and 5 are redistributed into RIP with metrics of 1, 1, 5, and 5, respectively. The OSPF routes with a tag of 4 are not redistributed.

```
router rip
 redistribute ospf 1 route-map 1
!
route-map 1 permit
 match tag 1 2
 set metric 1
!
route-map 1 permit
 match tag 3
 set metric 5
!
route-map 1 deny
 match tag 4
!
route map 1 permit
 match tag 5
 set metric 5
```

Given the following configuration, a RIP learned route for network 172.18.0.0 and an ISO-IGRP learned route with prefix 49.0001.0002 will be redistributed into an IS-IS Level 2 LSP with a metric of 5:

```
router isis
 redistribute rip route-map 1
 redistribute iso-igrp remote route-map 1
!
route-map 1 permit
 match ip address 1
 match clns address 2
 set metric 5
 set level level-2
!
access-list 1 permit 172.18.0.0 0.0.255.255
 clns filter-set 2 permit 49.0001.0002...
```

The following configuration example illustrates how a route map is referenced by the **default-information** router configuration command. This type of reference is called *conditional default origination*. OSPF will originate the default route (network 0.0.0.0) with a type 2 metric of 5 if 172.20.0.0 is in the routing table.

```
route-map ospf-default permit
 match ip address 1
 set metric 5
 set metric-type type-2
!
access-list 1 172.20.0.0 0.0.255.255
!
router ospf 1
 default-information originate route-map ospf-default
```

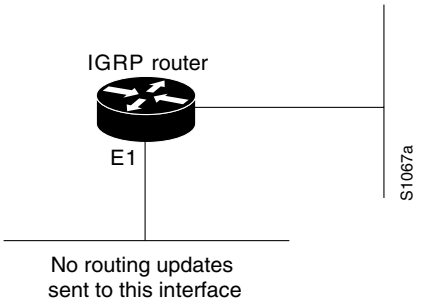
See more route map examples in the "BGP Route Map Examples" and "BGP Community with Route Maps Examples" sections of the 12.4 BGP documentation.

Passive Interface Examples

The following example configures Ethernet interface 1 as a passive interface under IGRP. Figure 65 shows the router topology. Routing updates are sent out all interfaces in the 192.168/16 network except for Ethernet interface 1.

```
 interface Ethernet 1
 ip address 192.168.0.1 255.255.0.0
router igrp 1
 network 192.168.0.0
 passive-interface Ethernet 1
```

Figure 65 Filtering IGRP Updates



In the following example, as in the first example, IGRP updates are sent out all interfaces in the 192.168/16 network except for Ethernet interface 1. However, in this configuration a neighbor statement is configured explicitly for the 192.168.0.2 neighbor. This neighbor statement will override the passive-interface configuration, and all interfaces in the 192.168/16 network, including Ethernet interface 1, will send routing advertisements to the 192.168.0.2 neighbor.

```
router igrp 1
 network 192.168.0.0
 passive-interface ethernet 1
 neighbor 192.18.0.2
```

The **passive-interface** command disables the transmission and receipt of EIGRP hello packets on an interface. Unlike IGRP or RIP, EIGRP sends hello packets in order to form and sustain neighbor adjacencies. Without a neighbor adjacency, EIGRP cannot exchange routes with a neighbor. Therefore, the **passive-interface** command prevents the exchange of routes on the interface. Although EIGRP does not send or receive routing updates on an interface configured with the **passive-interface** command, it still includes the address of the interface in routing updates sent out of other nonpassive interfaces.

Note For more information about configuring passive interfaces in EIGRP, see the *How Does the Passive Interface Feature Work in EIGRP?* document on cisco.com.

In OSPF, hello packets are not sent on an interface that is specified as passive. Hence, the router will not be able to discover any neighbors, and none of the OSPF neighbors will be able to see the router on that network. In effect, this interface will appear as a stub network to the OSPF domain. This configuration is useful if you want to import routes associated with a connected network into the OSPF domain without any OSPF activity on that interface.

The **passive-interface** router configuration command is typically used when the wildcard specification on the **network** router configuration command configures more interfaces than is desirable. The following configuration causes OSPF to run on all subnets of 172.18.0.0:

```
interface ethernet 0
 ip address 172.18.1.1 255.255.255.0
interface ethernet 1
 ip address 172.18.2.1 255.255.255.0
interface ethernet 2
 ip address 172.18.3.1 255.255.255.0
!
router ospf 1
 network 172.18.0.0 0.0.255.255 area 0
```

If you do not want OSPF to run on 172.18.3.0, enter the following commands:

```
router ospf 1
 network 172.18.0.0 0.0.255.255 area 0
 passive-interface ethernet 2
```

Default Passive Interface Example

The following example configures the network interfaces, sets all interfaces that are running OSPF as passive, and then enables serial interface 0:

```
interface Ethernet 0
 ip address 172.19.64.38 255.255.255.0 secondary
 ip address 172.19.232.70 255.255.255.240
 no ip directed-broadcast
!
interface Serial 0
 ip address 172.24.101.14 255.255.255.252
 no ip directed-broadcast
 no ip mroute-cache
!
interface TokenRing0
 ip address 172.20.10.4 255.255.255.0
 no ip directed-broadcast
 no ip mroute-cache
 ring-speed 16
!
router ospf 1
 passive-interface default
 no passive-interface Serial0
 network 172.16.10.0 0.0.0.255 area 0
 network 172.19.232.0 0.0.0.255 area 4
 network 172.24.101.0 0.0.0.255 area 4
```

Policy Routing Example

The following example provides two sources with equal access to two different service providers. Packets that arrive on asynchronous interface 1 from the source 10.1.1.1 are sent to the router at 172.16.6.6 if the router has no explicit route for the destination of the packet. Packets that arrive from the source 172.17.2.2 are sent to the router at 192.168.7.7 if the router has no explicit route for the destination of the packet. All other packets for which the router has no explicit route to the destination are discarded.

```
access-list 1 permit ip 10.1.1.1
access-list 2 permit ip 172.17.2.2
!
```

```
interface async 1
 ip policy route-map equal-access
!
route-map equal-access permit 10
 match ip address 1
 set ip default next-hop 172.16.6.6
route-map equal-access permit 20
 match ip address 2
 set ip default next-hop 192.168.7.7
route-map equal-access permit 30
 set default interface null0
```

Key Management Examples

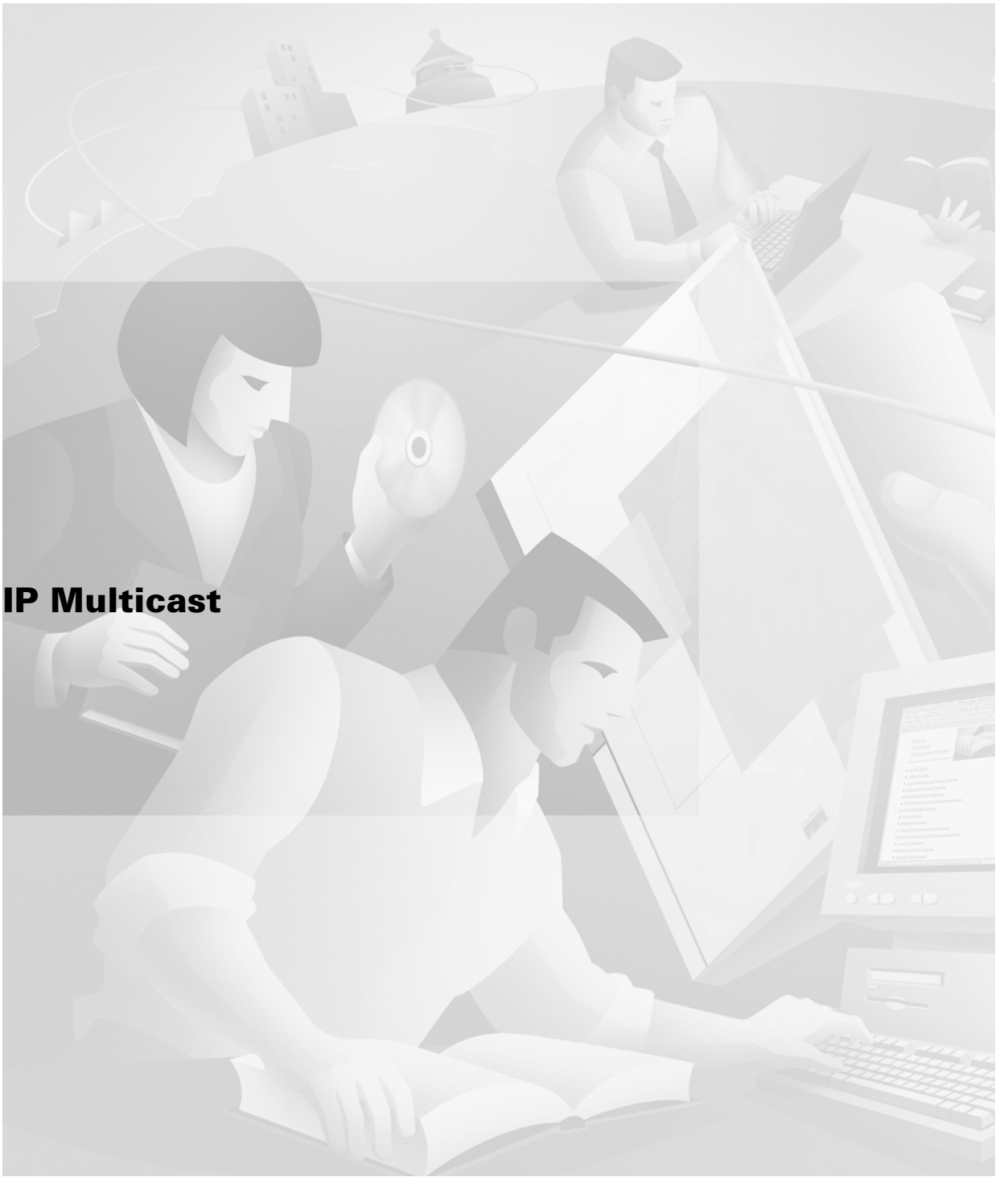
The following example configures a key chain named trees. In this example, the software will always accept and send willow as a valid key. The key chestnut will be accepted from 1:30 p.m. to 3:30 p.m. and be sent from 2:00 p.m. to 3:00 p.m. The overlap allows for migration of keys or discrepancy in the set time of the router. Likewise, the key birch immediately follows chestnut, and there is a 30-minute leeway on each side to handle time-of-day differences.

```
interface ethernet 0
 ip rip authentication key-chain trees
 ip rip authentication mode md5
!
router rip
 network 172.19.0.0
 version 2
!
key chain trees
 key 1
 key-string willow
 key 2
 key-string chestnut
 accept-lifetime 13:30:00 Jan 25 1996 duration 7200
 send-lifetime 14:00:00 Jan 25 1996 duration 3600
 key 3
 key-string birch
 accept-lifetime 14:30:00 Jan 25 1996 duration 7200
 send-lifetime 15:00:00 Jan 25 1996 duration 3600
```

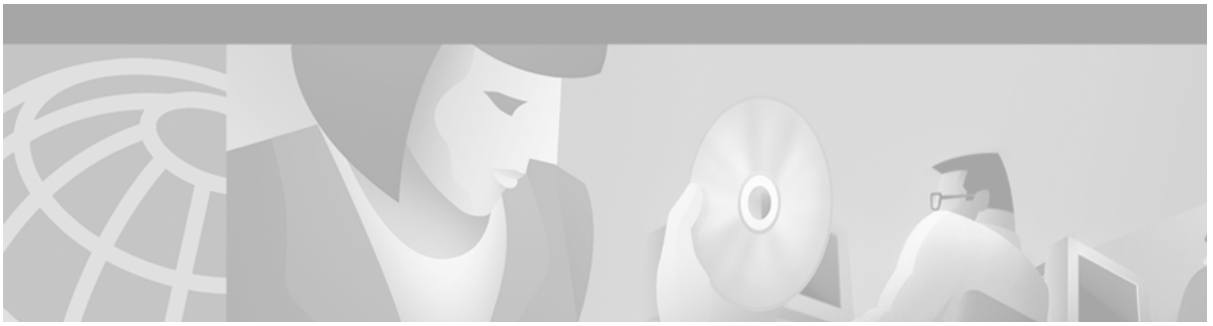
The following example configures a key chain named trees:

```
key chain trees
 key 1
 key-string willow
 key 2
 key-string chesnut
 accept-lifetime 00:00:00 Dec 5 1995 23:59:59 Dec 5 1995
 send-lifetime 06:00:00 Dec 5 1995 18:00:00 Dec 5 1995
!
interface Ethernet0
 ip address 172.19.104.75 255.255.255.0 secondary
 ip address 172.16.232.147 255.255.255.240
 ip rip authentication key-chain trees
 media-type 10BaseT
!
interface Ethernet1
 no ip address
 shutdown
 media-type 10BaseT
```

```
interface Fddi0
 ip address 10.1.1.1 255.255.255.0
 no keepalive
!
interface Fddi1
 ip address 172.16.1.1 255.255.255.0
 ip rip send version 1
 ip rip receive version 1
 no keepalive
!
router rip
 version 2
 network 172.19.0.0
 network 10.0.0.0
 network 172.16.0.0
```



IP Multicast



Configuring IP Multicast Routing

This chapter describes how to configure IP multicast routing. For a complete description of the IP multicast routing commands in this chapter, refer to the "IP Multicast Routing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*. To locate documentation of other commands in this chapter, use the command reference master index, or search online.

Traditional IP communication allows a host to send packets to a single host (*unicast transmission*) or to all hosts (*broadcast transmission*). IP multicast provides a third scheme, allowing a host to send packets to a subset of all hosts (*group transmission*). These hosts are known as group members.

Packets delivered to group members are identified by a single multicast group address. Multicast packets are delivered to a group using best-effort reliability, just like IP unicast packets.

The multicast environment consists of senders and receivers. Any host, regardless of whether it is a member of a group, can send to a group. However, only the members of a group receive the message.

A multicast address is chosen for the receivers in a multicast group. Senders use that address as the destination address of a datagram to reach all members of the group.

Membership in a multicast group is dynamic; hosts can join and leave at any time. There is no restriction on the location or number of members in a multicast group. A host can be a member of more than one multicast group at a time.

How active a multicast group is and what members it has can vary from group to group and from time to time. A multicast group can be active for a long time, or it may be very short-lived. Membership in a group can change constantly. A group that has members may have no activity.

Routers executing a multicast routing protocol, such as Protocol Independent Multicast (PIM), maintain forwarding tables to forward multicast datagrams. Routers use the Internet Group Management Protocol (IGMP) to learn whether members of a group are present on their directly attached subnets. Hosts join multicast groups by sending IGMP report messages.

Many multimedia applications involve multiple participants. IP multicast is naturally suitable for this communication paradigm.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

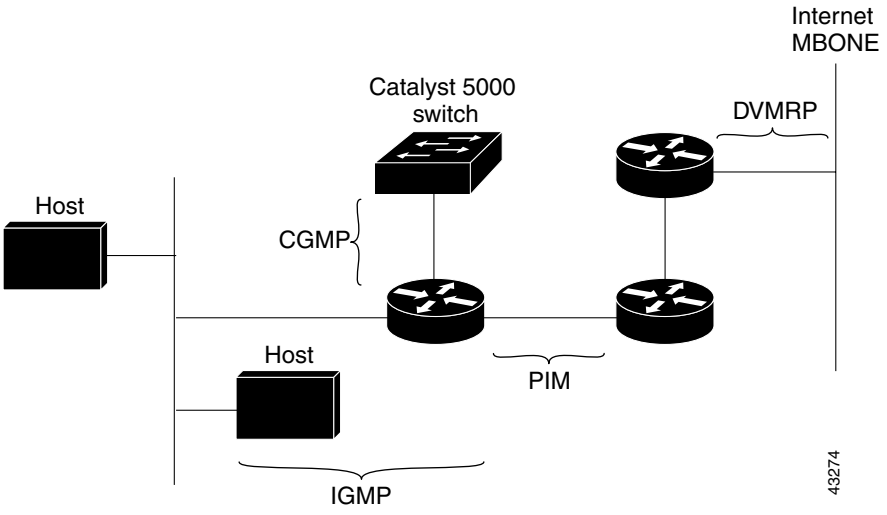
The Cisco IP Multicast Routing Implementation

The Cisco IOS software supports the following protocols to implement IP multicast routing:

- IGMP is used between hosts on a LAN and the routers on that LAN to track the multicast groups of which hosts are members.
- Protocol Independent Multicast (PIM) is used between routers so that they can track which multicast packets to forward to each other and to their directly connected LANs.
- Distance Vector Multicast Routing Protocol (DVMRP) is used on the MBONE (the multicast backbone of the Internet). The Cisco IOS software supports PIM-to-DVMRP interaction.
- Cisco Group Management Protocol (CGMP) is used on routers connected to Catalyst switches to perform tasks similar to those performed by IGMP.

Figure 66 shows where these protocols operate within the IP multicast environment. The protocols are further described in the sections following the figure.

Figure 66 IP Multicast Routing Protocols



IGMP

To start implementing IP multicast routing in your campus network, you must first define who receives the multicast. IGMP provides a means to automatically control and limit the flow of multicast traffic throughout your network with the use of special multicast queriers and hosts.

- A querier is a network device, such as a router, that sends query messages to discover which network devices are members of a given multicast group.
- A host is a receiver, including routers, that sends report messages (in response to query messages) to inform the querier of a host membership.

A set of queriers and hosts that receive multicast data streams from the same source is called a multicast group. Queries and hosts use IGMP messages to join and leave multicast groups.

IP multicast traffic uses group addresses, which are Class D IP addresses. The high-order four bits of a Class D address are 1110. Therefore, host group addresses can be in the range 224.0.0.0 to 239.255.255.255.

Multicast addresses in the range 224.0.0.0 to 224.0.0.255 are reserved for use by routing protocols and other network control traffic. The address 224.0.0.0 is guaranteed not to be assigned to any group.

IGMP packets are transmitted using IP multicast group addresses as follows:

- IGMP general queries are destined to the address 224.0.0.1 (all systems on a subnet).
- IGMP group-specific queries are destined to the group IP address for which the router is querying.
- IGMP group membership reports are destined to the group IP address for which the router is reporting.
- IGMP Version 2 (IGMPv2) Leave messages are destined to the address 224.0.0.2 (all routers on a subnet).
  - Note that in some old host IP stacks, Leave messages might be destined to the group IP address rather than to the all-routers address.

IGMP Versions

IGMP messages are used primarily by multicast hosts to signal their interest in joining a specific multicast group and to begin receiving group traffic.

The original IGMP Version 1 Host Membership model defined in RFC 1112 is extended to significantly reduce leave latency and provide control over source multicast traffic by use of Internet Group Management Protocol, Version 2.

- IGMP Version 1

  Provides for the basic Query-Response mechanism that allows the multicast router to determine which multicast groups are active and other processes that enable hosts to join and leave a multicast group. RFC 1112 defines *Host Extensions for IP Multicasting.*

- IGMP Version 2

  Extends IGMP allowing such features as the IGMP leave process, group-specific queries, and an explicit maximum query response time. IGMP Version 2 also adds the capability for routers to elect the IGMP querier without dependence on the multicast protocol to perform this task. RFC 2236 defines *Internet Group Management Protocol, Version 2*.

- IGMP Version 3

  Provides for "source filtering" which enables a multicast receiver host to signal to a router which groups it wants to receive multicast traffic from, and from which sources this traffic is expected.

PIM

The PIM protocol maintains the current IP multicast service mode of receiver-initiated membership. It is not dependent on a specific unicast routing protocol.

PIM is defined in RFC 2362, *Protocol-Independent Multicast-Sparse Mode (PIM-SM): Protocol Specification*. PIM is defined in the following Internet Engineering Task Force (IETF) Internet drafts:

- *Protocol Independent Multicast (PIM): Motivation and Architecture*
- *Protocol Independent Multicast (PIM), Dense Mode Protocol Specification*
- *Protocol Independent Multicast (PIM), Sparse Mode Protocol Specification*
- draft-ietf-idmr-igmp-v2-06.txt, *Internet Group Management Protocol, Version 2*
- draft-ietf-pim-v2-dm-03.txt, *PIM Version 2 Dense Mode*

PIM can operate in dense mode or sparse mode. It is possible for the router to handle both sparse groups and dense groups at the same time.

In dense mode, a router assumes that all other routers want to forward multicast packets for a group. If a router receives a multicast packet and has no directly connected members or PIM neighbors present, a prune message is sent back to the source. Subsequent multicast packets are not flooded to this router on this pruned branch. PIM builds source-based multicast distribution trees.

In sparse mode, a router assumes that other routers do not want to forward multicast packets for a group, unless there is an explicit request for the traffic. When hosts join a multicast group, the directly connected routers send PIM join messages toward the rendezvous point (RP). The RP keeps track of multicast groups. Hosts that send multicast packets are registered with the RP by the first hop router of that host. The RP then sends join messages toward the source. At this point, packets are forwarded on a shared distribution tree. If the multicast traffic from a specific source is sufficient, the first hop router of the host may send join messages toward the source to build a source-based distribution tree.

CGMP

CGMP is a protocol used on routers connected to Catalyst switches to perform tasks similar to those performed by IGMP. CGMP is necessary for those Catalyst switches that cannot distinguish between IP multicast data packets and IGMP report messages, both of which are addressed to the same group address at the MAC level.

Basic IP Multicast Routing Configuration Task List

Basic and advanced IP multicast routing configuration tasks are described in the following sections. The basic tasks in the first two sections are required; the tasks in the remaining sections are optional.

- Enabling IP Multicast Routing (Required)
- Enabling PIM on an Interface (Required)
- Configuring Auto-RP (Optional)
- IGMP Features Configuration Task List (Optional)
- Configuring the TTL Threshold (Optional)
- Disabling Fast Switching of IP Multicast (Optional)
- SAP Listener Support Configuration Task List (Optional)
- Enabling the Functional Address for IP Multicast over Token Ring LANs (Optional)
- Configuring PIM Version 2 (Optional)

Advanced IP Multicast Routing Configuration Task List

The advanced IP multicast routing tasks described in the following sections are optional:

- Advanced PIM Features Configuration Task List (Optional)
- Configuring an IP Multicast Static Route (Optional)
- Controlling the Transmission Rate to a Multicast Group (Optional)
- Configuring RTP Header Compression (Optional)

- Configuring IP Multicast over ATM Point-to-Multipoint Virtual Circuits (Optional)
- Configuring an IP Multicast Boundary (Optional)
- Configuring an Intermediate IP Multicast Helper (Optional)
- Storing IP Multicast Headers (Optional)
- Enabling CGMP (Optional)
- Configuring Stub IP Multicast Routing (Optional)
- Load Splitting IP Multicast Traffic Across Equal-Cost Paths Configuration Task List (Optional)
- Monitoring and Maintaining IP Multicast Routing Configuration Task List (Optional)

See the "IP Multicast Configuration Examples" later in this chapter for examples of multicast routing configurations.

To see information on IP multicast multilayer switching, refer to the *Cisco IOS Switching Services Configuration Guide* and *Cisco IOS Switching Services Command Reference*.

Enabling IP Multicast Routing

Enabling IP multicast routing allows the Cisco IOS software to forward multicast packets. To enable IP multicast routing on the router, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip multicast-routing`	Enables IP multicast routing.

Enabling PIM on an Interface

Enabling PIM on an interface also enables IGMP operation on that interface. An interface can be configured to be in dense mode, sparse mode, or sparse-dense mode. The mode determines how the router populates its multicast routing table and how the router forwards multicast packets it receives from its directly connected LANs. You must enable PIM in one of these modes for an interface to perform IP multicast routing.

In populating the multicast routing table, dense mode interfaces are always added to the table. Sparse mode interfaces are added to the table only when periodic join messages are received from downstream routers, or when a directly connected member is on the interface. When forwarding from a LAN, sparse mode operation occurs if an RP is known for the group. If so, the packets are encapsulated and sent toward the RP. When no RP is known, the packet is flooded in a dense mode fashion. If the multicast traffic from a specific source is sufficient, the first hop router of the receiver may send join messages toward the source to build a source-based distribution tree.

There is no default mode setting. By default, multicast routing is disabled on an interface.

Enabling Dense Mode

To configure PIM on an interface to be in dense mode, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim dense-mode`	Enables PIM dense mode on the interface.

See the "PIM Dense Mode Example" section later in this chapter for an example of how to configure a PIM interface in dense mode.

Enabling Sparse Mode

To configure PIM on an interface to be in sparse mode, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim sparse-mode`	Enables PIM sparse mode on the interface.

See the "PIM Sparse Mode Example" section later in this chapter for an example of how to configure a PIM interface in sparse mode.

Enabling Sparse-Dense Mode

If you configure either the **ip pim sparse-mode** or **ip pim dense-mode** interface configuration command, then sparseness or denseness is applied to the interface as a whole. However, some environments might require PIM to run in a single region in sparse mode for some groups and in dense mode for other groups.

An alternative to enabling only dense mode or only sparse mode is to enable sparse-dense mode. In this case, the interface is treated as dense mode if the group is in dense mode; the interface is treated in sparse mode if the group is in sparse mode. You must have an RP if the interface is in sparse-dense mode, and you want to treat the group as a sparse group.

If you configure sparse-dense mode, the idea of sparseness or denseness is applied to the group on the router, and the network manager should apply the same concept throughout the network.

Another benefit of sparse-dense mode is that Auto-RP information can be distributed in a dense mode manner; yet, multicast groups for user groups can be used in a sparse mode manner. Thus, there is no need to configure a default RP at the leaf routers.

When an interface is treated in dense mode, it is populated in the outgoing interface list of a multicast routing table when either of the following conditions is true:

- Members or DVMRP neighbors are on the interface.
- There are PIM neighbors and the group has not been pruned.

When an interface is treated in sparse mode, it is populated in the outgoing interface list of a multicast routing table when either of the following conditions is true:

- Members or DVMRP neighbors are on the interface.
- An explicit join message has been received by a PIM neighbor on the interface.

To enable PIM to operate in the same mode as the group, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim sparse-dense-mode`	Enables PIM to operate in sparse or dense mode, depending on the group.

Configuring PIM Dense Mode State Refresh

If you have PIM dense mode (PIM-DM) enabled on a router interface, the PIM Dense Mode State Refresh feature is enabled by default.

PIM-DM builds source-based multicast distribution trees that operate on a "flood and prune" principle. Multicast packets from a source are flooded to all areas of a PIM-DM network. PIM routers that receive multicast packets and have no directly connected multicast group members or PIM neighbors send a prune message back up the source-based distribution tree toward the source of the packets. As a result, subsequent multicast packets are not flooded to pruned branches of the distribution tree. However, the pruned state in PIM-DM times out approximately every 3 minutes and the entire PIM-DM network is reflooded with multicast packets and prune messages. This reflooding of unwanted traffic throughout the PIM-DM network consumes network bandwidth.

The PIM Dense Mode State Refresh feature keeps the pruned state in PIM-DM from timing out by periodically forwarding a control message down the source-based distribution tree. The control message refreshes the prune state on the outgoing interfaces of each router in the distribution tree.

This feature also enables PIM routers in a PIM-DM multicast network to recognize topology changes (sources joining or leaving a multicast group) before the default 3-minute state refresh timeout period expires.

By default, all PIM routers that are running a Cisco IOS software release that supports the PIM Dense Mode State Refresh feature automatically process and forward state refresh control messages. To disable the processing and forwarding of state refresh control messages on a PIM router, use the **ip pim state-refresh disable** global configuration command.

To configure the origination of the control messages on a PIM router, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface` *type number*	Specifies an interface and places the router in interface configuration mode.
Step 2	`Router(config-if)# ip pim state-refresh origination-interval` [*interval*]	Configures the origination of the PIM Dense Mode State Refresh control message. Optionally, you can configure the number of seconds between control messages by using the *interval* argument. The default interval is 60 seconds. The interval range is from 4 to 100 seconds.

Note The origination interval for the state refresh control message must be the same for all PIM routers on the same LAN. Specifically, the same origination interval must be configured on each router interface that is directly connected to the LAN.

See the "PIM Dense Mode State Refresh Example" section later in this chapter for an example of how to configure the PIM Dense Mode State Refresh feature.

Configuring a Rendezvous Point

If you configure PIM to operate in sparse mode, you must also choose one or more routers to be rendezvous points (RPs). You need not configure the routers to be RPs; they learn how to become RPs themselves. RPs are used by senders to a multicast group to announce their existence and by receivers of multicast packets to learn about new senders. The Cisco IOS software can be configured so that packets for a single multicast group can use one or more RPs.

The RP address is used by first hop routers to send PIM register messages on behalf of a host sending a packet to the group. The RP address is also used by last hop routers to send PIM join and prune messages to the RP to inform it about group membership. You must configure the RP address on all routers (including the RP router).

A PIM router can be an RP for more than one group. Only one RP address can be used at a time within a PIM domain. The conditions specified by the access list determine for which groups the router is an RP.

To configure the address of the RP, use the following command on a leaf router in global configuration mode:

Command	Purpose
`Router(config)# ip pim rp-address` *rp-address* [*access-list*] [**override**]	Configures the address of a PIM RP.

Configuring Auto-RP

Auto-RP is a feature that automates the distribution of group-to-RP mappings in a PIM network. This feature has the following benefits:

- The use of multiple RPs within a network to serve different group ranges is easy.
- It allows load splitting among different RPs and arrangement of RPs according to the location of group participants.
- It avoids inconsistent, manual RP configurations that can cause connectivity problems.

Multiple RPs can be used to serve different group ranges or serve as backups of each other. To make Auto-RP work, a router must be designated as an *RP-mapping agent*, which receives the RP-announcement messages from the RPs and arbitrates conflicts. The RP-mapping agent then sends the consistent group-to-RP mappings to all other routers. Thus, all routers automatically discover which RP to use for the groups they support.

Note If you configure PIM in sparse mode or sparse-dense mode and do not configure Auto-RP, you must statically configure an RP as described in the section "Assigning an RP to Multicast Groups" later in this chapter.

Note If router interfaces are configured in sparse mode, Auto-RP can still be used if all routers are configured with a static RP address for the Auto-RP groups.

Setting Up Auto-RP in a New Internetwork

If you are setting up Auto-RP in a new internetwork, you do not need a default RP because you configure all the interfaces for sparse-dense mode. Follow the process described in the section "Adding Auto-RP to an Existing Sparse Mode Cloud," except that you should omit the first step of choosing a default RP.

Adding Auto-RP to an Existing Sparse Mode Cloud

The following sections contain suggestions for the initial deployment of Auto-RP into an existing sparse mode cloud, to minimize disruption of the existing multicast infrastructure.

Choosing a Default RP

Sparse mode environments need a default RP; sparse-dense mode environments do not. If you have sparse-dense mode configured everywhere, you need not choose a default RP.

Adding Auto-RP to a sparse mode cloud requires a default RP. In an existing PIM sparse mode region, at least one RP is defined across the network that has good connectivity and availability. That is, the **ip pim rp-address** command is already configured on all routers in this network.

Use that RP for the global groups (for example, 224.x.x.x and other global groups). There is no need to reconfigure the group address range that RP serves. RPs discovered dynamically through Auto-RP take precedence over statically configured RPs. Assume it is desirable to use a second RP for the local groups.

Announcing the RP and the Group Range It Serves

Find another router to serve as the RP for the local groups. The RP-mapping agent can double as an RP itself. Assign the whole range of 239.x.x.x to that RP, or assign a subrange of that (for example, 239.2.x.x).

To designate that a router is the RP, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim send-rp-announce` *type number* **scope** *ttl-value* [**group-list** *access-list*] [**interval** *seconds*]	Configures a router to be the RP.

To change the group ranges this RP optimally will serve in the future, change the announcement setting on the RP. If the change is valid, all other routers automatically will adopt the new group-to-RP mapping.

The following example advertises the IP address of Ethernet interface 0 as the RP for the administratively scoped groups:

```
ip pim send-rp-announce ethernet0 scope 16 group-list 1
access-list 1 permit 239.0.0.0 0.255.255.255
```

Assigning the RP Mapping Agent

The RP mapping agent is the router that sends the authoritative discovery packets telling other routers which group-to-RP mapping to use. Such a role is necessary in the event of conflicts (such as overlapping group-to-RP ranges).

Find a router whose connectivity is not likely to be interrupted and assign it the role of RP-mapping agent. All routers within time-to-live (TTL) number of hops from the source router receive the Auto-RP discovery messages. To assign the role of RP mapping agent in that router, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim send-rp-discovery scope` *ttl-value*	Assigns the RP mapping agent.

Verifying the Group-to-RP Mapping

To learn if the group-to-RP mapping has arrived, use the following command in EXEC mode on the designated routers:

Command	Purpose
`Router# show ip pim rp [mapping | metric]` [*rp-address*]	Displays active RPs that are cached with associated multicast routing entries. Information learned by configuration or Auto-RP.

Starting to Use IP Multicast

Use your IP multicast application software to start joining and sending to a group.

Preventing Join Messages to False RPs

Note the **ip pim accept-rp** global configuration commands previously configured throughout the network. If the **ip pim accept-rp** command is not configured on any router, this problem can be addressed later. In those routers already configured with the **ip pim accept-rp** command, you must specify the command again to accept the newly advertised RP.

To accept all RPs advertised with Auto-RP and reject all other RPs by default, use the **ip pim accept-rp auto-rp** command.

If all interfaces are in sparse mode, a default RP is configured to support the two well-known groups 224.0.1.39 and 224.0.1.40. Auto-RP relies on these two well-known groups to collect and distribute RP-mapping information. When this is the case and the **ip pim accept-rp auto-rp** command is configured, another **ip pim accept-rp** command accepting the default RP must be configured, as follows:

```
ip pim accept-rp <default RP address> 1
access-list 1 permit 224.0.1.39
access-list 1 permit 224.0.1.40
```

Filtering Incoming RP Announcement Messages

To filter incoming RP announcement messages, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim rp-announce-filter rp-list` *access-list* `group-list` *access-list*	Filters incoming RP announcement messages.

IGMP Features Configuration Task List

To configure IGMP features, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Configuring a Router to Be a Member of a Group (Required)
- Controlling Access to IP Multicast Groups (Optional)
- Changing the IGMP Version (Optional)
- Modifying the IGMP Host-Query Message and Query Timeout Intervals (Optional)
- Configuring IGMP Version 3 (Optional)
- Changing the Maximum Query Response Time (Optional)
- Configuring the Router as a Statically Connected Member (Optional)
- Configuring IGMP Leave Latency (Optional)

For information about configuring IGMP unidirectional link routing (UDLR), see the chapter "Configuring Unidirectional Link Routing" in this document.

Configuring a Router to Be a Member of a Group

Cisco routers can be configured to be members of a multicast group. This strategy is useful for determining multicast reachability in a network. If a device is configured to be a group member and supports the protocol that is being sent to the group, it can respond (to the **ping** EXEC command, for example). The device responds to ICMP echo request packets addressed to a group of which it is a member. Another example is the multicast traceroute tools provided in the Cisco IOS software.

To have the router join a multicast group and enable IGMP, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp join-group group-address`	Joins a multicast group.

Controlling Access to IP Multicast Groups

Multicast routers send IGMP host query messages to determine which multicast groups have members in the attached local networks of the router. The routers then forward to these group members all packets addressed to the multicast group. You can place a filter on each interface that restricts the multicast groups that hosts on the subnet serviced by the interface can join.

To filter multicast groups allowed on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp access-group access-list`	Controls the multicast groups that hosts on the subnet serviced by an interface can join.

Changing the IGMP Version

By default, the router uses IGMP Version 2 (IGMPv2), which allows such features as the IGMP query timeout and the maximum query response time.

All routers on the subnet must support the same version. The router does not automatically detect Version 1 routers and switch to Version 1 as did earlier releases of the Cisco IOS software. However, a mix of IGMP Version 1 and Version 2 hosts on the subnet is acceptable. IGMP Version 2 routers will always work correctly in the presence of IGMP Version 1 hosts.

To control which version of IGMP the router uses, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp version {3 | 2 | 1}`	Selects the IGMP version that the router uses.

Modifying the IGMP Host-Query Message and Query Timeout Intervals

Multicast routers send IGMP host-query messages to discover which multicast groups are present on attached networks. These messages are sent to the all-systems group address of 224.0.0.1 with a time-to-live (TTL) of 1.

Multicast routers send host-query messages periodically to refresh their knowledge of memberships present on their networks. If, after some number of queries, the Cisco IOS software discovers that no local hosts are members of a multicast group, the software stops forwarding onto the local network multicast packets from remote origins for that group and sends a prune message upstream toward the source.

Routers That Run IGMP Version 1

If there are multiple routers on a LAN, a designated router (DR) must be elected to avoid duplicating multicast traffic for connected hosts. PIM routers follow an election process to select a DR. The PIM router with the highest IP address becomes the DR.

The DR is responsible for the following tasks:

- Sending PIM register and PIM join and prune messages toward the RP to inform it about host group membership.
- Sending IGMP host-query messages.

By default, the DR sends host-query messages every 60 seconds in order to keep the IGMP overhead on hosts and networks very low.

To modify this interval, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp query-interval` *seconds*	Configures the frequency at which the designated router sends IGMP host-query messages.

Routers That Run IGMP Version 2

IGMPv2 improved the query messaging capabilities of IGMPv1.

The query and membership report messages in IGMPv2 are identical to the IGMPv1 messages with two exceptions.

1. IGMPv2 query messages are broken into two categories: general queries (identical to IGMPv1 queries) and group-specific queries.
2. IGMPv1 membership reports and IGMPv2 membership reports have different IGMP type codes.

Unlike IGMPv1, in which the DR and the IGMP querier are typically the same router; in IGMPv2, the two functions are decoupled. The DR and the IGMP querier are selected based on different criteria and may be different routers on the same subnet. The DR is the router with the highest IP address on the subnet, whereas the IGMP querier is the router with the lowest IP address.

IP addresses in general query messages are used to elect the IGMP querier and this is the election process:

- When IGMPv2 routers start, they each multicast a general query message to the all-systems group address of 224.0.0.1 with their interface address in the source IP address field of the message.
- When an IGMPv2 router receives a general query message, the router compares the source IP address in the message with its own interface address. The router with the lowest IP address on the subnet is elected the IGMP querier.
- All routers (excluding the querier) start the query timer controlled by the **ip igmp query timeout** command that is reset whenever a general query message is received from the IGMP querier. If the query timer expires, it is assumed that the IGMP querier has gone down, and the election process is performed again to elect a new IGMP querier.

By default, the timer is 2 times the query interval controlled by the **ip igmp query-interval** command.

To change the query timeout and to specify the period of time before a new election is performed, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp query-timeout seconds`	Sets the IGMP query timeout.

Configuring IGMP Version 3

IGMP Version 3 (IGMPv3) adds support in Cisco IOS software for "source filtering," which enables a multicast receiver host to signal to a router which groups it wants to receive multicast traffic from, and from which sources this traffic is expected. This membership information enables Cisco IOS software to forward traffic only from those sources from which receivers requested the traffic.

IGMPv3 supports applications that explicitly signal sources from which they want to receive traffic. With IGMPv3, receivers signal membership to a multicast host group in the following two modes:

- INCLUDE mode—In this mode, the receiver announces membership to a host group and provides a list of IP addresses (the INCLUDE list) from which it wants to receive traffic.
- EXCLUDE mode—In this mode, the receiver announces membership to a host group and provides a list of IP addresses (the EXCLUDE list) from which it does not want to receive traffic. In other words, the host wants to receive traffic only from sources whose IP addresses are not listed in the EXCLUDE list. To receive traffic from all sources, like in the case of the Internet Standard Multicast (ISM) service model, a host expresses EXCLUDE mode membership with an empty EXCLUDE list.

IGMPv3 is the industry-designated standard protocol for hosts to signal channel subscriptions in Source Specific Multicast (SSM). For SSM to rely on IGMPv3, IGMPv3 must be available in last hop routers and host operating system network stacks, and be used by the applications running on those hosts.

In SSM deployment cases where IGMPv3 cannot be used because it is not supported by the receiver host or the receiver applications, two Cisco-developed transition solutions enable the immediate deployment of SSM services: URL Rendezvous Directory (URD) and IGMP Version 3 lite (IGMP v3lite). For more information on URD and IGMP v3lite, see the "Configuring Source Specific Multicast" chapter in this document.

Restrictions

Traffic Filtering with Multicast Groups That Are Not Configured in SSM Mode

IGMPv3 membership reports are not utilized by Cisco IOS software to filter or restrict traffic for multicast groups that are not configured in SSM mode. Effectively, Cisco IOS software interprets all IGMPv3 membership reports for groups configured in dense, sparse, or bidirectional mode to be group membership reports and forwards traffic from all active sources onto the network.

Interoperability with IGMP Snooping

You must be careful when using IGMPv3 with switches that support and are enabled for IGMP snooping, because IGMPv3 messages are different from the messages used in IGMP Version 1 (IGMPv1) and Version 2 (IGMPv2). If a switch does not recognize IGMPv3 messages, then hosts will not correctly receive traffic if IGMPv3 is being used. In this case, either IGMP snooping may be disabled on the switch or the router may be configured for IGMPv2 on the interface (which would remove the ability to use SSM for host applications that cannot resort to URD or IGMP v3lite).

Interoperability with CGMP

Networks using CGMP will have better group leave behavior if they are configured with IGMPv2 than IGMPv3. If CGMP is used with IGMPv2 and the switch is enabled for the CGMP leave functionality, then traffic to a port joined to a multicast group will be removed from the port shortly after the last member on that port has dropped membership to that group. This fast-leave mechanism is part of IGMPv2 and is specifically supported by the CGMP fast-leave enabled switch.

With IGMPv3, there is currently no CGMP switch support of fast leave. If IGMPv3 is used in a network, CGMP will continue to work, but CGMP fast-leave support is ineffective and the following conditions apply:

- Each time a host on a new port of the CGMP switch joins a multicast group, that port is added to the list of ports to which the traffic of this group is sent.
- If all hosts on a particular port leave the multicast group, but there are still hosts on other ports (in the same virtual LAN) joined to the group, then nothing happens. In other words, the port continues to receive traffic from that multicast group.
- Only when the last host in a virtual LAN (VLAN) has left the multicast group does forwarding of the traffic of this group into the VLAN revert to no ports on the switch forwarding.

This join behavior only applies to multicast groups that actually operate in IGMPv3 mode. If legacy hosts only supporting IGMPv2 are present in the network, then groups will revert to IGMPv2 and fast leave will work for these groups.

If fast leave is needed with CGMP-enabled switches, we recommend that you not enable IGMPv3 but configure IGMPv2 on that interface.

If IGMPv3 is needed to support SSM, then you have two configuration alternatives as follows:

- Configure only the interface for IGMPv2 and use IGMP v3lite and URD.
- Enable IGMPv3 and accept the higher leave latencies through the CGMP switch.

Changing the IGMP Query Timeout

You can specify the period of time before the router takes over as the querier for the interface, after the previous querier has stopped doing so. By default, the router waits two times the query interval controlled by the **ip igmp query-interval** interface configuration command. After that time, if the router has received no queries, it becomes the querier. This feature requires IGMP Version 2.

To change the query timeout, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp query-timeout` *seconds*	Sets the IGMP query timeout.

Changing the Maximum Query Response Time

By default, the maximum query response time advertised in IGMP queries is 10 seconds. If the router is using IGMP Version 2, you can change this value. The maximum query response time allows a router to quickly detect that there are no more directly connected group members on a LAN. Decreasing the value allows the router to *prune* groups faster.

To change the maximum query response time, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp query-max-response-time` *seconds*	Sets the maximum query response time advertised in IGMP queries.

Configuring the Router as a Statically Connected Member

Sometimes either there is no group member on a network segment or a host cannot report its group membership using IGMP. However, you may want multicast traffic to go to that network segment. The following are two ways to pull multicast traffic down to a network segment:

- Use the **ip igmp join-group** interface configuration command. With this method, the router accepts the multicast packets in addition to forwarding them. Accepting the multicast packets prevents the router from fast switching.
- Use the **ip igmp static-group** interface configuration command. With this method, the router does not accept the packets itself, but only forwards them. Hence, this method allows fast switching. The outgoing interface appears in the IGMP cache, but the router itself is not a member, as evidenced by lack of an "L" (local) flag in the multicast route entry.

To configure the router itself to be a statically connected member of a group (and allow fast switching), use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp static-group group-address`	Configures the router as a statically connected member of a group.

Configuring IGMP Leave Latency

In IGMPv2 and IGMPv3, hosts send IGMP messages to indicate that they do not wish to receive a particular group, source, or channel any more. The length of time between the host wanting to leave and the router stopping forwarding is called the IGMP leave latency. IGMP leave latency is only relevant when the last host on a subnet that was a member to a group, source, or channel intends to leave, because as long as there are still other interested members, the router still needs to forward the traffic.

When a router receives such a membership message that indicates a leave, by default, it needs to verify if there are still other members interested in the traffic. To do so, the IGMP querying router sends out a group-specific or group-source-specific query. This query contains the last member query interval (LMQI), which is the time within which other still interested hosts need to send a membership report or else the router will stop forwarding. Because IGMP messages may get lost between router and hosts, the router by default does not immediately stop forwarding after the LMQI has expired, but instead it repeats this process of sending the group or group-source-specific query and waiting for membership reports for a total of times specified by the last member query count (LMQC). Only thereafter will the router stop forwarding.

By default in Cisco IOS software and in the IGMPv2 and IGMPv3 RFCs, the LMQI is 1 second, and the LMQC is 2. Therefore, the default leave latency for individual leaves in Cisco IOS software is 3 seconds.

IGMPv3 explicit tracking allows to reduce the leave latency to approximately 0 for hosts that support IGMPv3. This feature is not available for hosts that support only IGMPv2 because of the protocol limitation.

In IGMPv2, if there is only one IP multicast receiving host connected to a subnet, the **ip igmp immediate-leave group-list** command can be configured so the router immediately stop forwarding traffic for the group, resulting in a leave latency of 0.

To change the values of the LMQI, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp last-member-query-interval interval`	Configures the interval at which the router sends IGMP group-specific or group-source-specific (with IGMPv3) query messages.

To change the values of the LMQC, use the following commands in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp last-member-query-count lmqc`	Configures the number of times that the router sends IGMP group-specific or group-source-specific (with IGMPv3) query messages.

Configuring the TTL Threshold

The TTL value controls whether packets are forwarded out of an interface. You specify the TTL value in hops. Only multicast packets with a TTL greater than the interface TTL threshold are forwarded on the interface. The default value is 0, which means that all multicast packets are forwarded on the interface. To change the default TTL threshold value, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip multicast ttl-threshold ttl-value`	Configures the TTL threshold of packets being forwarded out an interface.

Disabling Fast Switching of IP Multicast

Fast switching of IP multicast packets is enabled by default on all interfaces (including generic routing encapsulation [GRE] and DVMRP tunnels), with one exception: It is disabled and not supported over X.25 encapsulated interfaces. Note the following properties of fast switching:

- If fast switching is disabled on an *incoming* interface for a multicast routing table entry, the packet is sent at process level for all interfaces in the outgoing interface list.
- If fast switching is disabled on an *outgoing* interface for a multicast routing table entry, the packet is process-level switched for that interface, but may be fast switched for other interfaces in the outgoing interface list.

Disable fast switching if you want to log debug messages, because when fast switching is enabled, debug messages are not logged.

To disable fast switching of IP multicast, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# no ip mroute-cache`	Disables fast switching of IP multicast.

SAP Listener Support Configuration Task List

To configure Session Announcement Protocol (SAP) listener support, perform the tasks described in the following sections. The task in the first section is required; the task in the remaining section is optional.

- Enabling SAP Listener Support (Required)
- Limiting How Long a SAP Cache Entry Exists (Optional)

Enabling SAP Listener Support

Use session description and announcement protocols and applications to assist the advertisement of multicast multimedia conferences and other multicast sessions and to communicate the relevant session setup information to prospective participants. Sessions are described by the Session Description Protocol (SDP), which is defined in RFC 2327. SDP provides a formatted, textual description of session

properties (for example, contact information, session lifetime, and the media) being used in the session (for example, audio, video, and whiteboard) with their specific attributes like TTL scope, group address, and User Datagram Protocol (UDP) port number.

Many multimedia applications rely on SDP for session descriptions. However, they may use different methods to disseminate these session descriptions. For example, IP/TV relies on the Web to disseminate session descriptions to participants. In this example, participants must know of a Web server that provides the session information.

MBONE applications (for example, vic, vat, and wb) and other applications rely on multicast session information sent throughout the network. In these cases, a protocol called Session Announcement Protocol (SAP) is used to transport the SDP session announcements. SAP Version 2 uses the well-known session directory multicast group 224.2.127.254 to disseminate SDP session descriptions for global scope sessions and group 239.255.255.255 for administrative scope sessions.

Note The Session Directory (SDR) application is commonly used to send and receive SDP/SAP session announcements.

To enable the Cisco IOS software to listen to Session Directory announcements, use the following command on a multicast-enabled interface in interface configuration mode:

Command	Purpose
`Router(config-if)# ip sap listen`	Enables the Cisco IOS software to listen to Session Directory announcements.

Limiting How Long a SAP Cache Entry Exists

By default, entries are deleted 24 hours after they were last received from the network. To limit how long a SAP cache entry stays active in the cache, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip sap cache-timeout`	Limits how long a SAP cache entry stays active in the cache.

Enabling the Functional Address for IP Multicast over Token Ring LANs

By default, IP multicast datagrams on Token Ring LAN segments use the MAC-level broadcast address 0xFFFF.FFFF.FFFF. That default places an unnecessary burden on all devices that do not participate in IP multicast. The IP Multicast over Token Ring LANs feature defines a way to map IP multicast addresses to a single Token Ring MAC address.

This feature defines the Token Ring functional address (0xc000.0004.0000) that should be used over Token Ring. A functional address is a severely restricted form of multicast addressing implemented on Token Ring interfaces. Only 31 functional addresses are available. A bit in the destination MAC address designates it as a functional address.

The implementation used by Cisco complies with RFC 1469, *IP Multicast over Token-Ring Local Area Networks*.

If you configure this feature, IP multicast transmissions over Token Ring interfaces are more efficient than they formerly were. This feature reduces the load on other machines that do not participate in IP multicast because they do not process these packets.

The following restrictions apply to the Token Ring functional address:

- This feature can be configured only on a Token Ring interface.
- Neighboring devices on the Token Ring on which this feature is used should also use the same functional address for IP multicast traffic.
- Because there are a limited number of Token Ring functional addresses, other protocols could be assigned to the Token Ring functional address 0xc000.0004.0000. Therefore, not every frame sent to the functional address is necessarily an IP multicast frame.

To enable the mapping of IP multicast addresses to the Token Ring functional address 0xc000.0004.0000, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip multicast use-functional`	Enables the mapping of IP multicast addresses to the Token Ring functional address.

For an example of configuring the functional address, see the section "Functional Address for IP Multicast over Token Ring LAN Example" later in this chapter.

Configuring PIM Version 2

PIM Version 2 includes the following improvements over PIM Version 1:

- A single, active RP exists per multicast group, with multiple backup RPs. This single RP compares to multiple active RPs for the same group in PIM Version 1.
- A bootstrap router (BSR) provides a fault-tolerant, automated RP discovery and distribution mechanism. Thus, routers dynamically learn the group-to-RP mappings.
- Sparse mode and dense mode are properties of a group, as opposed to an interface. We strongly recommend sparse-dense mode, as opposed to either sparse mode or dense mode only.
- PIM join and prune messages have more flexible encodings for multiple address families.
- A more flexible hello packet format replaces the query packet to encode current and future capability options.
- Register messages to an RP indicate whether they were sent by a border router or a designated router.
- PIM packets are no longer inside IGMP packets; they are standalone packets.

PIM Version 1, together with the Auto-RP feature, can perform the same tasks as the PIM Version 2 BSR. However, Auto-RP is a standalone protocol, separate from PIM Version 1, and is Cisco proprietary. PIM Version 2 is a standards track protocol in the IETF. We recommend that you use PIM Version 2.

Note The simultaneous deployment of Auto-RP and BSR is not supported.

Either the BSR or Auto-RP should be chosen for a given range of multicast groups. If there are PIM Version 1 routers in the network, do not use the BSR.

The Cisco PIM Version 2 implementation allows interoperability and transition between Version 1 and Version 2, although there might be some minor problems. You can upgrade to PIM Version 2 incrementally. PIM Versions 1 and 2 can be configured on different routers within one network. Internally, all routers on a shared media network must run the same PIM version. Therefore, if a PIM Version 2 router detects a PIM Version 1 router, the Version 2 router downgrades itself to Version 1 until all Version 1 routers have been shut down or upgraded.

PIM uses the BSR to discover and announce RP-set information for each group prefix to all the routers in a PIM domain. This is the same function accomplished by Auto-RP, but the BSR is part of the PIM Version 2 specification.

To avoid a single point of failure, you can configure several candidate BSRs in a PIM domain. A BSR is elected among the candidate BSRs automatically; they use bootstrap messages to discover which BSR has the highest priority. This router then announces to all PIM routers in the PIM domain that it is the BSR.

Routers that are configured as candidate RPs then unicast to the BSR the group range for which they are responsible. The BSR includes this information in its bootstrap messages and disseminates it to all PIM routers in the domain. Based on this information, all routers will be able to map multicast groups to specific RPs. As long as a router is receiving the bootstrap message, it has a current RP map.

Prerequisites

- When PIM Version 2 routers interoperate with PIM Version 1 routers, Auto-RP should have already been deployed.-
- Because bootstrap messages are sent hop by hop, a PIM Version1 router will prevent these messages from reaching all routers in your network. Therefore, if your network has a PIM Version 1 router in it, and only Cisco routers, it is best to use Auto-RP rather than the bootstrap mechanism.

PIM Version 2 Configuration Task List

There are two approaches to using PIM Version 2. You can use Version 2 exclusively in your network, or migrate to Version 2 by employing a mixed PIM version environment. When deploying PIM Version 2 in your network, use the following guidelines:

- If your network is all Cisco routers, you may use either Auto-RP or the bootstrap mechanism (BSR).

Note The simultaneous deployment of Auto-RP and BSR is not supported.

- If you have routers other than Cisco in your network, you need to use the bootstrap mechanism.

To configure PIM Version 2, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Specifying the PIM Version (Required)
- Configuring PIM Version 2 Only (Optional)
- Making the Transition to PIM Version 2 (Optional)
- Monitoring the RP Mapping Information (Optional)

Specifying the PIM Version

All systems using Cisco IOS Release 11.3(2)T or later start in PIM Version 2 mode by default. To reenable PIM Version 2 or specify PIM Version 1 for some reason, control the PIM version by using the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim version [1 | 2]`	Configures the PIM version used.

Configuring PIM Version 2 Only

To configure PIM Version 2 exclusively, perform the tasks described in this section. It is assumed that no PIM Version 1 system exists in the PIM domain.

The first task is recommended. If you configure Auto-RP, none of the other tasks is required to run PIM Version 2. To configure Auto-RP, see the section "Configuring Auto-RP" earlier in this chapter.

If you want to configure a BSR, perform the tasks in the following sections. The tasks is the first section are required; the tasks in the remaining sections are optional.

- Configuring PIM Sparse-Dense Mode (Required)
- Defining a PIM Sparse Mode Domain Border Interface (Optional)
- Configuring Candidate BSRs (Optional)
- Configuring Candidate RPs (Optional)

Configuring PIM Sparse-Dense Mode

To configure PIM sparse-dense mode, use the following commands on all PIM routers inside the PIM domain beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip multicast-routing`	Enables IP multicast routing.
Step 2	`Router(config)# interface` *type number*	Configures an interface.
Step 3	`Router(config-if)# ip pim sparse-dense-mode`	Enables PIM on the interface. The sparse-dense mode is identical to the implicit interface mode in the PIM Version 2 specification.

Repeat Steps 2 and 3 for each interface on which you want to run PIM.

Defining a PIM Sparse Mode Domain Border Interface

A border interface in a PIM sparse mode (PIM-SM) domain requires special precautions to avoid exchange of certain traffic with a neighboring domain reachable through that interface, especially if that domain is also running PIM-SM. BSR and Auto-RP messages should not be exchanged between different domains, because routers in one domain may elect RPs in the other domain, resulting in protocol malfunction or loss of isolation between the domains.

To prevent BSR messages from being sent or received through an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim bsr-border`	Prevents BSR messages from being sent or received through an interface.

To prevent Auto-RP messages from being sent or received through an interface, use the following commands beginning in global configuration mode. The access list denies packets destined for the 224.0.1.39 and 224.0.1.40 multicast groups. These two groups are specifically assigned to carry Auto-RP information.

	Command	Purpose
Step 1	`Router(config)# access-list` *access-list-number* {**deny** | **permit**} *source* [*source-wildcard*]	Defines an administratively scoped boundary.
Step 2	`Router(config-if)# ip multicast boundary` *access-list*	Prevents Auto-RP messages (used in PIM Version 1) from being sent or received through an interface.

Configuring Candidate BSRs

Configure one or more candidate BSRs. The routers to serve as candidate BSRs should be well connected and be in the backbone portion of the network, as opposed to the dialup portion of the network.

Note The Cisco IOS implementation of PIM BSR uses the value 0 as the default priority for candidate RPs and BSRs. This implementation predates the draft-ietf-pim-sm-bsr IETF draft, the first IETF draft to specify 192 as the default priority value. The Cisco IOS implementation, thus, deviates from the IETF draft. To comply with the default priority value specified in the draft, you must explicitly set the priority value to 192.

To configure a router to be a candidate BSR, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim bsr-candidate` *type number hash-mask-length* [*priority*]	Configures the router to be a candidate BSR.

Configuring Candidate RPs

Configure one or more candidate RPs. Similar to BSRs, the RPs should also be well connected and in the backbone portion of the network. An RP can serve the entire IP multicast address space or a portion of it. Candidate RPs send candidate RP advertisements to the BSR.

Note The Cisco IOS implementation of PIM BSR uses the value 0 as the default priority for candidate RPs and BSRs. This implementation predates the draft-ietf-pim-sm-bsr IETF draft, the first IETF draft to specify 192 as the default priority value. The Cisco IOS implementation, thus, deviates from the IETF draft. To comply with the default priority value specified in the draft, you must explicitly set the priority value to 192.

Consider the following scenarios when deciding which routers should be RPs:

- In a network of Cisco routers where only Auto-RP is used, any router can be configured as an RP.
- In a network of routers that includes only Cisco PIM Version 2 routers and routers from other vendors, any router can be used as an RP.
- In a network of Cisco PIM Version 1 routers, Cisco PIM Version 2 routers, and routers from other vendors, only Cisco PIM Version 2 routers should be configured as RPs.

To configure a router to be a candidate RP, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim rp-candidate type number [group-list access-list] [priority value]`	Configures the router to be a candidate RP.

For examples of configuring PIM Version 2, see the section "PIM Version 2 Examples" later in this chapter.

Note The Cisco IOS implementation of PIM BSR selects an RP from a set of candidate RPs using a method that is incompatible with the specification in RFC 2362. Refer to CSCdy56806 using the Cisco Bug Toolkit for more information. See the "RFC 2362 Interoperable Candidate RP Example" section on page 450 for a configuration workaround.

Making the Transition to PIM Version 2

On each LAN, the Cisco implementation of PIM Version 2 automatically enforces the rule that all PIM messages on a shared LAN are in the same PIM version. To accommodate that rule, if a PIM Version 2 router detects a PIM Version 1 router on the same interface, the Version 2 router downgrades itself to Version 1 until all Version 1 routers have been shut down or upgraded.

Deciding When to Configure a BSR

If there are only Cisco routers in your network (no routers from other vendors), there is no need to configure a BSR. Configure Auto-RP in the mixed PIM Version 1/Version 2 environment.

Note The simultaneous deployment of Auto-RP and BSR is not supported.

Dense Mode

Dense mode groups in a mixed Version 1/Version 2 region need no special configuration; they will interoperate automatically.

Sparse Mode

Sparse mode groups in a mixed Version 1/Version 2 region are possible because the Auto-RP feature in Version 1 interoperates with the RP feature of Version 2. Although all PIM Version 2 routers also can use Version 1, we recommend that the RPs be upgraded to Version 2 (or at least upgraded to PIM Version 1 in the Cisco IOS Release 11.3 software).

To ease the transition to PIM Version 2, we also recommend the following configuration:

- Auto-RP be used throughout the region
- Sparse-dense mode be configured throughout the region

If Auto-RP was not already configured in the PIM Version 1 regions, configure Auto-RP. See the section "Configuring Auto-RP" earlier in this chapter.

Monitoring the RP Mapping Information

To monitor the RP mapping information, use the following commands in EXEC mode as needed:

Command	Purpose
`Router# show ip pim bsr`	Displays information about the currently elected BSR.
`Router# show ip pim rp-hash [group-address | group-name]`	Displays the RP that was selected for the specified group.
`Router# show ip pim rp mapping [rp-address]`	Displays how the router learns of the RP (via bootstrap or Auto-RP mechanism).

Advanced PIM Features Configuration Task List

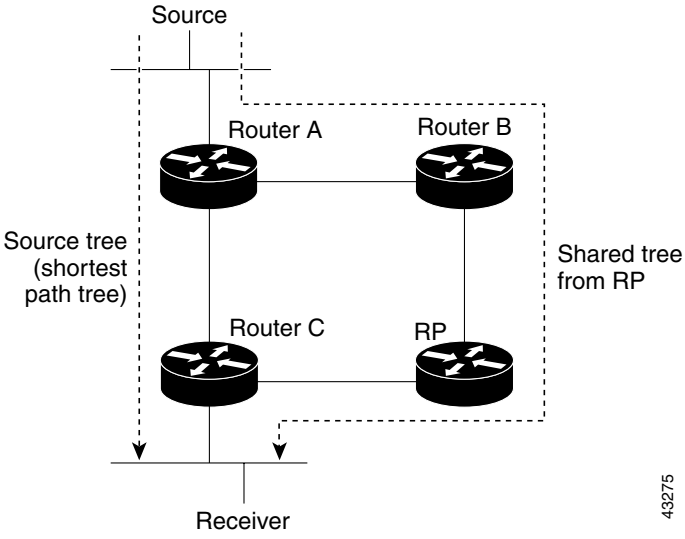
To configure PIM features, perform the optional tasks described in the following sections:

- Delaying the Use of PIM Shortest-Path Tree (Optional)
- Assigning an RP to Multicast Groups (Optional)
- Increasing Control over RPs (Optional)
- Modifying the PIM Router Query Message Interval (Optional)
- Limiting the Rate of PIM Register Messages (Optional)
- Configuring the IP Source Address of Register Messages (Optional)
- Enabling Proxy Registering (Optional)
- Enabling PIM Nonbroadcast Multiaccess Mode (Optional)

Understanding PIM Shared Tree and Source Tree (Shortest-Path Tree)

By default, members of a group receive data from senders to the group across a single data distribution tree rooted at the RP. This type of distribution tree is called *shared tree*, as shown in Figure 67. Data from senders is delivered to the RP for distribution to group members joined to the shared tree.

Figure 67 Shared Tree and Source Tree (Shortest-Path Tree)



If the data rate warrants, leaf routers on the shared tree may initiate a switch to the data distribution tree rooted at the source. This type of distribution tree is called a *shortest-path tree* or *source tree*. By default, the Cisco IOS software switches to a source tree upon receiving the first data packet from a source.

The following process describes the move from shared tree to source tree in more detail:

1. Receiver joins a group; leaf Router C sends a join message toward RP.
2. RP puts link to Router C in its outgoing interface list.
3. Source sends data; Router A encapsulates data in a register message and sends it to RP.
4. RP forwards data down the shared tree to Router C and sends a join message toward Source. At this point, data may arrive twice at Router C, once encapsulated and once natively.
5. When data arrives natively (through multicast) at RP, RP sends a register-stop message to Router A.
6. By default, reception of the first data packet prompts Router C to send a join message toward Source.
7. When Router C receives data on (S, G), it sends a prune message for Source up the shared tree.
8. RP deletes the link to Router C from the outgoing interface of (S, G). RP triggers a prune message toward Source.

Join and prune messages are sent for sources and RPs. They are sent hop-by-hop and are processed by each PIM router along the path to the source or RP. Register and register-stop messages are not sent hop-by-hop. They are sent by the designated router that is directly connected to a source and are received by the RP for the group.

Multiple sources sending to groups used the shared tree.

The network manager can configure the router to stay on the shared tree, as described in the following section, “Delaying the Use of PIM Shortest-Path Tree.”

Understanding Reverse Path Forwarding

Reverse Path Forwarding (RPF) is an algorithm used for forwarding multicast datagrams. It functions as follows:

- If a router receives a datagram on an interface it uses to send unicast packets to the source, the packet has arrived on the RPF interface.
- If the packet arrives on the RPF interface, a router forwards the packet out the interfaces present in the outgoing interface list of a multicast routing table entry.
- If the packet does not arrive on the RPF interface, the packet is silently discarded to prevent loops.

PIM uses both source trees and RP-rooted shared trees to forward datagrams; the RPF check is performed differently for each, as follows:

- If a PIM router has source-tree state (that is, an (S,G) entry is present in the multicast routing table), the router performs the RPF check against the IP address of the source of the multicast packet.
- If a PIM router has shared-tree state (and no explicit source-tree state), it performs the RPF check on the RP address of the RP (which is known when members join the group).

PIM sparse mode uses the RPF lookup function to determine where it needs to send join and prune messages. (S, G) join message (which are source-tree states) are sent toward the source. (*, G) join messages (which are shared-tree states) are sent toward the RP.

DVMRP and PIM dense mode use only source trees and use RPF as described previously.

Delaying the Use of PIM Shortest-Path Tree

The switch from shared to source tree happens upon the arrival of the first data packet at the last hop router (Router C in Figure 67). This switch occurs because the **ip pim spt-threshold** interface configuration command controls that timing, and its default setting is 0 kbps.

The shortest-path tree requires more memory than the shared tree, but reduces delay. You might want to postpone its use. Instead of allowing the leaf router to move to the shortest-path tree immediately, you can specify that the traffic must first reach a threshold.

You can configure when a PIM leaf router should join the shortest-path tree for a specified group. If a source sends at a rate greater than or equal to the specified kbps rate, the router triggers a PIM join message toward the source to construct a source tree (shortest-path tree). If the **infinity** keyword is specified, all sources for the specified group use the shared tree, never switching to the source tree.

The group list is a standard access list that controls which groups the shortest-path tree threshold applies to. If a value of 0 is specified or the group list is not used, the threshold applies to all groups.

To configure a traffic rate threshold that must be reached before multicast routing is switched from the source tree to the shortest-path tree, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim spt-threshold {kbps | infinity} [group-list access-list]`	Specifies the threshold that must be reached before moving to shortest-path tree.

Assigning an RP to Multicast Groups

If you have configured PIM sparse mode, you must configure a PIM RP for a multicast group. An RP can either be configured statically in each box, or learned through a dynamic mechanism. This section explains how to statically configure an RP. If the RP for a group is learned through a dynamic mechanism (such as Auto-RP), you need not perform this task for that RP. You should use Auto-RP, which is described in the section "Configuring Auto-RP" earlier in this chapter.

PIM designated routers forward data from directly connected multicast sources to the RP for distribution down the shared tree.

Data is forwarded to the RP in one of two ways. It is encapsulated in register packets and unicast directly to the RP, or, if the RP has itself joined the source tree, it is multicast forwarded per the RPF forwarding algorithm described in the preceding section, "Understanding Reverse Path Forwarding." Last hop routers directly connected to receivers may, at their discretion, join themselves to the source tree and prune themselves from the shared tree.

A single RP can be configured for multiple groups defined by an access list. If no RP is configured for a group, the router treats the group as dense using the PIM dense mode techniques.

If a conflict exists between the RP configured with this command and one learned by Auto-RP, the Auto-RP information is used, unless the **override** keyword is configured.

To assign an RP to one or more multicast groups, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim rp-address` *rp-address* [*access-list*] [**override**]	Assigns an RP to multicast groups.

Increasing Control over RPs

You can take a defensive measure to prevent a misconfigured leaf router from interrupting PIM service to the remainder of a network. To do so, configure the local router to accept join messages only if they contain the RP address specified, when the group is in the group range specified by the access list. To configure this feature, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim accept-rp` {*rp-address* | **auto-rp**} [*access-list*]	Controls which RPs the local router will accept join messages from.

Modifying the PIM Router Query Message Interval

Router query messages are used to elect a PIM designated router. The designated router is responsible for sending IGMP host query messages. By default, multicast routers send PIM router query messages every 30 seconds. To modify this interval, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim query-interval` *seconds*	Configures the frequency at which multicast routers send PIM router query messages.

Understanding the PIM Registering Process

IP multicast sources do not use a signalling mechanism to announce their presence. Sources just send their data into the attached network, as opposed to receivers that use IGMP to announce their presence. If a source sends traffic to a multicast group configured in PIM-SM, the DR leading toward the source must inform the RP about the presence of this source. If the RP has downstream receivers that want to receive the multicast traffic (natively) from this source and has not joined the shortest path leading toward the source, then the DR must send the traffic from the source to the RP. The PIM registering process, which is individually run for each (S, G) entry, accomplishes these tasks between the DR and RP.

The registering process begins when a DR creates a new (S, G) state. The DR encapsulates all the data packets that match the (S, G) state into PIM register messages and unicasts those register messages to the RP.

If an RP has downstream receivers that want to receive register messages from a new source, the RP can either continue to receive the register messages through the DR or join the shortest path leading toward the source. By default, the RP will join the shortest path, because delivery of native multicast traffic provides the highest throughput. Upon receipt of the first packet that arrives natively through the shortest path, the RP will send a register-stop message back to the DR. When the DR receives this register-stop message, it will stop sending register messages to the RP.

If an RP has no downstream receivers that want to receive register messages from a new source, the RP will not join the shortest path. Instead, the RP will immediately send a register-stop message back to the DR. When the DR receives this register-stop message, it will stop sending register messages to the RP.

Once a routing entry is established for a source, a periodic reregistering takes place between the DR and RP. One minute before the multicast routing table state times out, the DR will send one dataless register message to the RP each second that the source is active until the DR receives a register-stop message from the RP. This action restarts the timeout time of the multicast routing table entry, typically resulting in one reregistering exchange every 2 minutes. Reregistering is necessary to maintain state, to recover from lost state, and to keep track of sources on the RP. It will take place independently of the RP joining the shortest path.

PIM Version 1 Compatibility

If an RP is running PIM Version 1, it will not understand dataless register messages. In this case, the DR will not send dataless register messages to the RP. Instead, approximately every 3 minutes after receipt of a register-stop message from the RP, the DR encapsulates the incoming data packets from the source into register messages and sends them to the RP. The DR continues to send register messages until it receives another register-stop message from the RP. The same behavior occurs if the DR is running PIM Version 1.

When a DR running PIM Version 1 encapsulates data packets into register messages for a specific (S, G) entry, the entry is process-switched, not fast-switched or hardware-switched. On platforms that support these faster paths, the PIM registering process for an RP or DR running PIM Version 1 may lead to periodic out-of-order packet delivery. For this reason, we recommend upgrading your network from PIM Version 1 to PIM Version 2.

Limiting the Rate of PIM Register Messages

To set a limit on the maximum number of PIM-SM register messages sent per second for each (S, G) routing entry, use the following global configuration command on the DR:

Command	Purpose
`Router(config)# ip pim register-rate-limit rate`	Sets a limit on the maximum number of PIM-SM register messages sent per second for each (S, G) routing entry.

Dataless register messages are sent at a rate of 1 message per second. Continuous high rates of register messages may occur if a DR is registering bursty sources (sources with high data rates) and if the RP is not running PIM Version 2.

By default, this command is not configured and register messages are sent without limiting their rate. Enabling this command will limit the load on the DR and RP at the expense of dropping those register messages that exceed the set limit. Receivers may experience data packet loss within the first second in which packets are sent from bursty sources.

Configuring the IP Source Address of Register Messages

Register messages are unicast messages sent by the DR to the RP router when a multicast packet needs to be sent on a rendezvous point tree (RPT). By default, the IP source address of the register message is set to the address of the outgoing interface of the DR leading toward the RP. To configure the IP source address of a register message to an interface address other than the outgoing interface address of the DR leading toward the RP, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim register-source type number`	Configures the IP source address of a register message.

Enabling Proxy Registering

In a PIM-SM domain, receivers know about sources because the DR connected to the source registers the source with the RP. By default, a DR will only register sources that are connected to it or that are forwarded to the DR from a DVMRP router.

For a router in a PIM-SM domain configured to operate in sparse mode or sparse-dense mode, the **ip pim dense-mode proxy-register** interface configuration command must be configured on the interface leading toward the bordering dense mode region. This configuration will enable the router to register traffic from the dense mode region with the RP in the sparse mode domain.

To enable proxy registering, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim dense-mode [proxy-register {list access-list | route-map map-name}]`	Enables proxy registering on the interface of a DR (leading toward the bordering dense mode region) for multicast traffic from sources not connected to the DR.

For traffic from DVMRP neighbors, proxy registering is always active and cannot be influenced by the **ip pim dense-mode proxy-register** interface configuration command. For dense mode or DVMRP regions, proxy registering allows for limited interoperability between a dense mode region and a sparse mode domain. This limitation is referred to as "receiver must also be sender." The "receiver must also be sender" limit exists because there is no mechanism in dense mode protocols to convey the existence of receiver-only hosts to a border router, and the flooding (and pruning) of all multicast traffic originated in the dense mode domain inhibits the purpose of a sparse mode domain. The behavior of participating hosts in the dense mode region is as follows:

- A host in the dense mode region is only guaranteed to receive traffic from sources in the sparse mode domain through the proxy registering border router if at least one host is in the dense mode region that is a sender for the multicast group. This host is typically the receiving host itself.
- A sender in the dense mode region will trigger proxy registering in the border router, which in turn will cause the border router to join the multicast group and forward traffic from sources in the sparse mode domain toward the dense mode region.
- If no sender is in the dense mode region for a multicast group, then no traffic will be forwarded into the dense mode region.

Enabling PIM Nonbroadcast Multiaccess Mode

PIM nonbroadcast multiaccess (NBMA) mode allows the Cisco IOS software to replicate packets for each neighbor on the NBMA network. Traditionally, the software replicates multicast and broadcast packets to all "broadcast" configured neighbors. This action might be inefficient when not all neighbors want packets for certain multicast groups. NBMA mode enables you to reduce bandwidth on links leading into the NBMA network, and to reduce the number of CPU cycles in switches and attached neighbors.

Configure this feature on ATM, Frame Relay, Switched Multimegabit Data Service (SMDS), PRI ISDN, or X.25 networks only, especially when these media do not have native multicast available. Do not use this feature on multicast-capable LANs (such as Ethernet or FDDI).

You should use PIM sparse mode with this feature. Therefore, when each join message is received from NBMA neighbors, PIM stores each neighbor IP address and interface in the outgoing interface list for the group. When a packet is destined for the group, the software replicates the packet and unicasts (data-link unicasts) it to each neighbor that has joined the group.

To enable PIM NBMA mode on your serial link, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim nbma-mode`	Enables PIM NBMA mode.

Consider the following two factors before enabling PIM NBMA mode:

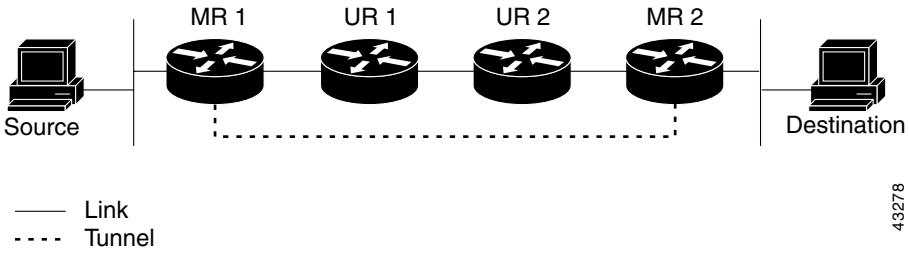
- If the number of neighbors grows, the outgoing interface list gets large, which costs memory and replication time.
- If the network (Frame Relay, SMDS, or ATM) supports multicast natively, you should use it so that replication is performed at optimal points in the network.

Configuring an IP Multicast Static Route

IP multicast static routes (mroutes) allow you to have multicast paths diverge from the unicast paths. When using PIM, the router expects to receive packets on the same interface where it sends unicast packets back to the source. This expectation is beneficial if your multicast and unicast topologies are congruent. However, you might want unicast packets to take one path and multicast packets to take another.

The most common reason for using separate unicast and multicast paths is tunneling. When a path between a source and a destination does not support multicast routing, a solution is to configure two routers with a GRE tunnel between them. In Figure 68, each unicast router (UR) supports unicast packets only; each multicast router (MR) supports multicast packets.

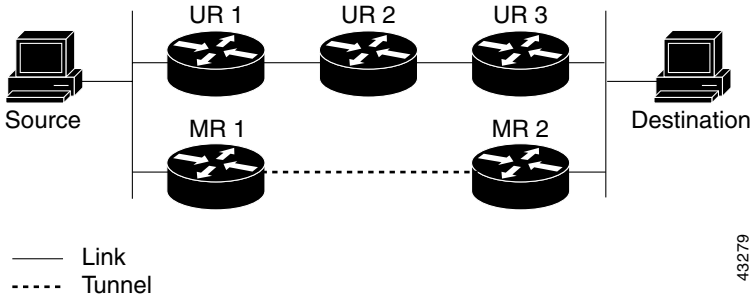
Figure 68 Tunnel for Multicast Packets



In Figure 68, Source delivers multicast packets to Destination by using MR 1 and MR 2. MR 2 accepts the multicast packet only if it believes it can reach Source over the tunnel. If this situation is true, when Destination sends unicast packets to Source, MR 2 sends them over the tunnel. Sending the packet over the tunnel could be slower than natively sending the it through UR 2, UR 1, and MR 1.

Prior to multicast static routes, the configuration in Figure 69 was used to overcome the problem of both unicasts and multicasts using the tunnel. In this figure, MR 1 and MR 2 are used as multicast routers only. When Destination sends unicast packets to Source, it uses the (UR 3, UR 2, UR 1) path. When Destination sends multicast packets, the UR routers do not understand or forward them. However, the MR routers forward the packets.

Figure 69 Separate Paths for Unicast and Multicast Packets



To make the configuration in Figure 69 work, MR 1 and MR 2 must run another routing protocol (typically a different instantiation of the same protocol running in the UR routers), so that paths from sources are learned dynamically.

A multicast static route allows you to use the configuration in Figure 68 by configuring a static multicast source. The Cisco IOS software uses the configuration information instead of the unicast routing table. Therefore, multicast packets can use the tunnel without having unicast packets use the tunnel. Static mroutes are local to the router they are configured on and not advertised or redistributed in any way to any other router.

To configure a multicast static route, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip mroute` *source-address mask* [*protocol as-number*] {*rpf-address* | *type number*} [*distance*]	Configures an IP multicast static route.

Controlling the Transmission Rate to a Multicast Group

By default, there is no limit as to how fast a sender can send packets to a multicast group. To control the rate that the sender from the source list can send to a multicast group in the group list, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip multicast rate-limit` {**in** | **out**} [**video** | **whiteboard**] [**group-list** *access-list*] [**source-list** *access-list*] *kbps*	Controls transmission rate to a multicast group.

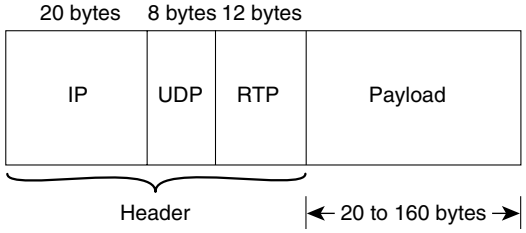
Configuring RTP Header Compression

Real-Time Transport Protocol (RTP) is a protocol used for carrying packetized audio and video traffic over an IP network. RTP, described in RFC 1889, is not intended for data traffic, which uses TCP or UDP. RTP provides end-to-end network transport functions intended for applications with real-time requirements (such as audio, video, or simulation data over multicast or unicast network services).

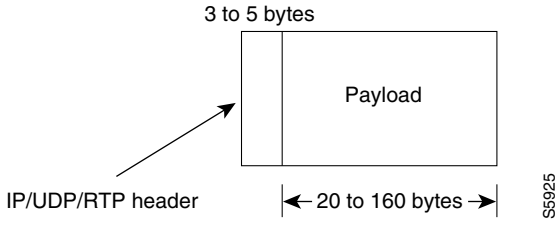
The minimal 12 bytes of the RTP header, combined with 20 bytes of IP header and 8 bytes of UDP header, create a 40-byte IP/UDP/RTP header, as shown in Figure 70. The RTP packet has a payload of approximately 20 to 150 bytes for audio applications that use compressed payloads. It is very inefficient to send the IP/UDP/RTP header without compressing it.

Figure 70 RTP Header Compression

Before RTP header compression:



After RTP header compression:



The RTP header compression feature compresses the IP/UDP/RTP header in an RTP data packet from 40 bytes to approximately 2 to 5 bytes, as shown in Figure 70. It is a hop-by-hop compression scheme similar to RFC 1144 for TCP/IP header compression. Using RTP header compression can benefit both telephony voice and MBONE applications running over slow links.

RTP header compression is supported on serial lines using Frame Relay, High-Level Data Link Control (HDLC), or PPP encapsulation. It is also supported over ISDN interfaces.

Enabling compression on both ends of a low-bandwidth serial link can greatly reduce the network overhead if substantial amounts of RTP traffic are on that slow link. This compression is beneficial especially when the RTP payload size is small (for example, compressed audio payloads of 20 to 50 bytes). Although the MBONE-style RTP traffic has higher payload sizes, compact encodings such as code excited linear prediction (CELP) compression can also help considerably.

Before you can enable RTP header compression, you must have configured a serial line that uses either Frame Relay, HDLC, or PPP encapsulation, or an ISDN interface. To configure RTP header compression, perform the tasks described in the following sections. Either one of the first two tasks is required.

- Enabling RTP Header Compression on a Serial Interface
- Enabling RTP Header Compression with Frame Relay Encapsulation
- Changing the Number of Header Compression Connections

You can compress the IP/UDP/RTP headers of RTP traffic to reduce the size of your packets, making audio or video communication more efficient. You must enable compression on both ends of a serial connection.

RTP header compression occurs in either the fast-switched or CEF-switched path, depending on whether certain prerequisites are met. Otherwise, it occurs in the process-switched path. For more information about where RTP header compression occurs, see the section "Enabling Express RTP Header Compression" later in this document.

Enabling RTP Header Compression on a Serial Interface

To enable RTP header compression for serial encapsulation HDLC or PPP, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip rtp header-compression [passive]`	Enables RTP header compression.

If you include the **passive** keyword, the software compresses outgoing RTP packets only if incoming RTP packets on the same interface are compressed. If you use the command without the **passive** keyword, the software compresses all RTP traffic.

See the "RTP Header Compression Examples" section later in this chapter for an example of how to enable RTP header compression on a serial interface.

Enabling RTP Header Compression with Frame Relay Encapsulation

To enable RTP header compression with Frame Relay encapsulation, use the following commands in interface configuration mode as needed:

Command	Purpose
`Router(config-if)# frame-relay ip rtp header-compression [passive]`	Enables RTP header compression on the physical interface, and all the interface maps inherit it. Subsequently, all maps will perform RTP/IP header compression.
`Router(config-if)# frame-relay map ip ip-address dlci [broadcast] rtp header-compression [active | passive] [connections number]`	Enables RTP header compression only on the particular map specified.
`Router(config-if)# frame-relay map ip ip-address dlci [broadcast] compress [active | passive] [connections number]`	Enables both RTP and TCP header compression on this link.

See the "RTP Header Compression Examples" section later in this chapter for an example of how to enable RTP header compression with Frame Relay encapsulation.

To disable RTP and TCP header compression with Frame Relay encapsulation, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# frame-relay map ip ip-address dlci [broadcast] nocompress`	Disables both RTP and TCP header compression on this link.

Changing the Number of Header Compression Connections

For Frame Relay encapsulation, the software does not specify a maximum number of RTP header compression connections. You can configure from 3 to 256 RTP header compression connections on an interface.

By default, for PPP or HDLC encapsulation, the software allows 32 RTP header compression connections (16 calls). This default can be increased to a maximum of 1000 RTP header compression connections on an interface.

To change the number of compression connections supported, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# frame-relay ip rtp compression-connections` *number*	Specifies the maximum number of RTP header compression connections supported on the Frame Relay interface.
`Router(config-if)# ip rtp compression-connections` *number*	Specifies the total number of RTP header compression connections supported on the PPP or HDLC interface.

See the "RTP Header Compression Examples" section later in this chapter for an example of how to change the number of header compression connections.

Enabling Express RTP Header Compression

Before Cisco IOS Release 12.0(7)T, if compression of TCP or RTP headers was enabled, compression was performed in the process-switching path, which meant that packets traversing interfaces that had TCP or RTP header compression enabled were queued and passed up to the process to be switched. This procedure slowed down transmission of the packet, and therefore some users preferred to fast switch uncompressed TCP and RTP packets.

With Release 12.1 and later releases, if TCP or RTP header compression is enabled, it occurs by default in the fast-switched path or the Cisco Express Forwarding-switched (CEF-switched) path, depending on which switching method is enabled on the interface.

If neither fast switching nor CEF switching is enabled, if enabled, RTP header compression will occur in the process-switched path as before.

For examples of RTP header compression, see the sections "Express RTP Header Compression with PPP Encapsulation Example" and "Express RTP Header Compression with Frame Relay Encapsulation Example."

The Express RTP and TCP Header Compression feature has the following benefits:

- It reduces network overhead.
- It speeds up transmission of TCP and RTP packets. The faster speed provides a greater benefit on slower links than faster links.

One restriction affects Multilink PPP (MLP) interfaces that have link fragment and interleave (LFI). In this case, if RTP header compression is configured, RTP packets originating on or destined to the router will be process switched. Transit traffic will be fast switched.

The CEF and fast-switching aspects of this feature are related to these documents:

- *Cisco IOS Switching Services Configuration Guide*
- *Cisco IOS Switching Services Command Reference*

In order for the Express RTP Header Compression feature to work, the following conditions must exist:

- CEF switching or fast switching must be enabled on the interface.
- HDLC, PPP, or Frame Relay encapsulation must be configured.
- RTP header compression must be enabled.

The Express RTP Header Compression feature supports the following RFCs:

- RFC 1144, *Compressing TCP/IP Headers for Low-Speed Serial Links*
- RFC 2507, *IP Header Compression*
- RFC 2508, *Compressing IP/UDP/RTP Headers for Low-Speed Serial Links*

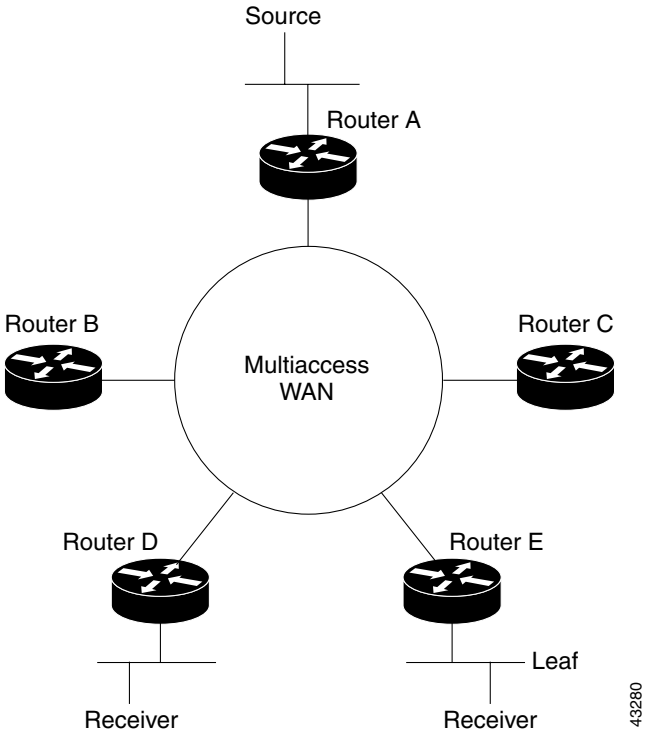
Configuring IP Multicast over ATM Point-to-Multipoint Virtual Circuits

IP multicast over ATM point-to-multipoint virtual circuits (VCs) is a feature that dynamically creates ATM point-to-multipoint switched virtual circuits (SVCs) to handle IP multicast traffic more efficiently.

The feature can enhance router performance and link utilization because packets are not replicated and sent multiple times over the ATM interface.

Traditionally, over NBMA networks, Cisco routers would perform a pseudobroadcast to get broadcast or multicast packets to all neighbors on a multiaccess network. For example, assume in Figure 71 that routers A, B, C, D, and E were running the Open Shortest Path First (OSPF) protocol. Router A must deliver to Routers D and E. When Router A sends an OSPF hello packet, the data link layer replicates the hello packet and sends one to each neighbor (this procedure is known as *pseudobroadcast*), which results in four copies being sent over the link from Router A to the multiaccess WAN.

Figure 71 Environment for IP Multicast over ATM Point-to-Multipoint VCs



With the advent of IP multicast, where high-rate multicast traffic can occur, that approach does not scale. Furthermore, in the preceding example, routers B and C would get data traffic they do not need. To handle this problem, PIM can be configured in NBMA mode using the **ip pim nbma-mode** interface configuration command. PIM in NBMA mode works only for sparse mode groups. Configuring PIM in NBMA mode would allow only routers D and E to get the traffic without distributing to routers B and C. However, two copies are still delivered over the link from Router A to the multiaccess WAN.

If the underlying network supported multicast capability, the routers could handle this situation more efficiently. If the multiaccess WAN were an ATM network, IP multicast could use multipoint VCs.

To configure IP multicast using multipoint VCs, routers A, B, C, D, and E in Figure 71 must run PIM sparse mode. If the Receiver directly connected to Router D joins a group and A is the PIM RP, the following sequence of events occur:

1. Router D will send a PIM join message to Router A.
2. When Router A receives the PIM join, it sets up a multipoint VC for the multicast group.
3. Later, when the Receiver directly connected to Router E joins the same group, E will send a PIM join message to Router A.
4. Router A will see there is a multipoint VC already associated with the group, and will add Router E to the existing multipoint VC.
5. When the Source sends a data packet, Router A can send a single packet over its link that gets to both Router D and Router E. The replication occurs in the ATM switches at the topological diverging point from Router A to Router D and Router E.

If a host sends an IGMP report over an ATM interface to a router, the router adds the host to the multipoint VC for the group.

This feature can also be used over ATM subinterfaces.

You must have ATM configured for multipoint signalling. Refer to the "Configuring ATM" chapter in the *Cisco IOS Wide-Area Networking Configuration Guide* for more information on how to configure ATM for point-to-multipoint signalling.

You also must have IP multicast routing and PIM sparse mode configured. This feature does not work with PIM dense mode.

To configure IP multicast over ATM point-to-multipoint VCs, perform the tasks described in the following sections. The task in the first section is required; the task in the remaining section is optional.

- Enabling IP Multicast over ATM Point-to-Multipoint VCs (Required)
- Limiting the Number of VCs (Optional)

Enabling IP Multicast over ATM Point-to-Multipoint VCs

To enable PIM to open ATM point-to-multipoint VCs for each multicast group that a receiver joins, use the following commands in interface configuration mode on the ATM interface:

	Command	Purpose
Step 1	`Router(config-if)# ip pim multipoint-signalling`	Enables IP multicast over ATM point-to-multipoint VCs.
Step 2	`Router(config-if)# atm multipoint-signalling`	Enables point-to-multipoint signaling to the ATM switch.

The **atm multipoint-signaling** interface configuration command is required so that static map multipoint VCs can be opened. The router uses existing static map entries that include the **broadcast** keyword to establish multipoint calls. You must have the map list to act like a static ARP table.

Use the **show ip pim vc** EXEC command to display ATM VC status information for multipoint VCs opened by PIM.

See the "IP Multicast over ATM Point-to-Multipoint VC Example" section later in this chapter for an example of how to enable IP multicast over ATM point-to-multipoint VCs.

Limiting the Number of VCs

By default, PIM can open a maximum of 200 VCs. When the router reaches this number, it deletes inactive VCs so it can open VCs for new groups that might have activity. To change the maximum number of VCs that PIM can open, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim vc-count` *number*	Changes the maximum number of VCs that PIM can open.

Idling Policy

An idling policy uses the **ip pim vc-count** *number* interface configuration command to limit the number of VCs created by PIM. When the router stays at or below this *number* value, no idling policy is in effect. When the next VC to be opened will exceed the *number* value, an idling policy is exercised. An idled VC does not mean that the multicast traffic is not forwarded; the traffic is switched to VC 0. The VC 0 is the broadcast VC that is open to all neighbors listed in the map list. The name "VC 0" is unique to PIM and the mrouting table.

How the Idling Policy Works

The idling policy works as follows:

- The only VCs eligible for idling are those with a current 1-second activity rate less than or equal to the value configured by the **ip pim minimum-vc-rate** interface configuration command on the ATM interface. Activity level is measured in packets per second (pps).
- The VC with the least amount of activity below the configured **ip pim minimum-vc-rate** *pps* rate is idled.
- If the **ip pim minimum-vc-rate** command is not configured, all VCs are eligible for idling.
- If other VCs are at the same activity level, the VC with the highest fanout (number of leaf routers on the multipoint VC) is idled.
- The activity level is rounded to three orders of magnitude (less than 10 pps, 10 to 100 pps, and 100 to 1000 pps). Therefore, a VC that has 40 pps activity and another that has 60 pps activity are considered to have the same rate, and the fanout count determines which one is idled. If the first VC has a fanout of 5 and the second has a fanout of 3, the first one is idled.
- Idling a VC means releasing the multipoint VC that is dedicated for the multicast group. The traffic of the group continues to be sent; it is moved to the static map VC. Packets will flow over a shared multipoint VC that delivers packets to all PIM neighbors.
- If all VCs have a 1-minute rate greater than the *pps* value, the new group (that exceeded the **ip pim vc-count** *number*) will use the shared multipoint VC.

Keeping VCs from Idling

You can configure the minimum rate required to keep VCs from being idled. By default, all VCs are eligible for idling. To configure a minimum rate, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pim minimum-vc-rate` *pps*	Sets the minimum activity rate required to keep VCs from being idled.

Configuring an IP Multicast Boundary

You can set up an administratively scoped boundary on an interface for multicast group addresses. A standard access list defines the range of addresses affected. When a boundary is set up, no multicast data packets are allowed to flow across the boundary from either direction. The boundary allows the same multicast group address to be reused in different administrative domains.

The Internet Assigned Numbers Authority (IANA) has designated the multicast address range 239.0.0.0 to 239.255.255.255 as the administratively scoped addresses. This range of addresses can be reused in domains administered by different organizations. They would be considered local, not globally unique.

You can configure the **filter-autorp** keyword to examine and filter Auto-RP discovery and announcement messages at the administratively scoped boundary. Any Auto-RP group range announcements from the Auto-RP packets that are denied by the boundary access control list (ACL) are removed. An Auto-RP group range announcement is permitted and passed by the boundary only if all addresses in the Auto-RP group range are permitted by the boundary ACL. If any address is not permitted, the entire group range is filtered and removed from the Auto-RP message before the Auto-RP message is forwarded.

To set up an administratively scoped boundary, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# access-list` *access-list-number* {**deny** | **permit**} *source* [*source-wildcard*]	Creates a standard access list, repeating the command as many times as necessary. **Note** An access-list entry that uses the **deny** keyword creates a multicast boundary for packets that match that entry.
Step 2	`Router(config)# interface` *type number*	Configures an interface.
Step 3	`Router(config-if)# ip multicast boundary` *access-list* [**filter-autorp**]	Configures the boundary, specifying the access list you created in Step 1. Optionally configures Auto-RP message filtering.

See the section "Administratively Scoped Boundary Example" later in this chapter for an example of configuring a boundary.

Configuring an Intermediate IP Multicast Helper

When a multicast-capable internetwork is between two subnets with broadcast-only-capable hosts, you can convert broadcast traffic to multicast at the first hop router, and convert it back to broadcast at the last hop router to deliver the packets to the broadcast clients. Thus, you can take advantage of the multicast capability of the intermediate multicast internetwork. Configuring an intermediate IP multicast helper prevents unnecessary replication at the intermediate routers and can take advantage of multicast fast switching in the multicast internetwork.

See Figure 73 and the example of this feature in the section "IP Multicast Helper Example" later in this chapter.

An extended IP access list controls which broadcast packets are translated, based on the UDP port number.

To configure an intermediate IP multicast helper, the first hop router and the last hop router must be configured. To configure the first hop router, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies an interface.
Step 2	`Router(config-if)# ip multicast helper-map broadcast multicast-address access-list`	Configures a first hop router to convert broadcast traffic to multicast traffic.
Step 3	`Router(config-if)# ip directed-broadcast`	Configures directed broadcasts.
Step 4	`Router(config)# ip forward-protocol udp [port]`	Configures IP to forward the protocol you are using.

After configuring the first hop router, use the following commands on the last hop router beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies an interface.
Step 2	`Router(config-if)# ip directed-broadcast`	Configures directed broadcasts.
Step 3	`Router(config-if)# ip multicast helper-map group-address broadcast-address extended-access-list-number`	Configures a last hop router to convert multicast traffic to broadcast traffic.
Step 4	`Router(config)# access-list access-list-number {deny | permit} udp source source-wildcard destination destination-wildcard port`	Configures an access list.
Step 5	`Router(config)# ip forward-protocol udp [port]`	Configures IP to forward the protocol you are using.

Note On the last hop router, the **ip multicast helper-map** interface configuration command automatically introduces **ip igmp join-group** *group-address* on that interface. This command must stay on that interface for the intermediate IP multicast helper feature to work. If you remove the **ip igmp join-group** command, the feature will fail.

Storing IP Multicast Headers

You can store IP multicast packet headers in a cache and then display them to determine any of the following information:

- Who is sending IP multicast packets to what groups
- Interpacket delay
- Duplicate IP multicast packets (if any)
- Multicast forwarding loops in your network (if any)
- Scope of the group
- UDP port numbers
- Packet length

To allocate a circular buffer to store IP multicast packet headers that the router receives, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip multicast cache-headers`	Allocates a buffer to store IP multicast packet headers.

Note The **ip multicast cache-headers** global configuration command allocates a circular buffer of approximately 32 KB.

Use the **show ip mpacket** EXEC command to display the buffer.

Enabling CGMP

CGMP is a protocol used on routers connected to Catalyst switches to perform tasks similar to those performed by IGMP. CGMP is necessary because the Catalyst switch cannot distinguish between IP multicast data packets and IGMP report messages, which are both at the MAC level and are addressed to the same group address.

Enabling CGMP triggers a CGMP join message. CGMP should be enabled only on 802 or ATM media, or LAN emulation (LANE) over ATM. CGMP should be enabled only on routers connected to Catalyst switches.

To enable CGMP for IP multicast on a LAN, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip cgmp [proxy]`	Enables CGMP.

When the **proxy** keyword is specified, the CGMP proxy function is enabled. That is, any router that is not CGMP-capable will be advertised by the proxy router. The proxy router advertises the existence of other non-CGMP-capable routers by sending a CGMP join message with the MAC address of the non-CGMP-capable router and group address of 0000.0000.0000.

Configuring Stub IP Multicast Routing

When you use PIM in a large network, there are often stub regions over which the administrator has limited control. To reduce the configuration and administration burden, you can configure a subset of PIM functionality that provides the stub region with connectivity, but does not allow it to participate in or potentially complicate any routing decisions.

Stub IP multicast routing allows simple multicast connectivity and configuration at stub networks. It eliminates periodic flood-and-prune behavior across slow-speed links (ISDN and below) using dense mode. It eliminates that behavior by using forwarded IGMP reports as a type of join message and using selective PIM message filtering.

Stub IP multicast routing allows stub sites to be configured quickly and easily for basic multicast connectivity, without the flooding of multicast packets and subsequent group pruning that occurs in dense mode, and without excessive administrative burden at the central site.

Before configuring stub IP multicast routing, you must have IP multicast routing configured on both the stub router and the central router. You must also have PIM dense mode configured on both the incoming and outgoing interfaces of the stub router.

Two steps are required to enable stub IP multicast routing. One task is performed on the stub router, and the other is performed on a central router one hop away from the stub router. By definition, a stub region is marked by a leaf router. That is, the stub router (leaf router) is the last stop before any hosts receiving multicast packets or the first stop for anyone sending multicast packets.

The first step is to configure the stub router to forward all IGMP host reports and leave messages received on the interface to an IP address. The reports are re-sent out the next hop interface toward the IP address, with the source address of that interface. This action enables a sort of "dense mode" join message, allowing stub sites not participating in PIM to indicate membership in multicast groups.

To configure the stub router to forward IGMP host reports and leave messages, use the following command in interface configuration mode. Specify the IP address of an interface on the central router. When the central router receives IGMP host report and leave messages, it appropriately adds or removes the interface from its outgoing list for that group.

Command	Purpose
`Router(config-if)#` **`ip igmp helper-address`** *`ip-address`*	On the stub router, forwards all IGMP host reports and leave messages to the specified IP address on a central router.

The second step is to configure an access list on the central router to filter all PIM control messages from the stub router. Thus, the central router does not by default add the stub router to its outgoing interface list for any multicast groups. This task has the side benefit of preventing a misconfigured PIM neighbor from participating in PIM.

To filter PIM control messages, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)#` **`ip pim neighbor-filter`** *`access-list`*	On the central router, filters all PIM control messages based on the specified access list.

For an example of stub IP multicast routing, see the section "Stub IP Multicast Example" later in this chapter.

Load Splitting IP Multicast Traffic Across Equal-Cost Paths Configuration Task List

To configure load splitting of IP multicast traffic across equal-cost paths, perform the optional tasks described in either of the following sections:

- Enabling Native Load Splitting (Optional)
- Enabling Load Splitting Across Tunnels (Optional)

Enabling Native Load Splitting

If two or more equal-cost paths from a source are available, unicast traffic will be load split across those paths. However, by default multicast traffic will not be load split across multiple equal-cost paths. In general, multicast traffic will flow down from the RPF neighbor. According to PIM specifications, this neighbor must have the highest IP address if more than one neighbor has the same metric (refer to RFC 2362 for PIM sparse mode information).

To enable load splitting of IP multicast traffic across multiple equal-cost paths, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip multicast multipath`	Enables load splitting of IP multicast traffic across multiple equal-cost paths.

When the **ip multicast multipath** global configuration command is configured and multiple equal-cost paths exist, the path in which multicast traffic will travel is selected based on the source IP address. Multicast traffic from different sources will be load split across the different equal-cost paths. Load splitting will not occur across equal-cost paths for multicast traffic from the same source sent to different multicast groups.

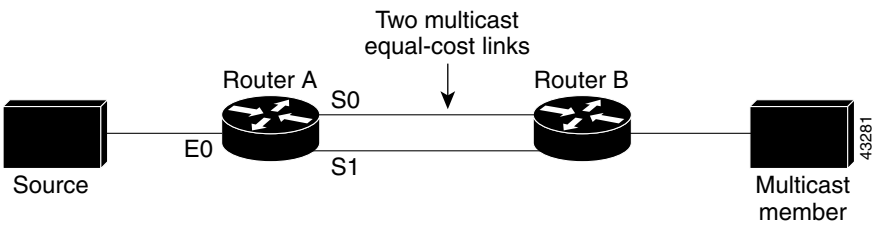
Note The **ip multicast multipath** global configuration command load splits the traffic and does not load balance the traffic. Traffic from a source will use only one path, even if the traffic far outweighs traffic from other sources.

The **ip multicast multipath** command does not support configurations in which the same PIM neighbor IP address is reachable through multiple equal-cost paths. This situation typically occurs if unnumbered interfaces are used. We recommend using different IP addresses for all interfaces when configuring the **ip multicast multipath** command.

Enabling Load Splitting Across Tunnels

Load splitting of IP multicast traffic can be achieved by consolidating multiple parallel links into a single tunnel over which the multicast traffic is then routed. Figure 72 shows an example of a topology in which this method can be used. Router A and Router B are connected with two equal-cost links.

Figure 72 Two Multicast Links Without Load Splitting



If a tunnel is configured between Router A and Router B, and multicast traffic is made to reverse path forward over the tunnel, then the multicast packets are sent encapsulated into the tunnel as unicast packets between Router A and Router B. The underlying unicast mechanism will then perform load splitting across the equal-cost links.

To configure load splitting across tunnels, perform the tasks described in the following sections. The tasks in the first three sections are required; the task in the remaining section is optional.

- Configuring the Access Router (Required)
- Configuring the Router at the Opposite End of the Tunnel (Required)
- Configuring Both Routers to RPF (Required)
- Verifying the Load Splitting (Optional)

Configuring the Access Router

To configure the access router end of the tunnel (the end of the tunnel near the source), use the following commands beginning in global configuration mode. The tunnel mode is GRE IP by default.

	Command	Purpose
Step 1	`Router(config)# interface tunnel number`	Configures a tunnel interface.
Step 2	`Router(config-if)# ip unnumbered type number`	Enables IP processing without assigning an IP address to the interface.
Step 3	`Router(config-if)# ip pim {dense-mode | sparse-mode | sparse-dense-mode}`	Enables PIM on the tunnel interface.
Step 4	`Router(config-if)# tunnel source {ip-address | type number}`	Configures the tunnel source.
Step 5	`Router(config-if)# tunnel destination {hostname | ip-address}`	Configures the tunnel destination.

Configuring the Router at the Opposite End of the Tunnel

After configuring the access router end of the tunnel, use the following commands on the router at the opposite end of the tunnel beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface tunnel number`	Configures a tunnel interface.
Step 2	`Router(config-if)# ip unnumbered type number`	Enables IP processing without assigning an IP address to the interface.
Step 3	`Router(config-if)# ip pim {dense-mode | sparse-mode | sparse-dense-mode}`	Enables PIM on the tunnel interface.
Step 4	`Router(config-if)# tunnel source {ip-address | type number}`	Configures the tunnel source. This configuration matches the tunnel destination at the opposite end of the tunnel.
Step 5	`Router(config-if)# tunnel destination {hostname | ip-address}`	Configures the tunnel destination. This configuration matches the tunnel source at the opposite end of the tunnel.

Configuring Both Routers to RPF

Because the use of the tunnel makes the multicast topology incongruent with the unicast topology, and only multicast traffic traverses the tunnel, you must configure the routers to reverse path forward correctly over the tunnel. The following sections describe two ways to configure the routers to reverse path forward multicast traffic over the tunnel, depending on your topology:

- Load Splitting to a Stub Network
- Load Splitting to the Middle of a Network

Load Splitting to a Stub Network

To load split to a stub network using a static multicast router, use the following command on the stub router in global configuration mode:

Command	Purpose
`Router(config)# ip mroute 0.0.0.0 0.0.0.0 tunnel` *number*	Configures a static multicast route over which to reverse path forward from the stub router to the other end of the tunnel.

After configuring a static multicast route, use the following commands on the router at the opposite end of the tunnel from the stub router in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip mroute` *source-address mask* `tunnel` *number*	Configures a static route over which to reverse path forward from the access router to the other end of the tunnel. Configure the *source-address* argument to be the network address of the network connected to the stub router.
Step 2	`Router(config)# ip mroute` *source-address mask* `tunnel` *number*	Repeat Step 1 for each network connected to the stub router.

Load Splitting to the Middle of a Network

You can also use static mroutes to load split to the middle of a network, but you must make sure that Router A would reverse path forward to the tunnel for source networks behind Router B, and Router B would reverse path forward to the tunnel for source networks behind Router A.

Another option is to run a separate unicast routing protocol with a better administrative distance to provide the RPF. You must make sure that your multicast routers do not advertise the tunnel to your real network. For details, refer to the "Configuring an IP Multicast Static Route" section in this chapter.

If you are using a DVMRP routing table for RPF information within your network, you could configure the **ip dvmrp unicast-routing** interface configuration command on your tunnel interfaces to make the routers reverse path forward correctly over the tunnel.

Verifying the Load Splitting

Load splitting works for both fast switching and process switching, but splitting the traffic among the physical interfaces is performed differently for each case. Fast switching occurs if both the incoming and outgoing interfaces are configured with the **ip mroute-cache** interface configuration command. IP multicast fast switching is enabled by default. Note the following properties of load splitting:

- With process switching, load splitting occurs on a per-packet basis by round robin on the equal-cost links. To verify that load splitting is working, look at the interface statistics using the **show interfaces accounting** EXEC command, and verify that the packet count is about equal for the underlying interfaces that provide the equal-cost paths.
- With fast switching, load splitting occurs on a per-flow basis. A flow is a set of traffic with the same source and destination. Once the cache is populated for the (S, G) pair, that flow is pinned to the physical interface assigned on the cache (the outgoing interface used by the first packet of the flow). If the cached interface goes down, the cache entry for the (S, G) pair is torn down and the flow is automatically switched to a different physical interface.

In the case of fast switching, you can verify that load splitting is occurring by viewing the multicast fast-switched cache by using the **show ip mcache** EXEC command. The flows should be split among the underlying interfaces, as shown in the following example:

```
Router# show ip mcache

IP Multicast Fast-Switching Cache
(100.1.1.6/32, 224.1.1.1), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial1)
(100.1.1.6/32, 224.1.1.2), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial1)
(100.1.1.5/32, 224.1.1.3), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial0)
(100.1.1.5/32, 224.1.1.4), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial0)
```

For an example of load splitting IP multicast traffic across equal-cost paths, see the section “Load Splitting IP Multicast Traffic Across Equal-Cost Paths Example” later in this chapter.

Monitoring and Maintaining IP Multicast Routing Configuration Task List

To monitor and maintain IP multicast routing, perform the optional tasks described in the following sections.

- Clearing Caches, Tables, and Databases (Optional)
- Displaying System and Network Statistics (Optional)
- Using IP Multicast Heartbeat (Optional)

Note For information about Multicast Routing Monitor (MRM) and commands that monitor IP multicast information, see the chapter “Using IP Multicast Tools.”

Clearing Caches, Tables, and Databases

You can remove all contents of a particular cache, table, or database. Clearing a cache, table, or database can become necessary when the contents of the particular structure have become, or are suspected to be, invalid.

To clear IP multicast caches, tables, and databases, use the following commands in EXEC mode as needed:

Command	Purpose
Router# **clear ip cgmp**	Clears all group entries the Catalyst switches have cached.
Router# **clear ip igmp group** [*group-name* | *group-address* | *type number*]	Deletes entries from the IGMP cache.
Router# **clear ip mroute** {***** | *group-name* [*source-name* | *source-address*] | *group-address* [*source-name* | *source-address*]}	Deletes entries from the IP multicast routing table.
Router# **clear ip pim auto-rp** *rp-address*	Clears the Auto-RP cache.
Router# **clear ip rtp header-compression** [*type number*]	Clears RTP header compression structures and statistics.
Router# **clear ip sap** [*group-address* | **"***session-name***"**]	Deletes the SAP cache or a SAP cache entry. The session name is enclosed in quotation marks (**" "**) that the user must enter.

Displaying System and Network Statistics

You can display specific statistics such as the contents of IP routing tables, caches, and databases. Information provided can be used to determine resource utilization and solve network problems. You can also display information about node reachability and discover the routing path the packets of your device are taking through the network.

To display various routing statistics, use the following commands in EXEC mode, as needed:

Command	Purpose
Router# **ping** [*group-name* | *group-address*]	Sends an ICMP echo request message to a multicast group address.
Router# **show frame-relay ip rtp header-compression** [**interface** *type number*]	Displays Frame Relay RTP header compression statistics.
Router# **show ip igmp groups** [*group-name* | *group-address* | *type number*] [**detail**]	Displays the multicast groups that are directly connected to the router and that were learned via IGMP.
Router# **show ip igmp interface** [*type number*]	Displays multicast-related information about an interface.
Router# **show ip mcache** [*group-address* | *group-name*] [*source-address* | *source-name*]	Displays the contents of the IP fast-switching cache.
Router# **show ip mpacket** [*group-address* | *group-name*] [*source-address* | *source-name*] [**detail**]	Displays the contents of the circular cache header buffer.
Router# **show ip mroute** [*group-address* | *group-name*] [*source-address* | *source-name*] [*type number*] [**summary**] [**count**] [**active** *kbps*]	Displays the contents of the IP multicast routing table.
Router# **show ip pim interface** [*type number*] [**df** | **count**] [*rp-address*] [**detail**]	Displays information about interfaces configured for PIM.

Command	Purpose
Router# **show ip pim neighbor** [*type number*]	Lists the PIM neighbors discovered by the router.
Router# **show ip pim rp** [**mapping** | **metric**] [*rp-address*]	Displays the RP routers associated with a sparse mode multicast group.
Router# **show ip pim vc** [*group-address* | *name*] [*type number*]	Displays ATM VC status information for multipoint VCs opened by PIM.
Router# **show ip rpf** {*source-address* | *source-name*} [**metric**]	Displays how the router is doing RPF (that is, from the unicast routing table, DVMRP routing table, or static mroutes). Also displays the unicast routing metric.
Router# **show ip rtp header-compression** [*type number*] [**detail**]	Displays RTP header compression statistics.
Router# **show ip sap** [*group* | **"***session-name***"** | **detail**]	Displays the SAP cache.

Using IP Multicast Heartbeat

The IP multicast heartbeat feature enables you to monitor the delivery of IP multicast packets and to be alerted if the delivery fails to meet certain parameters.

Although you can also use MRM to monitor IP multicast, you can perform the following tasks with IP multicast heartbeat that you cannot do with MRM:

- Generate an SNMP trap
- Monitor a production multicast stream

When IP multicast heartbeat is enabled, the router monitors IP multicast packets destined for a particular multicast group at a particular interval. If the number of packets observed is less than a configured minimum amount, the router sends an Simple Network Management Protocol (SNMP) trap to a specified network management station to indicate a loss of heartbeat exception.

To configure IP multicast heartbeat, use the following commands in global configuration mode:

	Command	Purpose
Step 1	Router(config)# **ip multicast-routing**	Enables IP multicast routing.
Step 2	Router(config)# **snmp-server host** *host* **traps** *community-string*	Specifies the recipient of an SNMP notification operation.
Step 3	Router(config)# **snmp-server enable traps ipmulticast**	Enables the router to send IP multicast traps.
Step 4	Router(config)# **ip multicast heartbeat** *group-address minimum-number window-size interval*	Enables the monitoring of the IP multicast packet delivery.

See the "IP Multicast Heartbeat Example" section later in this chapter for an example of how to configure IP multicast heartbeat.

For more information on the information contained in IP multicast SNMP notifications, refer to the *Cisco IOS Configuration Fundamentals Command Reference*.

IP Multicast Configuration Examples

This section provides the following IP multicast routing configuration examples:

- PIM Dense Mode Example
- PIM Sparse Mode Example
- PIM Dense Mode State Refresh Example
- Functional Address for IP Multicast over Token Ring LAN Example
- PIM Version 2 Examples
- RTP Header Compression Examples
- IP Multicast over ATM Point-to-Multipoint VC Example
- Administratively Scoped Boundary Example
- IP Multicast Helper Example
- Stub IP Multicast Example
- Load Splitting IP Multicast Traffic Across Equal-Cost Paths Example
- IP Multicast Heartbeat Example

PIM Dense Mode Example

The following example configures PIM dense mode on Fast Ethernet interface 0/1 of the router:

```
ip multicast-routing

interface FastEthernet0/1
ip address 172.16.8.1 255.255.255.0
 ip pim dense-mode
```

PIM Sparse Mode Example

The following example configures the Cisco IOS software to operate in PIM sparse mode. The RP router is the router whose address is 10.8.0.20.

```
ip multicast-routing
 ip pim rp-address 10.8.0.20 1
interface ethernet 1
 ip pim sparse-mode
```

PIM Dense Mode State Refresh Example

The following example shows a PIM router that is originating, processing, and forwarding PIM Dense Mode State Refresh control messages on Fast Ethernet interface 0/1 every 60 seconds:

```
ip multicast-routing

interface FastEthernet0/1
 ip address 172.16.8.1 255.255.255.0
 ip pim state-refresh origination-interval 60
 ip pim dense-mode
```

The following example shows a PIM router that is processing and forwarding PIM Dense Mode State Refresh control messages and not originating messages on Fast Ethernet interface 1/1:

```
ip multicast-routing

interface FastEthernet1/1
 ip address 172.16.7.3 255.255.255.0
 ip pim dense-mode
```

Functional Address for IP Multicast over Token Ring LAN Example

In the following example, any IP multicast packets going out Token Ring interface 0 are mapped to MAC address 0xc000.0004.0000:

```
interface token 0
 ip address 1.1.1.1 255.255.255.0
 ip pim dense-mode
 ip multicast use-functional
```

PIM Version 2 Examples

This section provides examples in the following sections:

- BSR Configuration Example
- Border Router Configuration Example
- RFC 2362 Interoperable Candidate RP Example

BSR Configuration Example

The following example is a configuration for a candidate BSR, which also happens to be a candidate RP:

```
version 11.3
!
ip multicast-routing
!
interface Ethernet0
 ip address 171.69.62.35 255.255.255.240
!
interface Ethernet1
 ip address 172.21.24.18 255.255.255.248
 ip pim sparse-dense-mode
!
interface Ethernet2
 ip address 172.21.24.12 255.255.255.248
```

```
 ip pim sparse-dense-mode
!
router ospf 1
 network 172.21.24.8 0.0.0.7 area 1
 network 172.21.24.16 0.0.0.7 area 1
!
ip pim bsr-candidate Ethernet2 30 10
ip pim rp-candidate Ethernet2 group-list 5
access-list 5 permit 239.255.2.0 0.0.0.255
```

Border Router Configuration Example

The following example shows how to configure a border router in a PIM-SM domain on Ethernet interface 1. The **ip pim bsr-border** interface configuration command will prevent BSR messages from being sent or received through the interface. The **ip multicast boundary** interface configuration command and access list 1 will prevent Auto-RP messages from being sent or received through the interface.

```
version 12.0
!
ip multicast-routing
!
interface Ethernet0
ip address 171.69.62.35 255.255.255.240

!
interface Ethernet1
ip address 172.21.24.18 255.255.255.248
ip pim sparse-dense-mode
ip pim bsr-border
ip multicast boundary 1
!
! Access list to deny Auto-RP (224.0.1.39, 224.0.1.40) and
! all administrately scoped multicast groups (239.X.X.X)
access-list 1 deny 239.0.0.0 0.255.255.255
access-list 1 deny 224.0.1.39
access-list 1 deny 224.0.1.40
access-list 1 permit 224.0.0.0 15.255.255.255
```

RFC 2362 Interoperable Candidate RP Example

When Cisco and non-Cisco routers are being operated in a single PIM domain with PIM Version 2 BSR, care must be taken when configuring candidate RPs because the Cisco IOS implementation of the BSR RP selection is not fully compatible with RFC 2362.

RFC 2362 specifies that the BSR RP be selected as follows (RFC 2362, 3.7):

Step 1 Select the candidate RP with the highest priority (lowest configured priority value).

Step 2 If there is a tie in the priority level, select the candidate RP with the highest hash function value.

Step 3 If there is a tie in the hash function value, select the candidate RP with the highest IP address.

Cisco routers always select the candidate RP based on the longest match on the announced group address prefix before selecting an RP based on priority, hash function, or IP address.

Inconsistent candidate RP selection between Cisco and non-Cisco RFC 2362-compliant routers in the same domain if multiple candidate RPs with partially overlapping group address ranges are configured can occur. Inconsistent candidate RP selection can lead to disconnectivity between sources and receivers in the PIM domain. A source may register with one candidate RP and a receiver may connect to a different candidate RP even though it is in the same group.

The following example shows a configuration that can cause inconsistent RP selection between a Cisco and a non-Cisco router in a single PIM domain with PIM Version 2 BSR:

```
access-list 10 permit 224.0.0.0  7.255.255.255
ip pim rp-candidate ethernet1 group-list 10 priority 20

access-list 20 permit 224.0.0.0 15.255.255.255
ip pim rp-candidate ethernet2 group-list 20 priority 10
```

In this example, a candidate RP on Ethernet interface 1 announces a longer group prefix of 224.0.0.0/5 with a lower priority of 20. The candidate RP on Ethernet interface 2 announces a shorter group prefix of 224.0.0.0/4 with a higher priority of 10. For all groups that match both ranges a Cisco router will always select the candidate RP on Ethernet interface 1 because it has the longer announced group prefix. A non-Cisco fully RFC 2362-compliant router will always select the candidate RP on Ethernet interface 2 because it is configured with a higher priority.

To avoid this interoperability issue, do not configure different candidate RPs to announce partially overlapping group address prefixes. Configure any group prefixes that you want to announce from more than one candidate RP with the same group prefix length.

The following example shows how to configure the previous example so that there is no incompatibility between a Cisco router and a non-Cisco router in a single PIM domain with PIM Version 2 BSR:

```
access-list 10 permit 224.0.0.0  7.255.255.255
ip pim rp-candidate ethernet1 group-list 10 priority 20

access-list 20 permit 224.0.0.0  7.255.255.255
access-list 20 permit 232.0.0.0  7.255.255.255
ip pim rp-candidate ethernet2 group-list 20 priority 10
```

In this configuration the candidate RP on Ethernet interface 2 announces group address 224.0.0.0/5 and 232.0.0.0/5 which equal 224.0.0.0/4, but gives the interface the same group prefix length (5) as the candidate RP on Ethernet 1. As a result, both a Cisco router and an RFC 2362-compliant router will select the RP Ethernet interface 2.

RTP Header Compression Examples

The following example enables RTP header compression for a serial, ISDN, or asynchronous interface. For ISDN, you also need a broadcast dialer map.

```
interface serial 0 :or interface bri 0
 ip rtp header-compression
 encapsulation ppp
 ip rtp compression-connections 25
```

The following Frame Relay encapsulation example shows how to enable RTP header compression on the specified map.

```
interface serial 0
 ip address 1.0.0.2 255.0.0.0
 encapsulation frame-relay
```

```
 no keepalive
 clockrate 64000
 frame-relay map ip 1.0.0.1 17 broadcast rtp header-compression connections 64
 frame-relay ip rtp header-compression
 frame-relay ip rtp compression-connections 32
```

Express RTP Header Compression with PPP Encapsulation Example

The following example shows how to configure a Cisco 7200 router with the Express RTP Header Compression and PPP encapsulation:

```
version 12.0
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname abc-1234
!
enable password lab
!
ip subnet-zero
no ip domain-lookup
ip host xy-tftp 172.17.249.2
clock timezone GMT 1
clock summer-time GMT recurring
ip routing
ip cef
!
!
controller E1 3/0
!
controller E1 3/1
!
!
interface Ethernet2/0
 ip address 9.1.72.104 255.255.255.0
 no ip directed-broadcast
 no ip route-cache
!
interface Ethernet2/1
 ip address 15.1.1.1 255.255.255.0
 no ip directed-broadcast
 ip route-cache
 no shutdown
!
interface Serial4/0
 ip address 15.3.0.1 255.255.255.0
 no ip directed-broadcast
 encapsulation ppp
 ip rtp header-compression iphc-format
 ip tcp header-compression iphc-format
 ip rtp compression-connections 1000
 no ip mroute-cache
 clockrate 2015232
 bandwidth 2000
 ip route-cache
 no shutdown
!
interface Serial4/1
 no ip address
 no ip directed-broadcast
```

```
 no ip route-cache
 shutdown
 clockrate 2015232
!
ip default-gateway 9.1.72.1
ip classless
ip route 0.0.0.0 0.0.0.0 9.1.72.1
!
router igrp 1
 network 15.0.0.0
!
line con 0
 exec-timeout 0 0
 transport input none
line aux 0
line vty 0 4
 password lab
 login
!
no scheduler max-task-time
end
```

Express RTP Header Compression with Frame Relay Encapsulation Example

The following example shows how to configure a Cisco 7200 router with the Express RTP Header Compression feature and Frame Relay encapsulation:

```
version 12.0
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname ed1-72a
!
enable password lab
!
ip subnet-zero
no ip domain-lookup
ip host xy-tftp 172.17.249.2
clock timezone GMT 1
clock summer-time GMT recurring
ip routing
ip cef
!
!
controller E1 3/0
!
controller E1 3/1
!
interface Ethernet2/0
 ip address 9.1.72.104 255.255.255.0
 no ip directed-broadcast
 no ip route-cache
 no ip mroute-cache
 ntp broadcast client
!
interface Ethernet2/1
 ip address 15.1.1.1 255.255.255.0
 no ip directed-broadcast
 ip route-cache
 no ip mroute-cache
 no shutdown
```

```
!
interface Serial4/0
 ip address 15.3.0.1 255.255.255.0
 encapsulation frame-relay
 frame-relay map ip 15.3.0.2 100 broadcast compress connections 16
 frame-relay ip rtp header-compression
 frame-relay ip tcp header-compression
 frame-relay ip rtp compression-connections 32
no ip mroute-cache
 ip route-cache
 bandwidth 2000
 no keepalive
 no shutdown
!
interface Serial4/1
 no ip address
 no ip directed-broadcast
 no ip route-cache
 no ip mroute-cache
 shutdown
 no fair-queue
!
router igrp 1
 network 15.0.0.0
!
!
ip default-gateway 9.1.72.1
ip classless
!
map-class frame-relay frag
 frame-relay cir 64000
 frame-relay bc 1000
 frame-relay be 0
 frame-relay mincir 64000
 frame-relay adaptive-shaping becn
 frame-relay fair-queue
 frame-relay fragment 70
!
dialer-list 1 protocol ip permit
dialer-list 1 protocol ipx permit
!
line con 0
 exec-timeout 0 0
 transport input none
line aux 0
line vty 0 4
 password lab
 login
!
!
ntp clock-period 17179866
end
```

IP Multicast over ATM Point-to-Multipoint VC Example

The following example shows how to enable IP multicast over ATM point-to-multipoint VCs:

```
interface ATM2/0
 ip address 171.69.214.43 255.255.255.248
 ip pim sparse-mode
 ip pim multipoint-signalling
 ip ospf network broadcast
```

```
 atm nsap-address 47.0091810000000410B0A1981.333333333333.00
 atm pvc 1 0 5 qsaal
 atm pvc 2 0 16 ilmi
 atm multipoint-signalling
 map-group mpvc
router ospf 9
 network 171.69.214.0 0.0.0.255 area 0
!
ip classless
 ip pim rp-address 171.69.10.13 98
!
map-list mpvc
 ip 171.69.214.41 atm-nsap 47.0091810000000410B0A1981.111111111111.00 broadcast
 ip 171.69.214.42 atm-nsap 47.0091810000000410B0A1981.222222222222.00 broadcast
 ip 171.69.214.43 atm-nsap 47.0091810000000410B0A1981.333333333333.00 broadcast
```

Administratively Scoped Boundary Example

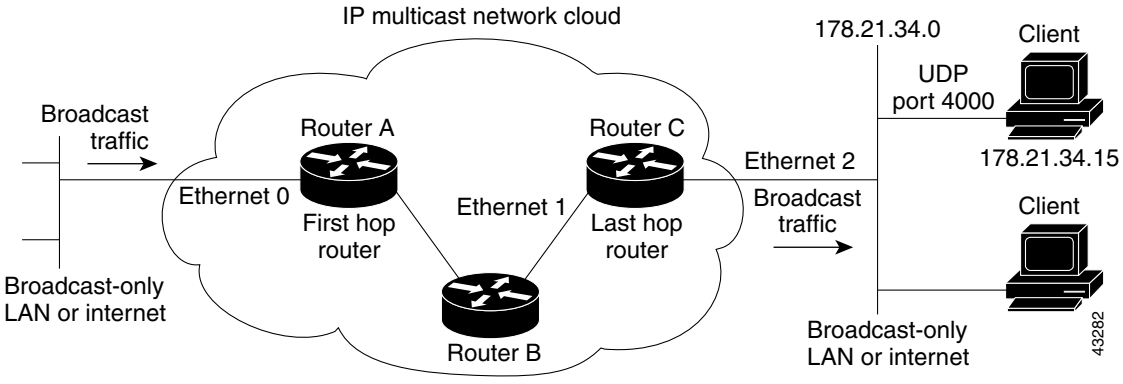
The following example shows how to set up a boundary for all administratively scoped addresses:

```
access-list 1 deny 239.0.0.0 0.255.255.255
access-list 1 permit 224.0.0.0 15.255.255.255
interface ethernet 0
 ip multicast boundary 1
```

IP Multicast Helper Example

Figure 73 illustrates how a helper address on two routers converts from broadcast to multicast and back to broadcast.

Figure 73 IP Multicast Helper Scenario



The configuration on the first hop router converts a broadcast stream arriving at incoming Ethernet interface 0 destined for UDP port 4000 to a multicast stream. The access list denies other traffic from being forwarded into the multicast cloud. The traffic is sent to group address 224.5.5.5. Because fast switching does not perform such a conversion, the **ip forward-protocol** global configuration command causes the proper process level to perform the conversion.

The second configuration on the last hop router converts the multicast stream at Ethernet interface 2 back to broadcast. Again, all multicast traffic emerging from the multicast cloud should not be converted to broadcast, only the traffic destined for UDP port 4000.

The configurations for Router A and Router C are as follows:

Router A—First Hop Router Configuration

```
interface ethernet 0
 ip directed-broadcast
 ip multicast helper-map broadcast 224.5.5.5 120
 ip pim dense-mode
!
access-list 120 permit udp any any eq 4000
access-list 120 deny udp any any
 ip forward-protocol udp 4000
```

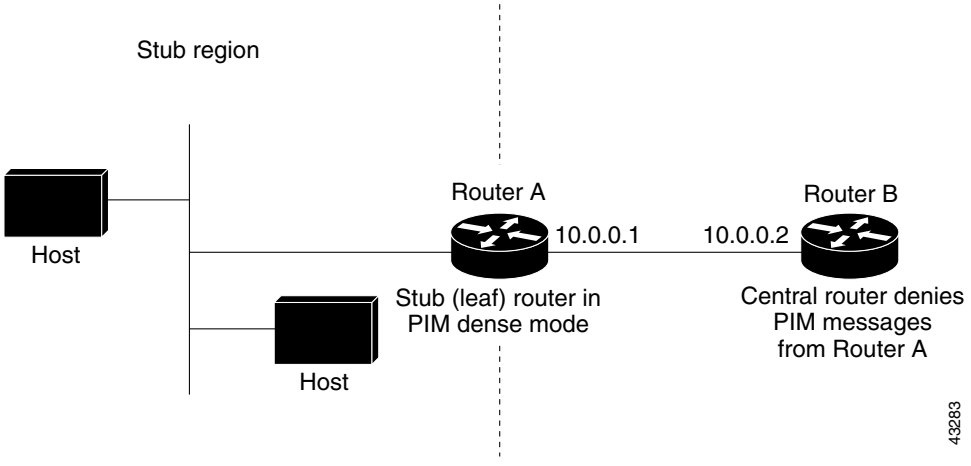
Router C—Last Hop Router Configuration

```
interface ethernet 2
 ip directed-broadcast
 ip multicast helper-map 224.5.5.5 178.21.34.255 135
 ip pim dense-mode
!
access-list 135 permit udp any any eq 4000
access-list 135 deny udp any any
 ip forward-protocol udp 4000
```

Stub IP Multicast Example

The following example shows how to configure stub IP multicast routing for Router A. Figure 74 illustrates the example. On stub Router A, the interfaces must be configured for PIM dense mode. The helper address is configured on the host interfaces. Central site Router B can be configured for either PIM sparse mode or dense mode. The access list on Router B denies any PIM messages from Router A.

Figure 74 Stub IP Multicast Routing Scenario



The configurations for Router A and Router B are as follows:

Router A Configuration

```
ip multicast-routing
 ip pim dense-mode
 ip igmp helper-address 10.0.0.2
```

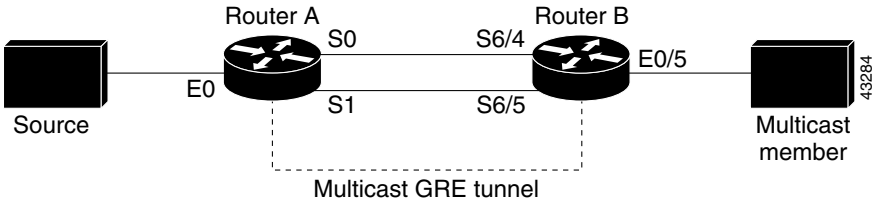
Router B Configuration

```
ip multicast-routing
 ip pim dense-mode : or ip pim sparse-mode
 ip pim neighbor-filter 1
access-list 1 deny 10.0.0.1
```

Load Splitting IP Multicast Traffic Across Equal-Cost Paths Example

The following example shows how to configure a GRE tunnel between Router A and Router B. Figure 75 illustrates the tunneled topology. The configurations follow the figure.

Figure 75 IP Multicast Load Splitting Across Equal-Cost Paths



Router A Configuration

```
interface tunnel 0
 ip unnumbered Ethernet0
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
 tunnel source 100.1.1.1
 tunnel destination 100.1.5.3
!
interface ethernet 0
 ip address 100.1.1.1 255.255.255.0
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
!
interface Serial0
 ip address 100.1.2.1 255.255.255.0
 bandwidth 125
 clock rate 125000
!
interface Serial1
 ip address 100.1.3.1 255.255.255.0
 bandwidth 125
```

Router B Configuration

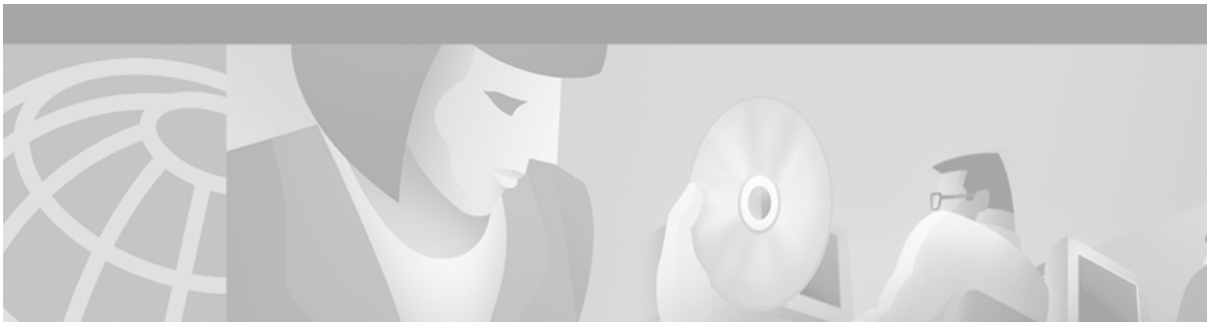
```
interface tunnel 0
 ip unnumbered ethernet 0/5
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
 tunnel source 100.1.5.3
 tunnel destination 100.1.1.1
!
interface ethernet 0/5
 ip address 100.1.5.3 255.255.255.0
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
!
interface serial 6/4
 ip address 100.1.2.3 255.255.255.0
 bandwidth 125
!
interface Serial6/5
```

```
 ip address 100.1.3.3 255.255.255.0
 bandwidth 125
 clock rate 125000
```

IP Multicast Heartbeat Example

The following example shows how to monitor IP multicast packets forwarded through this router to group address 244.1.1.1. If no packet for this group is received in a 10-second interval, an SNMP trap will be sent to the SNMP management station with the IP address of 224.1.0.1.

```
!
ip multicast-routing
!
snmp-server host 224.1.0.1 traps public
snmp-server enable traps ipmulticast
ip multicast heartbeat ethernet0 224.1.1.1 1 1 10
```



Configuring Source Specific Multicast

This chapter describes how to configure Source Specific Multicast (SSM). For a complete description of the SSM commands in this chapter, refer to the "IP Multicast Routing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

The Source Specific Multicast feature is an extension of IP multicast where datagram traffic is forwarded to receivers from only those multicast sources to which the receivers have explicitly joined. For multicast groups configured for SSM, only source-specific multicast distribution trees (no shared trees) are created.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

SSM Components Overview

SSM is a datagram delivery model that best supports one-to-many applications, also known as broadcast applications. SSM is a core networking technology for the Cisco implementation of IP multicast solutions targeted for audio and video broadcast application environments. This chapter discusses the following Cisco IOS components that support the implementation of SSM:

- Protocol Independent Multicast source specific mode (PIM-SSM)
- Internet Group Management Protocol Version 3 (IGMPv3)
- Internet Group Management Protocol Version 3 lite (IGMP v3lite)
- URL Rendezvous Directory (URD)

PIM-SSM is the routing protocol that supports the implementation of SSM and is derived from PIM sparse mode (PIM-SM). IGMP is the Internet Engineering Task Force (IETF) standards track protocol used for hosts to signal multicast group membership to routers. Version 3 of this protocol supports source filtering, which is required for SSM. To run SSM with IGMPv3, SSM must be supported in the Cisco IOS router, the host where the application is running, and the application itself. IGMP v3lite and URD are two Cisco-developed transition solutions that enable the immediate development and deployment of SSM services, without the need to wait for the availability of full IGMPv3 support in host operating systems and SSM receiver applications. IGMP v3lite is a solution for application developers that allows immediate development of SSM receiver applications switching to IGMPv3 as soon as it becomes available. URD is a solution for content providers and content aggregators that enables them to

deploy receiver applications that are not yet SSM enabled (through support for IGMPv3). IGMPv3, IGMP v3lite, and URD interoperate with each other, so that both IGMP v3lite and URD can easily be used as transitional solutions toward full IGMPv3 support in hosts.

How SSM Differs from Internet Standard Multicast

The current IP multicast infrastructure in the Internet and many enterprise intranets is based on the PIM-SM protocol and Multicast Source Discovery Protocol (MSDP). These protocols have proved to be reliable, extensive, and efficient. However, they are bound to the complexity and functionality limitations of the Internet Standard Multicast (ISM) service model. For example, with ISM, the network must maintain knowledge about which hosts in the network are actively sending multicast traffic. With SSM, this information is provided by receivers through the source addresses relayed to the last hop routers by IGMPv3, IGMP v3lite, or URD. SSM is an incremental response to the issues associated with ISM and is intended to coexist in the network with the protocols developed for ISM. In general, SSM provides a more advantageous IP multicast service for applications that utilize SSM.

ISM service is described in RFC 1112. This service consists of the delivery of IP datagrams from any source to a group of receivers called the multicast host group. The datagram traffic for the multicast host group consists of datagrams with an arbitrary IP unicast source address S and the multicast group address G as the IP destination address. Systems will receive this traffic by becoming members of the host group. Membership to a host group simply requires signalling the host group through IGMP Version 1, 2, or 3.

In SSM, delivery of datagrams is based on (S, G) channels. Traffic for one (S, G) channel consists of datagrams with an IP unicast source address S and the multicast group address G as the IP destination address. Systems will receive this traffic by becoming members of the (S, G) channel. In both SSM and ISM, no signalling is required to become a source. However, in SSM, receivers must subscribe or unsubscribe to (S, G) channels to receive or not receive traffic from specific sources. In other words, receivers can receive traffic only from (S, G) channels to which they are subscribed, whereas in ISM, receivers need not know the IP addresses of sources from which they receive their traffic. The proposed standard approach for channel subscription signalling utilizes IGMP INCLUDE mode membership reports, which are supported only in IGMP Version 3.

SSM IP Address Range

SSM can coexist with the ISM service by applying the SSM delivery model to a configured subset of the IP multicast group address range. The Internet Assigned Numbers Authority (IANA) has reserved the address range 232.0.0.0 through 232.255.255.255 for SSM applications and protocols. Cisco IOS software allows SSM configuration for an arbitrary subset of the IP multicast address range 224.0.0.0 through 239.255.255.255. When an SSM range is defined, existing IP multicast receiver applications will not receive any traffic when they try to use addresses in the SSM range (unless the application is modified to use explicit (S, G) channel subscription or is SSM enabled through URD).

SSM Operations

An established network, in which IP multicast service is based on PIM-SM, can support SSM services. SSM can also be deployed alone in a network without the full range of protocols that are required for interdomain PIM-SM (for example, MSDP, Auto-RP, or bootstrap router [BSR]) if only SSM service is needed.

If SSM is deployed in a network already configured for PIM-SM (Cisco IOS Release 12.0 or later releases is recommended), then only the last hop routers must be upgraded to a Cisco IOS software image that supports SSM. Routers that are not directly connected to receivers do not have to upgrade to a Cisco IOS software image that supports SSM. In general, these nonlast hop routers must only run PIM-SM in the SSM range, and may need additional access control configuration to suppress MSDP signalling, registering, or PIM-SM shared tree operations from occurring within the SSM range.

The SSM mode of operation is enabled by configuring the SSM range through the **ip pim ssm** global configuration command. This configuration has the following effects:

- For groups within the SSM range, (S, G) channel subscriptions are accepted through IGMPv3 INCLUDE mode membership reports, IGMP v3lite, or URD (each of these methods must be configured on a per-interface basis). IGMP v3lite and URD (S, G) channel subscriptions are ignored for groups outside the SSM range.

  Both IGMP v3lite and URD are based on utilizing existing application IGMP group membership and extending it with their respective (S, G) channel subscription mechanism, which is ignored by Cisco IOS software outside the SSM range of addresses. Within the SSM range, IGMP Version 1 (IGMPv1) or Version 2 (IGMPv2) group membership reports or IGMPv3 EXCLUDE mode membership reports are acted upon only in conjunction with an (S, G) specific membership report from URD or IGMP v3lite.
- PIM operations within the SSM range of addresses change to PIM-SSM, a mode derived from PIM-SM. In this mode, only PIM (S, G) join and prune messages are generated by the router, and no (S, G) rendezvous point tree (RPT) or (*, G) RPT messages are generated. Incoming messages related to RPT operations are ignored or rejected and incoming PIM register messages are immediately answered with register-stop messages. PIM-SSM is backward compatible with PIM-SM, unless a router is a last hop router. Therefore, routers that are not last hop routers can run PIM-SM for SSM groups (for example, if they do not yet support SSM).
- No MSDP Source-Active (SA) messages within the SSM range will be accepted, generated, or forwarded.

IGMPv3 Host Signalling

IGMPv3 is the third version of the IETF standards track protocol in which hosts signal membership to last hop routers of multicast groups. IGMPv3 introduces the ability for hosts to signal group membership with filtering capabilities with respect to sources. A host can either signal that it wants to receive traffic from all sources sending to a group except for some specific sources (called EXCLUDE mode), or that it wants to receive traffic only from some specific sources sending to the group (called INCLUDE mode).

IGMPv3 can operate with both ISM and SSM. In ISM, both EXCLUDE and INCLUDE mode reports are applicable. In SSM, only INCLUDE mode reports are accepted by the last hop router. EXCLUDE mode reports are ignored.

For more information on IGMPv3, see the “Configuring IP Multicast Routing” chapter in this document.

IGMP v3lite Host Signalling

IGMP v3lite is a Cisco-developed transitional solution for application developers to immediately start programming SSM applications. It allows you to write and run SSM applications on hosts that do not yet support IGMPv3 in their operating system kernel.

Applications must be compiled with the Host Side IGMP Library (HSIL) for IGMP v3lite. This software provides applications with a subset of the IGMPv3 applications programming interface (API) that is required to write SSM applications. HSIL was developed for Cisco by Talarian and is available from the following web page:

http://www.talarianmulticast.com/cgi-bin/igmpdownld

One part of the HSIL is a client library linked to the SSM application. It provides the SSM subset of the IGMPv3 API to the SSM application. If possible, the library checks whether the operating system kernel supports IGMPv3. If it does, then the API calls simply are passed through to the kernel. If the kernel does not support IGMPv3, then the library uses the IGMP v3lite mechanism.

When using the IGMP v3lite mechanism, the library tells the operating system kernel to join to the whole multicast group, because joining to the whole group is the only method for the application to receive traffic for that multicast group (if the operating system kernel only supports IGMPv1 or IGMPv2). In addition, the library signals the (S, G) channel subscriptions to an IGMP v3lite server process, which is also part of the HSIL. A server process is needed because multiple SSM applications may be on the same host. This server process will then send IGMP v3lite-specific (S, G) channel subscriptions to the last hop Cisco IOS router, which needs to be enabled for IGMP v3lite. This Cisco IOS router will then "see" both the IGMPv1 or IGMPv2 group membership report from the operating system kernel and the (S, G) channel subscription from the HSIL daemon. If the router sees both of these messages, it will interpret them as an SSM (S, G) channel subscription and join to the channel through PIM-SSM. We recommend referring to the documentation accompanying the HSIL software for further information on how to utilize IGMP v3lite with your application.

IGMP v3lite is supported by Cisco only through the API provided by the HSIL, not as a function of the router independent of the HSIL. By default, IGMP v3lite is disabled. When IGMP v3lite is configured through the **ip igmp v3lite** interface configuration command on an interface, it will be active only for IP multicast addresses in the SSM range.

URD Host Signalling

URD is a Cisco-developed transitional solution that allows existing IP multicast receiver applications to be used with SSM without the need to modify the application and change or add any software on the receiver host running the application. URD is a content provider solution in which the receiver applications can be started or controlled through a web browser.

URD operates by passing a special URL from the web browser to the last hop router. This URL is called a URD intercept URL. A URD intercept URL is encoded with the (S, G) channel subscription and has a format that allows the last hop router to easily intercept it.

As soon as the last hop router intercepts both an (S, G) channel subscription encoded in a URD intercept URL and sees an IGMP group membership report for the same multicast group from the receiver application, the last hop router will use PIM-SSM to join toward the (S, G) channel as long as the application maintains the membership for the multicast group G. The URD intercept URL is thus only needed initially to provide the last hop router with the address of the sources to join to.

A URD intercept URL has the following syntax:

`http://`*`webserver`*`:465/`*`path`*`?group=`*`group`*`&source=`*`source1`*`&...source=`*`sourceN`*`&`

The *webserver* string is the name or IP address to which the URL is targeted. This target need not be the IP address of an existing web server, except for situations where the web server wants to recognize that the last hop router failed to support the URD mechanism. The number 465 indicates the URD port. Port 465 is reserved for Cisco by the IANA for the URD mechanism so that no other applications can use this port.

When the browser of a host encounters a URD intercept URL, it will try to open a TCP connection to the web server on port 465. If the last hop router is enabled for URD on the interface where the router receives the TCP packets from the host, it will intercept all packets for TCP connections destined to port 465 independent of the actual destination address of the TCP connection (independent of the address of the web server). Once intercepted, the last hop router will "speak" a very simple subset of HTTP on this TCP connection, emulating a web server. The only HTTP request that the last hop router will understand and reply to is the following GET request:

```
GET argument HTTP/1.0
argument = /path?group=group&source=source1&...source=sourceN&
```

When it receives a GET command, the router tries to parse the argument according to this syntax to derive one or more (S, G) channel memberships. The *path* string of the argument is anything up to, but not including, the first question mark, and is ignored. The *group* and *source1* through *sourceN* strings are the IP addresses or fully qualified domain names of the channels for which this argument is a subscription request. If the argument matches the syntax shown, the router interprets the argument to be subscriptions for the channels (*source1*, *group*) through (*sourceN*, *group*).

The router will accept the channel subscriptions if the following conditions are met:

- The IP address of the multicast group is within the SSM range.
- The IP address of the host that originated the TCP connection is directly connected to the router.

If the channel subscription is accepted, the router will respond to the TCP connection with the following HTML page format:

```
HTTP/1.1 200 OK
Server:cisco IOS
Content-Type:text/html
<html>
<body>
Retrieved URL string successfully
</body>
</html>
```

If an error condition occurs, the <body> part of the returned HTML page will carry an appropriate error message. The HTML page is a by-product of the URD mechanism. This returned text may, depending on how the web pages carrying a URD intercept URL are designed, be displayed to the user or be sized so that the actual returned HTML page is invisible.

The primary effect of the URD mechanism is that the router will remember received channel subscriptions and will match them against IGMP group membership reports received by the host. The router will "remember" a URD (S, G) channel subscription for up to 3 minutes without a matching IGMP group membership report. As soon as the router sees that it has received both an IGMP group membership report for a multicast group G and a URD (S, G) channel subscription for the same group G, it will join the (S, G) channel through PIM-SSM. The router will then continue to join to the (S, G) channel based only on the presence of a continuing IGMP membership from the host. Thus, one initial URD channel subscription is all that is needed to be added through a web page to enable SSM with URD.

If the last hop router from the receiver host is not enabled for URD, then it will not intercept the HTTP connection toward the web server on port 465. This situation will result in a TCP connection to port 465 on the web server. If no further provisions on the web server are taken, then the user may see a notice (for example, "Connection refused") in the area of the web page reserved for displaying the URD intercept URL (if the web page was designed to show this output). It is also possible to let the web server "listen" to requests on port 465 and install a Common Gateway Interface (CGI) script that would allow the web server to know if a channel subscription failed (for example, to subsequently return more complex error descriptions to the user).

Because the router returns a Content-Type of text and HTML, the best way to include the URD intercept URL into a web page is to use a frame. By defining the size of the frame, you can also hide the URD intercept URL on the displayed page.

By default, URD is disabled on all interfaces. When URD is configured through the **ip urd** interface configuration command on an interface, it will be active only for IP multicast addresses in the SSM range.

Benefits

IP Multicast Address Management Not Required

In the ISM service, applications must acquire a unique IP multicast group address because traffic distribution is based only on the IP multicast group address used. If two applications with different sources and receivers use the same IP multicast group address, then receivers of both applications will receive traffic from the senders of both applications. Even though the receivers, if programmed appropriately, can filter out the unwanted traffic, this situation would cause generally unacceptable levels of unwanted traffic.

Allocating a unique IP multicast group address for an application is still a problem. Most short-lived applications use mechanisms like Session Description Protocol (SDP) and Session Announcement Protocol (SAP) to get a random address, a solution that does not work well with a rising number of applications in the Internet. The best current solution for long-lived applications is described in RFC 2770, but this solution suffers from the restriction that each autonomous system is limited to only 255 usable IP multicast addresses.

In SSM, traffic from each source is forwarded between routers in the network independent of traffic from other sources. Thus different sources can reuse multicast group addresses in the SSM range.

Denial of Service Attacks from Unwanted Sources Inhibited

In SSM, multicast traffic from each individual source will be transported across the network only if it was requested (through IGMPv3, IGMP v3lite, or URD memberships) from a receiver. In contrast, ISM forwards traffic from any active source sending to a multicast group to all receivers requesting that multicast group. In Internet broadcast applications, this ISM behavior is highly undesirable because it allows unwanted sources to easily disturb the actual Internet broadcast source by simply sending traffic to the same multicast group. This situation depletes bandwidth at the receiver side with unwanted traffic and thus disrupts the undisturbed reception of the Internet broadcast. In SSM, this type of denial of service (DoS) attack cannot be made by simply sending traffic to a multicast group.

Easy to Install and Manage

SSM is easy to install and provision in a network because it does not require the network to maintain which active sources are sending to multicast groups. This requirement exists in ISM (with IGMPv1, IGMPv2, or IGMPv3).

The current standard solutions for ISM service are PIM-SM and MSDP. Rendezvous point (RP) management in PIM-SM (including the necessity for Auto-RP or BSR) and MSDP is required only for the network to learn about active sources. This management is not necessary in SSM, which makes SSM easier than ISM to install and manage, and therefore easier than ISM to operationally scale in

deployment. Another factor that contributes to the ease of installation of SSM is the fact that it can leverage preexisting PIM-SM networks and requires only the upgrade of last hop routers to support IGMPv3, IGMP v3lite, or URD.

Ideal for Internet Broadcast Applications

The three benefits previously described make SSM ideal for Internet broadcast-style applications for the following reasons:

- The ability to provide Internet broadcast services through SSM without the need for unique IP multicast addresses allows content providers to easily offer their service (IP multicast address allocation has been a serious problem for content providers in the past).
- The prevention against DoS attacks is an important factor for Internet broadcast services because, with their exposure to a large number of receivers, they are the most common targets for such attacks.
- The ease of installation and operation of SSM makes it ideal for network operators, especially in those cases where content needs to be forwarded between multiple independent PIM domains (because there is no need to manage MSDP for SSM between PIM domains).

Restrictions

Legacy Applications Within the SSM Range Restrictions

Existing applications in a network predating SSM will not work within the SSM range unless they are modified to support (S, G) channel subscriptions or are enabled through URD. Therefore, enabling SSM in a network may cause problems for existing applications if they use addresses within the designated SSM range.

IGMP v3lite and URD Require a Cisco IOS Last Hop Router

SSM and IGMPv3 are solutions that are being standardized in the IETF. However, IGMP v3lite and URD are Cisco-developed solutions. For IGMP v3lite and URD to operate properly for a host, the last hop router toward that host must be a Cisco IOS router with IGMP v3lite or URD enabled.

Note This limitation does not apply to an application using the HSIL if the host has kernel support for IGMPv3, because then the HSIL will use the kernel IGMPv3 instead of IGMP v3lite.

Address Management Restrictions

Address management is still necessary to some degree when SSM is used with Layer 2 switching mechanisms. Cisco Group Management Protocol (CGMP), IGMP snooping, or Router-Port Group Management Protocol (RGMP) currently support only group-specific filtering, not (S, G) channel-specific filtering. If different receivers in a switched network request different (S, G) channels sharing the same group, then they will not benefit from these existing mechanisms. Instead, both

receivers will receive all (S, G) channel traffic (and filter out the unwanted traffic on input). Because of the ability of SSM to reuse the group addresses in the SSM range for many independent applications, this situation can lead to less than expected traffic filtering in a switched network. For this reason it is important to follow the recommendations set forth in the IETF drafts for SSM to use random IP addresses out of the SSM range for an application to minimize the chance for reuse of a single address within the SSM range between different applications. For example, an application service providing a set of television channels should, even with SSM, use a different group for each television (S, G) channel. This setup will guarantee that multiple receivers to different channels within the same application service will never experience traffic aliasing in networks that include Layer 2 switches.

IGMP Snooping and CGMP Limitations

IGMPv3 uses new membership report messages that may not be recognized correctly by older IGMP Snooping switches, in which case hosts will not properly receive traffic. This situation is not an issue if URD or IGMP v3lite is used with hosts where the operating system is not upgraded for IGMPv3, because IGMP v3lite and URD rely only on IGMPv1 or IGMPv2 membership reports. For more information about switching issues related to IGMP (especially with CGMP), refer to the "Configuring IGMP Version 3" section of the "Configuring IP Multicast Routing" chapter in this document.

URD Intercept URL Limitations

A URD intercept URL string must be fewer than 256 bytes in length, starting from the */path* argument. In the HTTP/TCP connection, this string must also be contained within a single TCP/IP packet. For example, for a 256-byte string, a link maximum transmission unit (MTU) of 128 bytes between the host and intercepting router would cause incorrect operation of URD.

State Maintenance Limitations

In PIM-SSM, the last hop router will continue to periodically send (S, G) join messages if appropriate (S, G) subscriptions are on the interfaces. Therefore, as long as receivers send (S, G) subscriptions, the shortest path tree (SPT) state from the receivers to the source will be maintained, even if the source is not sending traffic for longer periods of time (or even never).

This case is opposite to PIM-SM, where (S, G) state is maintained only if the source is sending traffic and receivers are joining the group. If a source stops sending traffic for more than 3 minutes in PIM-SM, the (S, G) state will be deleted and only reestablished after packets from the source arrive again through the RPT. Because no mechanism in PIM-SSM notifies a receiver that a source is active, the network must maintain the (S, G) state in PIM-SSM as long as receivers are requesting receipt of that channel.

HSIL Limitations

As explained in the "IGMP v3lite Host Signalling" section, the HSIL tries to determine if the host operating system supports IGMPv3. This check is made so that a single application can be used both on hosts where the operating system has been upgraded to IGMPv3 and on hosts where the operating system only supports IGMPv1 or IGMPv2. Checking for the availability of IGMPv3 in the host operating system can only be made by the HSIL if IGMPv3 kernel support exists for at least one version of this operating system at the time when the HSIL was provided. If such an IGMPv3 kernel implementation has become available only recently, then users may need to also upgrade the HSIL on their hosts so that applications

compiled with the HSIL will then dynamically bind to the newest version of the HSIL, which should support the check for IGMPv3 in the operating system kernel. Upgrading the HSIL can be done independently of upgrading the application itself.

SSM Configuration Task List

To configure SSM, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining section are optional.

- Configuring SSM (Required)
- Monitoring SSM (Optional)

Configuring SSM

To configure SSM, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip pim ssm [default | range access-list]`	Defines the SSM range of IP multicast addresses.
Step 2	`Router(config)# interface type number`	Selects an interface that is connected to hosts on which IGMPv3, IGMP v3lite, and URD can be enabled.
Step 3	`Router(config-if)# ip pim {sparse-mode | sparse-dense-mode}`	Enables PIM on an interface. You must use either sparse mode or sparse-dense mode.
Step 4	`Router(config-if)# ip igmp version 3`	Enables IGMPv3 on this interface. The default version of IGMP is set to Version 2.
	or	or
	`Router(config-if)# ip igmp v3lite`	Enables the acceptance and processing of IGMP v3lite membership reports on an interface.
	or	or
	`Router(config-if)# ip urd`	Enables interception of TCP packets sent to the reserved URD port 465 on an interface and processing of URD channel subscription reports.

Monitoring SSM

To monitor SSM, use the following commands in privileged EXEC mode, as needed:

Command	Purpose
`Router# show ip igmp groups detail`	Displays the (S, G) channel subscription through IGMPv3, IGMP v3lite, or URD.
`Router# show ip mroute`	Displays whether a multicast group supports SSM service or whether a source-specific host report was received.

SSM Configuration Examples

This section provides the following SSM configuration examples:

- SSM with IGMPv3 Example
- SSM with IGMP v3lite and URD Example
- SSM Filtering Example

SSM with IGMPv3 Example

The following example shows how to configure a router (running IGMPv3) for SSM:

```
ip multicast-routing
!
interface Ethernet3/1
 ip address 172.21.200.203 255.255.255.0
 description backbone interface
 ip pim sparse-dense-mode
!
interface Ethernet3/2
 ip address 131.108.1.2 255.255.255.0
 ip pim sparse-dense-mode
 description ethernet connected to hosts
 ip igmp version 3
!
ip pim ssm default
```

SSM with IGMP v3lite and URD Example

The following example shows how to configure IGMP v3lite and URD on interfaces connected to hosts for SSM. Configuring IGMP v3lite and URD is not required or recommended on backbone interfaces.

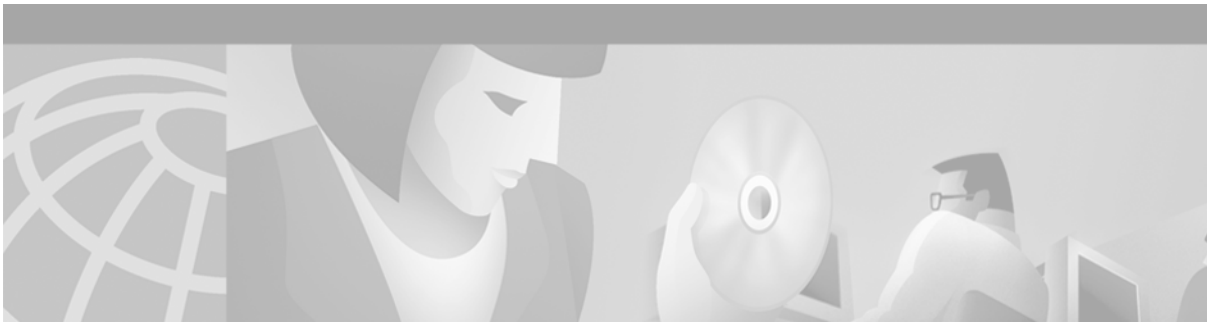
```
interface ethernet 3/1
 ip address 172.21.200.203 255.255.255.0
 ip pim sparse-dense-mode
 description ethernet connected to hosts
!
interface ethernet 1
description ethernet connected to hosts
 ip address 131.108.1.2 255.255.255.0
 ip pim sparse-dense-mode
 ip urd
 ip igmp v3lite
```

SSM Filtering Example

The following example shows how to configure filtering on a legacy RP router running Cisco IOS releases earlier than Release 12.1(3)T for SSM routing. This filtering will suppress all unwanted PIM-SM and MSDP traffic in the SSM range. Without this filtering, SSM will still operate, but there may be additional RPT traffic if legacy first hop and last hop routers exist in the network.

```
ip access-list extended  no-ssm-range
  deny   ip any 232.0.0.0 0.255.255.255 ! SSM range
  permit ip any any
! Deny registering in SSM range
```

```
ip pim accept-register list no-ssm-range

ip access-list extended msdp-nono-list
  deny   ip any 232.0.0.0 0.255.255.255 ! SSM Range
  ! .
  ! .
  ! .
  ! See ftp://ftpeng.cisco.com/ipmulticast/config-notes/msdp-sa-filter.txt for other SA
  ! messages that typically need to be filtered.
  permit ip any any

! Filter generated SA messages in SSM range. This configuration is only needed if there
! are directly connected sources to this router. The "ip pim accept-register" command
! filters remote sources.
ip msdp redistribute list msdp-nono-list

! Filter received SA messages in SSM range. "Filtered on receipt" means messages are
! neither processed or forwarded. Needs to be configured for each MSDP peer.
ip msdp sa-filter in msdp-peer1 list msdp-nono-list
! .
! .
! .
ip msdp sa-filter in msdp-peerN list msdp-nono-list
```



Configuring Bidirectional PIM

This chapter describes how to configure the Bidirectional PIM (bidir-PIM) feature. Bidir-PIM is a variant of the Protocol Independent Multicast (PIM) suite of routing protocols for IP multicast and is an extension of the existing PIM sparse mode (PIM-SM) feature. Bidir-PIM resolves some limitations of PIM-SM for groups with a large number of sources.

Bidir-PIM is based on the draft-kouvelas-pim-bidir-new-00.txt Internet Engineering Task Force (IETF) protocol specification. This draft and other drafts referenced by it can be found at the following URL: ftp://ftpeng.cisco.com/ipmulticast/drafts.

For more information on PIM-SM, refer to the "Configuring IP Multicast Routing" chapter of the *Cisco IOS IP Configuration Guide* and the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*.

For a complete description of the bidir-PIM commands used in this chapter, refer to the "IP Multicast Routing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast.* To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

Bidir-PIM Overview

Bidir-PIM is a variant of the PIM suite of routing protocols for IP multicast. In PIM, packet traffic for a multicast group is routed according to the rules of the mode configured for that multicast group. The Cisco IOS implementation of PIM supports three modes for a multicast group:

- Bidirectional mode
- Dense mode
- Sparse mode

A router can simultaneously support all three modes or any combination of them for different multicast groups. In bidirectional mode, traffic is routed only along a bidirectional shared tree that is rooted at the rendezvous point (RP) for the group. In bidir-PIM, the IP address of the RP acts as the key to having all routers establish a loop-free spanning tree topology rooted in that IP address. This IP address need not be a router, but can be any unassigned IP address on a network that is reachable throughout the PIM domain. This technique is the preferred configuration method for establishing a redundant RP configuration for bidir-PIM.

Membership to a bidirectional group is signalled via explicit join messages. Traffic from sources is unconditionally sent up the shared tree toward the RP and passed down the tree toward the receivers on each branch of the tree.

Bidir-PIM is designed to be used for many-to-many applications within individual PIM domains. Multicast groups in bidirectional mode can scale to an arbitrary number of sources without incurring overhead due to the number of sources.

Bidir-PIM is derived from the mechanisms of PIM-SM and shares many shortest-path tree (SPT) operations. Bidir-PIM also has unconditional forwarding of source traffic toward the RP upstream on the shared tree, but no registering process for sources as in PIM-SM. These modifications are necessary and sufficient to allow forwarding of traffic in all routers solely based on the (*, G) multicast routing entries. This feature eliminates any source-specific state and allows scaling capability to an arbitrary number of sources. Figure 76 and Figure 77 show the difference in state created per router for a unidirectional shared tree and source tree versus a bidirectional shared tree.

Figure 76 Unidirectional Shared Tree and Source Tree

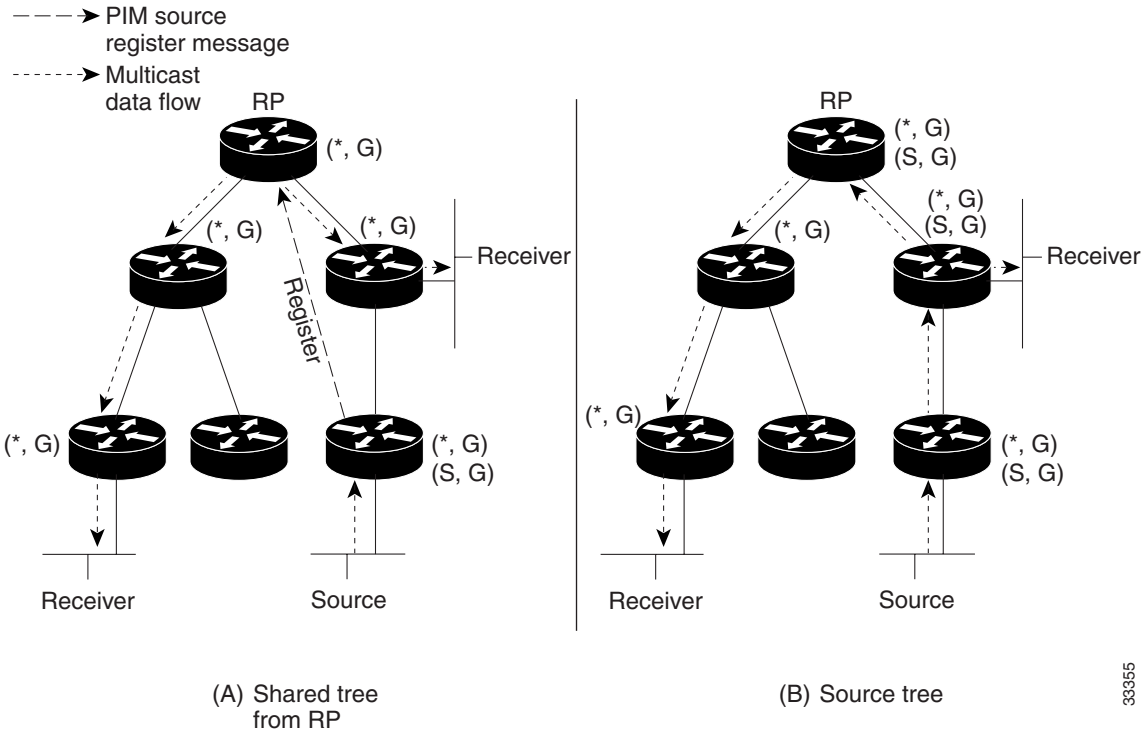
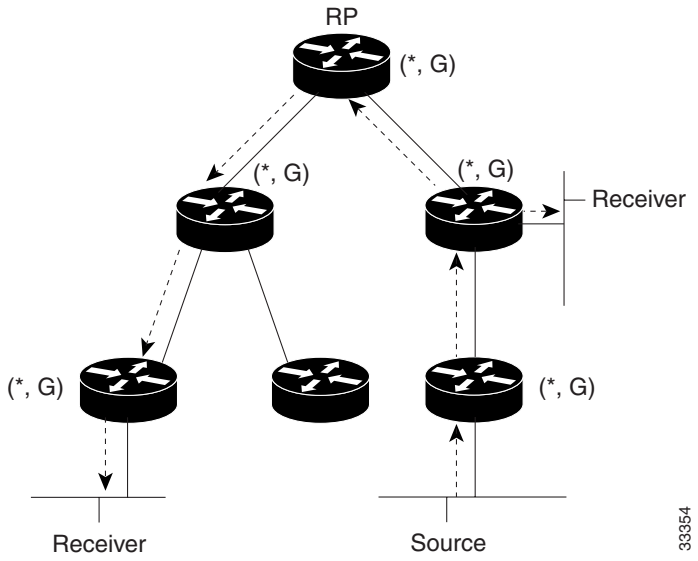


Figure 77 Bidirectional Shared Tree



When packets are forwarded downstream from the RP toward receivers, there are no fundamental differences between bidir-PIM and PIM-SM. Bidir-PIM deviates substantially from PIM-SM when passing traffic from sources upstream toward the RP.

PIM-SM cannot forward traffic in the upstream direction of a tree, because it only accepts traffic from one Reverse Path Forwarding (RPF) interface. This interface (for the shared tree) points toward the RP, therefore allowing only downstream traffic flow. In this case, upstream traffic is first encapsulated into unicast register messages, which are passed from the designated router (DR) of the source toward the RP. In a second step, the RP joins an SPT that is rooted at the source. Therefore, in PIM-SM, traffic from sources traveling toward the RP does not flow upstream in the shared tree, but downstream along the SPT of the source until it reaches the RP. From the RP, traffic flows along the shared tree toward all receivers.

In bidir-PIM, the packet forwarding rules have been improved over PIM-SM, allowing traffic to be passed up the shared tree toward the RP. To avoid multicast packet looping, bidir-PIM introduces a new mechanism called designated forwarder (DF) election, which establishes a loop-free SPT rooted at the RP.

DF Election

On every network segment and point-to-point link, all PIM routers participate in a procedure called DF election. The procedure selects one router as the DF for every RP of bidirectional groups. This router is responsible for forwarding multicast packets received on that network upstream to the RP.

The DF election is based on unicast routing metrics and uses the same tie-break rules employed by PIM assert processes. The router with the most preferred unicast routing metric to the RP becomes the DF. Use of this method ensures that only one copy of every packet will be sent to the RP, even if there are parallel equal cost paths to the RP.

A DF is selected for every RP of bidirectional groups. As a result, multiple routers may be elected as DF on any network segment, one for each RP. In addition, any particular router may be elected as DF on more than one interface.

Bidirectional Group Tree Building

The procedure for joining the shared tree of a bidirectional group is almost identical to that used in PIM SM. One main difference is that, for bidirectional groups, the role of the DR is assumed by the DF for the RP.

On a network with local receivers, only the router elected as the DF populates the outgoing interface list (olist) upon receiving Internet Group Management Protocol (IGMP) join messages, and sends (*, G) join and leave messages upstream toward the RP. When a downstream router wishes to join the shared tree, the RPF neighbor in the PIM join and leave messages is always the DF elected for the interface leading to the RP.

When a router receives a join or leave message, and the router is not the DF for the receiving interface, the message is ignored. Otherwise, the router updates the shared tree in the same way as in sparse mode.

In a network where all routers support bidirectional shared trees, (S, G) join and leave messages are ignored. There is also no need to send PIM assert messages, because the DF election procedure eliminates parallel downstream paths from any RP. In addition, an RP never joins a path back to the source, nor will it send any register stops.

Packet Forwarding

A router only creates (*, G) entries for bidirectional groups. The olist of a (*, G) entry includes all the interfaces for which the router has been elected DF and that have received either an IGMP or PIM join message. If a router is located on a sender-only branch, it will also create (*, G) state, but the olist will not include any interfaces.

If a packet is received from the RPF interface toward the RP, the packet is forwarded downstream according to the olist of the (*, G) entry. Otherwise, only the router that is the DF for the receiving interface forwards the packet upstream toward the RP; all other routers must discard the packet.

Bidir-PIM Configuration Task List

To configure bidir-PIM, perform the tasks described in the following sections. The tasks in the first section are required; the task in the remaining sections are optional.

- Configuring Bidir-PIM (Required)
- Verifying Bidirectional Groups (Optional)
- Monitoring and Maintaining Bidir-PIM (Optional)

Prerequisites

Before configuring bidir-PIM, ensure that the feature is supported on all IP multicast-enabled routers in that domain. It is not possible to enable groups for bidir-PIM operation in a partially upgraded network.

Note Packet loops will occur immediately in networks that are only partially upgraded to support bidir-PIM.

Configuring Bidir-PIM

Most of the configuration requirements for bidir-PIM are the same as those for configuring PIM-SM. You need not enable or disable an interface for carrying traffic for multicast groups in bidirectional mode. Instead, you configure which multicast groups you want to operate in bidirectional mode. Similar to PIM-SM, this configuration can be done via Auto-RP, static RP configurations, or the PIM Version 2 bootstrap router (PIMv2 BSR) mechanism.

To enable bidir-PIM, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pim bidir-enable`	Enables bidir-PIM on a router.

To configure bidir-PIM, use the following commands in global configuration mode, depending on which method you use to distribute group-to-RP mappings:

Command	Purpose
`Router(config)# ip pim rp-address` *rp-address* [*access-list*] [**override**] **bidir**	Configures the address of a PIM RP for a particular group, and specifies bidirectional mode. Use this command when you are not distributing group-to-RP mappings using either Auto-RP or the PIMv2 BSR mechanism.
`Router(config)# ip pim rp-candidate` *type number* [**group-list** *access-list*] **bidir**	Configures the router to advertise itself as a PIM Version 2 candidate RP to the BSR, and specifies bidirectional mode. Use this command when you are using the PIMv2 BSR mechanism to distribute group-to-RP mappings.
`Router(config)# ip pim send-rp-announce` *type number* **scope** *ttl-value* [**group-list** *access-list*] [**interval** *seconds*] **bidir**	Configures the router to use Auto-RP to configure for which groups the router is willing to act as RP, and specifies bidirectional mode. Use this command when you are using Auto-RP to distribute group-to-RP mappings.

See the "Bidir-PIM Configuration Example" section later in this chapter for an example of how to configure bidir-PIM.

Verifying Bidirectional Groups

To verify configuration of bidirectional groups, use the following **show** commands:

- To examine RP-to-group mappings and determine the bidirectional groups advertised by an RP, use the **show ip pim rp mapping** command in EXEC mode.
- To display the IP multicast routing table information for groups operating in bidirectional mode, sparse mode, and dense mode, use the **show ip mroute** command in EXEC mode.
- To display information about the elected DF for each RP of an interface and the metric associated with the DF, use the **show ip pim interface df** command in EXEC mode.

Monitoring and Maintaining Bidir-PIM

To display bidir-PIM information, use the following commands in EXEC mode, as needed:

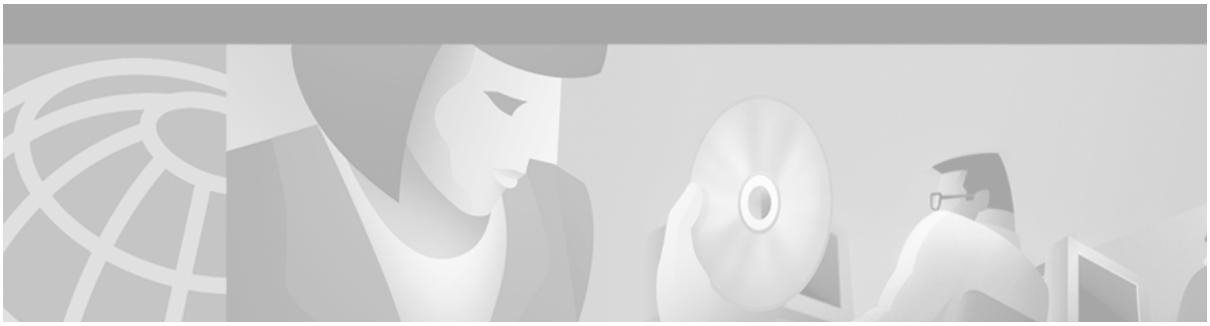
Command	Purpose
Router# **show ip pim interface** [*type number*] [**df** | **count**] [*rp-address*]	Displays information about the elected DF for each RP of an interface, along with the unicast routing metric associated with the DF.
Router# **show ip pim rp** [**mapping** | **metric**] [*rp-address*]	Displays information about configured RPs, learned via Auto-RP or BSR, along with their unicast routing metric.

Bidir-PIM Configuration Example

By default a bidirectional RP advertises all groups as bidirectional. An access list on the RP can be used to specify a list of groups to be advertised as bidirectional. Groups with the **deny** keyword will operate in dense mode. A different, nonbidirectional RP address is required for groups that operate in sparse mode, because a single access list only allows either a **permit** or **deny** keyword.

The following example shows how to configure an RP for both sparse mode and bidirectional mode groups. 224/8 and 227/8 are bidirectional groups, 226/8 is sparse mode, and 225/8 is dense mode. The RP must be configured to use different IP addresses for the sparse mode and bidirectional mode operations. Two loopback interfaces are used to allow this configuration. The addresses of these loopback interfaces must be routed throughout the PIM domain such that the other routers in the PIM domain can receive Auto-RP announcements and communicate with the RP.

```
ip multicast-routing !Enable IP multicast routing
ip pim bidir-enable  !Enable bidir-PIM
!
interface loopback 0
 description One Loopback adddress for this routers Bidir Mode RP function
 ip address 10.0.1.1 255.255.255.0
 ip pim sparse-dense-mode
!
interface loopback 1
 description One Loopback adddress for this routers Sparse Mode RP function
 ip address 10.0.2.1 255.255.255.0
 ip pim sparse-dense-mode

ip pim send-rp-announce Loopback0 scope 10 group-list 45 bidir
ip pim send-rp-announce Loopback1 scope 10 group-list 46
ip pim send-rp-discovery scope 10

access-list 45 permit 224.0.0.0 0.255.255.255
access-list 45 permit 227.0.0.0 0.255.255.255
access-list 45 deny   225.0.0.0 0.255.255.255

access-list 46 permit 226.0.0.0 0.255.255.255
```



Configuring Multicast Source Discovery Protocol

This chapter describes the Multicast Source Discovery Protocol (MSDP) feature. For a complete description of the MSDP commands in this chapter, refer to the "Multicast Source Discovery Protocol Commands" chapter of the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast* publication. To locate documentation of other commands in this chapter, use the command reference master index, or search online.

MSDP is a mechanism to connect multiple Protocol Independent Multicast sparse mode (PIM-SM) domains. MSDP allows multicast sources for a group to be known to all rendezvous points (RPs) in different domains. Each PIM-SM domain uses its own RPs and need not depend on RPs in other domains. An RP runs MSDP over TCP to discover multicast sources in other domains.

An RP in a PIM-SM domain has an MSDP peering relationship with MSDP-enabled routers in another domain. The peering relationship occurs over a TCP connection, where primarily a list of sources sending to multicast groups is exchanged. The TCP connections between RPs are achieved by the underlying routing system. The receiving RP uses the source lists to establish a source path.

The purpose of this topology is to have domains discover multicast sources in other domains. If the multicast sources are of interest to a domain that has receivers, multicast data is delivered over the normal, source-tree building mechanism in PIM-SM.

MSDP is also used to announce sources sending to a group. These announcements must originate at the RP of the domain.

MSDP depends heavily on BGP or MBGP for interdomain operation. We recommend that you run MSDP in RPs in your domain that are RPs for sources sending to global groups to be announced to the internet.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

How MSDP Works

Figure 78 illustrates MSDP operating between two MSDP peers. PIM uses MSDP as the standard mechanism to register a source with the RP of a domain.

When MSDP is configured, the following sequence occurs. When the first data packet of a source is registered by the first hop router, that same data packet is decapsulated by the RP and forwarded down the shared tree. That packet is also reencapsulated in a Source-Active (SA) message that is immediately forwarded to all MSDP peers. The SA message identifies the source, the group the source is sending to,

and the address or the originator ID of the RP, if configured. If the peer is an RP and has a member of that multicast group, the data packet is decapsulated and forwarded down the shared-tree in the remote domain.

The PIM designated router (DR) directly connected to the source sends the data encapsulated in a PIM register message to the RP in the domain.

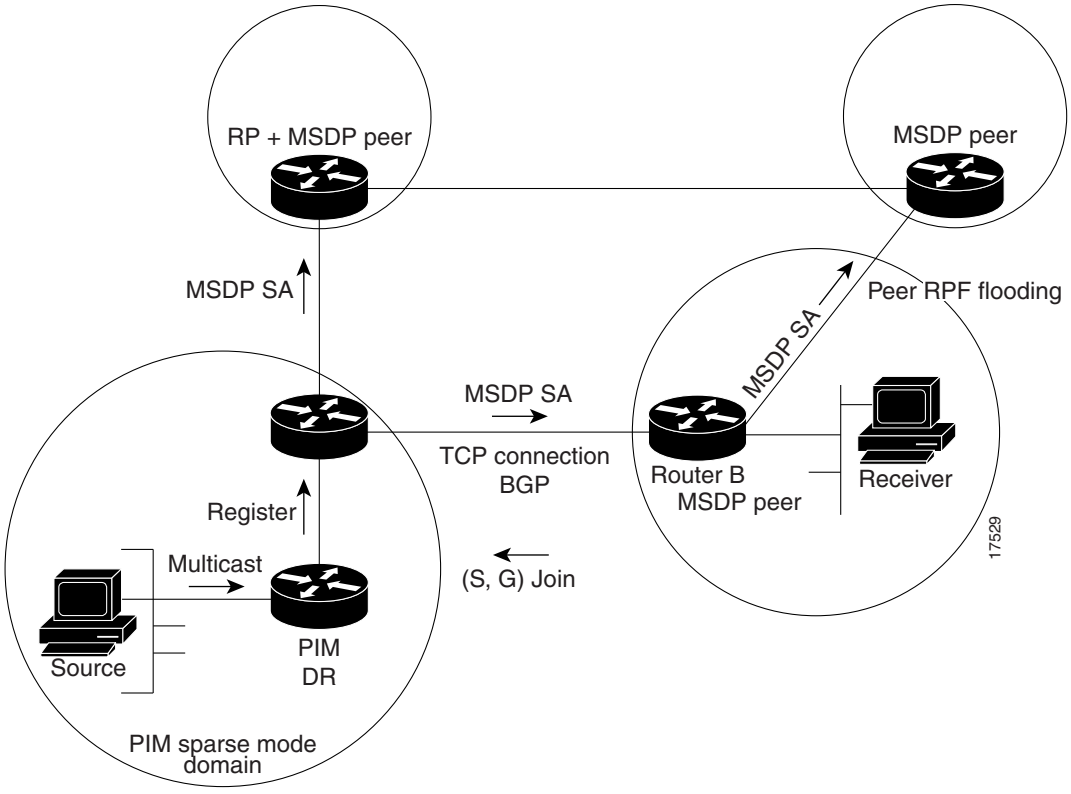
Note The DR sends the encapsulated data to the RP only once per source, when the source goes active. If the source times out, this process happens again when it goes active again. This situation is different from the periodic SA message that contains all sources that are registered to the originating RP. These messages have no data.

Each MSDP peer receives and forwards the SA message away from the originating RP to achieve *peer-RPF flooding*. The concept of peer-RPF flooding is with respect to forwarding SA messages. The router examines the BGP or MBGP routing table to determine which peer is the next hop toward the originating RP of the SA message. Such a peer is called an "RPF peer" (Reverse Path Forwarding peer). The router forwards the message to all MSDP peers other than the RPF peer.

If the MSDP peer receives the same SA message from a non-RPF peer toward the originating RP, it drops the message. Otherwise, it forwards the message on to all its MSDP peers.

When an RP for a domain receives an SA message from an MSDP peer, it determines if it has any group members interested in the group the SA message describes. If the (*, G) entry exists with a nonempty outgoing interface list, the domain is interested in the group, and the RP triggers an (S, G) join toward the source.

Figure 78 MSDP Running Between RP Peers



Benefits

MSDP has the following benefits:

- It breaks up the shared multicast distribution tree. You can make the shared tree local to your domain. Your local members join the local tree, and join messages for the shared tree never need to leave your domain.
- PIM-SM domains can rely on their own RPs only, thus decreasing reliance on RPs in another domain. This increases security because you can prevent your sources from being known outside your domain.
- Domains with only receivers can receive data without globally advertising group membership.
- Global source multicast routing table state is not required, thus saving on memory.

Prerequisites

Before configuring MSDP, the addresses of all MSDP peers must be known in BGP or MBGP. If that does not occur, you must configure MSDP default peering when you configure MSDP.

MSDP Configuration Task List

To configure an MSDP peer and various MSDP options, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Configuring an MSDP Peer (Required)
- Caching SA State (Optional)
- Requesting Source Information from an MSDP Peer (Optional)
- Controlling Source Information That Your Router Originates (Optional)
- Controlling Source Information That Your Router Forwards (Optional)
- Controlling Source Information That Your Router Receives (Optional)
- Configuring a Default MSDP Peer (Optional)
- Configuring an MSDP Mesh Group (Optional)
- Shutting Down an MSDP Peer (Optional)
- Including a Bordering PIM Dense Mode Region in MSDP (Optional)
- Configuring an Originating Address Other Than the RP Address (Optional)

See the “MSDP Configuration Examples” section later in this chapter for configuration examples.

Configuring an MSDP Peer

You enable MSDP by configuring an MSDP peer to the local router.

Note The router you specify by Domain Naming System (DNS) name or IP address as an MSDP peer is probably a Border Gateway Protocol (BGP) neighbor. If it is not, see the section "Configuring a Default MSDP Peer" later in this document.

To configure an MSDP peer, use the following commands in global configuration mode as needed. The second command is optional.

Command	Purpose
`Router(config)# ip msdp peer {peer-name | peer-address} [connect-source type number] [remote-as as-number]`	Enables MSDP and configures an MSDP peer as specified by the DNS name or IP address. If you specify the **connect-source** keyword, the primary address of the specified local interface *type* and *number* values are used as the source IP address for the TCP connection. The **connect-source** keyword is recommended, especially for MSDP peers on a border that peer with a router inside the remote domain.
`Router(config)# ip msdp description {peer-name | peer-address} text`	Configures a description for a specified peer to make it easier to identify in a configuration or in **show** command output.

Caching SA State

By default, the router does not cache source/group pairs from received SA messages. Once the router forwards the MSDP SA information, it does not store it in memory. Therefore, if a member joins a group soon after an SA message is received by the local RP, that member will need to wait until the next SA message to hear about the source. This delay is known as join latency.

If you want to sacrifice some memory in exchange for reducing the latency of the source information, you can configure the router to cache SA messages. To have the router cache source/group pairs, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip msdp cache-sa-state [list access-list]`	Creates SA state (cache source/group pairs). Those pairs that pass the access list are cached.

An alternative to caching the SA state is to request source information from a peer, which is described in the following section, "Requesting Source Information from an MSDP Peer." If you cache the information, you need not trigger a request for it.

Requesting Source Information from an MSDP Peer

Local RPs can send SA requests and get immediate response for all active sources for a given group. By default, the router does not send any SA request messages to its MSDP peers when a new member joins a group and wants to receive multicast traffic. The new member just waits to receive the next periodic SA message.

If you want a new member of a group to learn the current, active multicast sources in a connected PIM-SM domain that are sending to a group, configure the router to send SA request messages to the specified MSDP peer when a new member joins a group. Doing so reduces join latency, but requires some memory.

Note that information can be requested only from caching peers.

To configure this feature, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip msdp sa-request {peer-address | peer-name}`	Configures the router to send SA request messages to the specified MSDP peer when a receiver becomes active, so the receiver can learn about multicast sources in a group. The peer replies with the information it is SA cache. If the peer does not have a cache configured, this command provides nothing.

Repeat the preceding command for each MSDP peer that you want to supply you with SA messages.

An alternative to requesting source information is to cache the SA state, which is described in the section "Caching SA State" earlier in this chapter. If you cache the information, you need not trigger a request for it.

Controlling Source Information That Your Router Originates

There are two ways to control the multicast source information that originates with your router. You can control the following:

- Which sources you will advertise (based on your sources)
- Whom you will provide source information to (based on knowing who is asking you for information)

To control which sources you will advertise, see the following section, "Redistributing Sources." To control whom you will provide source information to, see the section "Controlling Source Information That Your Router Forwards" later in this chapter.

Redistributing Sources

SA messages are originated on RPs to which sources have registered. By default, any source that registers with an RP will be advertised. The "A flag" is set in the RP when a source is registered. This flag indicates that the source will be advertised in an SA unless it is filtered with the following command.

To further restrict which registered sources are advertised, use the following command in global configuration mode. The access list or autonomous system path access list determines which (S, G) pairs are advertised.

Command	Purpose
`Router(config)# ip msdp redistribute [list access-list] [asn as-access-list] [route-map map-name]`	Advertises (S, G) pairs that pass the access list or route map to other domains.

Note The **ip msdp redistribute** global configuration command could also be used to advertise sources that are known to the RP but not registered. However, we strongly recommend that you NOT originate advertisements for sources that have not registered with the RP.

Filtering SA Request Messages

By default, only routers that are caching SA information can respond to SA request messages. By default, such a router honors all SA request messages from its MSDP peers. That is, it will supply the IP addresses of the sources that are active.

However, you can configure the router to ignore all SA request messages from an MSDP peer. Or, you can honor only those SA request messages from a peer for groups described by a standard access list. If the access list passes, SA request messages will be accepted. All other such messages from the peer for other groups will be ignored.

To configure one of these options, use either of the following commands in global configuration mode:

Command	Purpose
`Router(config)# ip msdp filter-sa-request {peer-address | peer-name}`	Filters all SA request messages from the specified MSDP peer.
`Router(config)# ip msdp filter-sa-request {peer-address | peer-name} list access-list`	Filters SA request messages from the specified MSDP peer for groups that pass the standard access list. The access list describes a multicast group address.

Controlling Source Information That Your Router Forwards

By default, the router forwards all SA messages it receives to all of its MSDP peers. However, you can prevent outgoing messages from being forwarded to a peer by using a filter or by setting a time-to-live (TTL) value. These methods are described in the following sections.

Using an MSDP Filter

By creating an MSDP filter, you can do one of the following:

- Filter all source/group pairs
- Specify an extended access list to pass only certain source/group pairs
- Filter based on match criteria in a route map

To apply an MSDP filter, use the following commands in global configuration mode as needed:

Command	Purpose
`Router(config)# ip msdp sa-filter out {peer-address | peer-name}`	Filters all SA messages to the specified MSDP peer.
`Router(config)# ip msdp sa-filter out {peer--address | peer-name} list access-list`	To the specified MSDP peer, passes only those SA messages that pass the extended access list.
`Router(config)# ip msdp sa-filter out {peer-address | peer-name} route-map map-name`	To the specified MSDP peer, passes only those SA messages that meet the match criteria in the route map *map-tag* value.

Using TTL to Limit the Multicast Data Sent in SA Messages

You can use TTL to control what data will be encapsulated in the first SA message for every source. For example, you could limit internal traffic to a TTL of 8. If you want other groups to go to external locations, you would need to send those packets with a TTL greater than 8.

To establish a TTL threshold, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip msdp ttl-threshold {peer-address | peer-name} ttl-value`	Limits which multicast data will be encapsulated in the first SA message to the specified MSDP peer.

Controlling Source Information That Your Router Receives

By default, the router receives all SA messages its MSDP RPF peers send to it. However, you can control the source information you receive from MSDP peers by filtering incoming SA messages. In other words, you can configure the router not to accept them.

You can do one of the following to control the source information you receive from MSDP peers:

- Filter all incoming SA messages from an MSDP peer
- Specify an extended access list to pass certain source/group pairs
- Filter based on match criteria in a route map

To apply a filter, use the following commands in global configuration mode as needed:

Command	Purpose
`Router(config)# ip msdp sa-filter in {peer-address | peer-name}`	From the specified MSDP peer, filters all SA messages received.
`Router(config)# ip msdp sa-filter in {peer-address | peer-name} list access-list`	From the specified MSDP peer, passes incoming SA messages that pass the extended access list.
`Router(config)# ip msdp sa-filter in {peer-address | peer-name} route-map map-name`	From the specified MSDP peer, passes only those SA messages that meet the match criteria in the route map *map-name* value.

Configuring a Default MSDP Peer

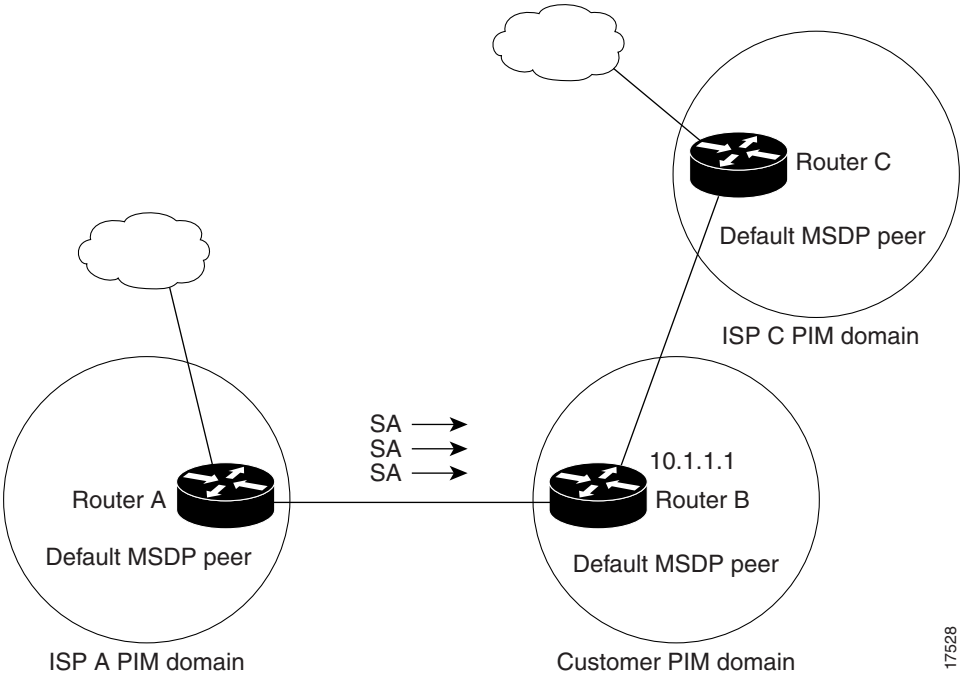
An MSDP peer of the local router is probably a BGP peer also. However, if you do not want to have or cannot have a BGP peer, you could define a default MSDP peer from which to accept all SA messages. The default MSDP peer must be a previously configured MSDP peer. Configure a default MSDP peer when you are not BGP- or multiprotocol BGP-peering with an MSDP peer. If a single MSDP peer is configured, a router will always accept all SA messages sent to it from that peer.

Figure 79 illustrates a scenario where default MSDP peers might be used. In the figure, a customer that owns Router B is connected to the internet via two Internet service providers (ISPs), one that owns Router A and the other that owns Router C. They are not running BGP or MBGP between them. In order for the customer to learn about sources in the ISP domain or in other domains, Router B identifies Router A as its default MSDP peer. Router B advertises SA messages to both Router A and Router C, but accepts SA messages either from Router A only or Router C only. If Router A is first in the configuration file, it will be used if it is up and running. If Router A is not running, then and only then will Router B accept SA messages from Router C.

The ISP will also likely use a prefix list to define which prefixes it will accept from the customer router. The customer will define multiple default peers, each having one or more prefixes associated with it.

The customer has two ISPs to use. The customer defines both ISPs as default peers. As long as the first default peer identified in the configuration is up and running, it will be the default peer and the customer will accept all SA messages it receives from that peer.

Figure 79 Default MSDP Peer Scenario



Router B advertises SAs to Router A and Router C, but uses only Router A or Router C to accept SA messages. If Router A is first in the configuration file, it will be used if it is up and running. If Router A is not running, then and only then will Router B accept SAs from Router C. This is the behavior without a prefix list.

If you specify a prefix list, the peer will be a default peer only for the prefixes in the list. You can have multiple active default peers when you have a prefix list associated with each. When you do not have any prefix lists, you can configure multiple default peers, but only the first one is the active default peer as long as the router has connectivity to this peer and the peer is alive. If the first configured peer goes down or the connectivity to this peer goes down, the second configured peer becomes the active default, and so on.

To specify a default MSDP peer, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip msdp default-peer {peer-address | peer-name} [prefix-list list]`	Defines a default MSDP peer.

See the section "Default MSDP Peer" later in this chapter for a sample configuration.

Configuring an MSDP Mesh Group

An MSDP mesh group is a group of MSDP speakers that have fully meshed MSDP connectivity between one another. Any SA messages received from a peer in a mesh group are not forwarded to other peers in the same mesh group. Thus, you reduce SA message flooding and simplify peer-RPF flooding. The following command is used when multiple RPs are within a domain. It is especially used to send SA messages across a domain.

You can configure multiple mesh groups (with different names) in a single router.

To create a mesh group, use the following command in global configuration mode for each MSDP peer in the group:

Command	Purpose
`Router(config)# ip msdp mesh-group mesh-name {peer-address | peer-name}`	Configures an MSDP mesh group and indicates that an MSDP peer belongs to that mesh group.

Shutting Down an MSDP Peer

If you want to configure many MSDP commands for the same peer and you do not want the peer to go active, you can shut down the peer, configure it, and later bring it up.

You might also want to shut down an MSDP session without losing configuration information for the peer.

When a peer is shut down, the TCP connection is terminated and not restarted.

To shut down a peer, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip msdp shutdown {peer-name | peer address}`	Administratively shuts down the specified MSDP peer.

Including a Bordering PIM Dense Mode Region in MSDP

You might have a router that borders a PIM-SM region with a dense mode region. By default, sources in the dense mode region are not included in MSDP. You could configure this border router to send SA messages for sources active in the dense mode region. If you do so, it is very important to also configure the **ip msdp redistribute** global configuration command to apply to only local sources. Not configuring this command can result in (S, G) state remaining long after a source in the dense mode domain has stopped sending.

To configure the border router to send SA messages for sources active in the dense mode region, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip msdp border sa-address` *type number*	Configures the router on the border between a dense mode and sparse mode region to send SA messages about active sources in the dense mode region. The IP address of the interface is used as the originator ID, which is the RP field in the SA message.

Note The **ip msdp border** command is not recommended. It is better to configure the border router in the sparse mode domain to proxy-register sources in the dense mode domain to the RP of the sparse mode domain and have the sparse mode domain use standard MSDP procedures to advertise these sources.

Configuring an Originating Address Other Than the RP Address

If you want to change the originator ID for any reason, use the **ip msdp originator-id** global configuration command in this section. For example, you might change the originator ID in one of these cases:

- If you configure a logical RP on multiple routers in an MSDP mesh group. For an example of a logical RP, see the section "Logical RP" later in this document.
- If you have a router that borders a PIM sparse mode domain and a dense mode domain. If a router borders a dense mode domain for a site, and sparse mode is being used externally, you might want dense mode sources to be known to the outside world. Because this router is not an RP, it would not have an RP address to use in an SA message. Therefore, this command provides the RP address by specifying the address of the interface.

To allow an MSDP speaker that originates an SA message to use the IP address of its interface as the RP address in the SA message, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip msdp originator-id` *type number*	Configures the RP address in SA messages to be the address of the originating router's interface.

Monitoring and Maintaining MSDP

To monitor MSDP SA messages, peers, state, or peer status, use the following commands in EXEC mode as needed:

Command	Purpose
Router# **debug ip msdp** [*peer-address* | *peer-name*] [**detail**] [**routes**]	Debugs an MSDP activity.
Router# **debug ip msdp resets**	Debugs MSDP peer reset reasons.
Router# **show ip msdp count** [*as-number*]	Displays the number of sources and groups originated in SA messages from each autonomous system. The **ip msdp cache-sa-state** global configuration command must be configured for this command to produce any output.
Router# **show ip msdp peer** [*peer-address* | *peer-name*]	Displays detailed information about an MSDP peer.
Router# **show ip msdp sa-cache** [*group-address* | *source-address* | *group-name* | *source-name*] [*as-number*]	Displays (S, G) state learned from MSDP peers.
Router# **show ip msdp summary**	Displays MSDP peer status and SA message counts.

To clear MSDP connections, statistics, or SA cache entries, use the following commands in EXEC modeas needed:

Command	Purpose
Router# **clear ip msdp peer** [*peer-address* | *peer-name*]	Clears the TCP connection to the specified MSDP peer, resetting all MSDP message counters.
Router# **clear ip msdp statistics** [*peer-address* | *peer-name*]	Clears the TCP connection to the specified MSDP peer, resetting all MSDP message counters.
Router# **clear ip msdp sa-cache** [*group-address* | *peer-name*]	Clears the SA cache entries for all entries, all sources for a specific group, or all entries for a specific source/group pair.

To enable Simple Network Management Protocol (SNMP) monitoring of MSDP, use the following commands in global configuration mode:

	Command	Purpose
Step 1	Router# **snmp-server enable traps msdp**	Enables the sending of MSDP notifications for use with SNMP. The **snmp-server enable traps** command enables both traps and informs.
Step 2	Router# **snmp-server host** *host* [**traps** | **informs**] [**version** {**1** | **2c** | **3** [**auth** | **priv** | **noauth**]}] *community-string* [**udp-port** *port-number*] **msdp**	Specifies the recipient (host) for MSDP traps or informs.

For more information about network monitoring using SNMP, refer to the "Configuring Simple Network Management Protocol (SNMP)" chapter in the *Cisco IOS Configuration Fundamentals Configuration Guide*.

MSDP Configuration Examples

This section contains the following MSDP configurations examples:

- Default MSDP Peer
- Logical RP

Default MSDP Peer

The following example is a partial configuration of Router A and Router C in Figure 79. Each of these ISPs may have more than one customer like the customer in Figure 79 that use default peering (no BGP or MBGP). In that case, they may have similar configurations. That is, they will only accept SAs from a default peer if the SA is permitted by the corresponding prefix list.

Router A Configuration

```
ip msdp default-peer 10.1.1.1
ip msdp default-peer 10.1.1.1 prefix-list site-a ge 32
ip prefix-list site-b permit 10.0.0.0/8
```

Router C Configuration

```
ip msdp default-peer 10.1.1.1 prefix-list site-a ge 32
ip prefix-list site-b permit 10.0.0.0/8
```

Logical RP

The following example configures a logical RP using an MSDP mesh group. The four routers that are logical RPs are RouterA, RouterB, RouterC, and RouterD. RouterE is an MSDP border router that is not an RP. Figure 80 illustrates the logical RP environment in this example; the configurations for routers A, B, and E follow the figure.

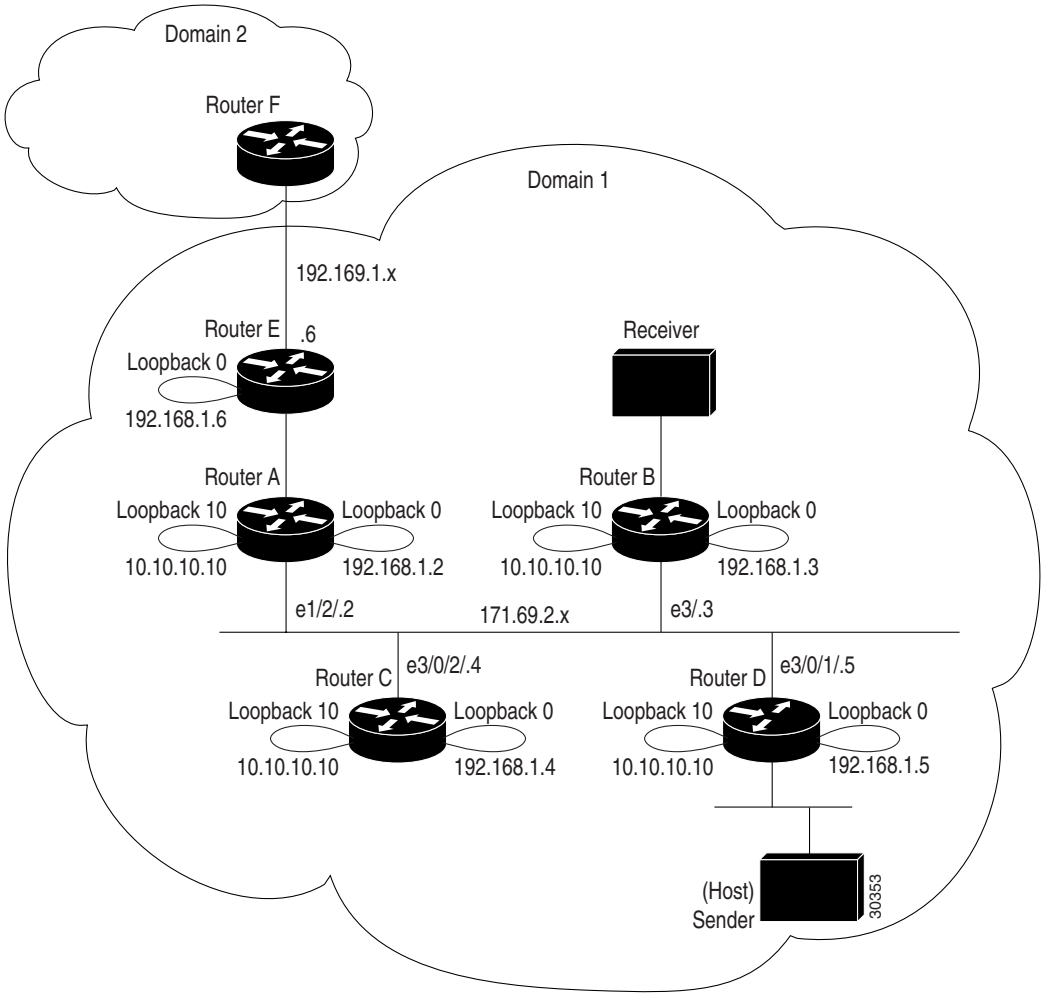
It is important to note the use of the loopback interface and how those host routes are advertised in Open Shortest Path First (OSPF). It is also important to carefully choose the OSPF router ID loopback so the ID does not use the logical RP address.

In this example, all the logical RPs are on the same LAN, but this situation is not typical. The host route for the RP address is advertised throughout the domain and each PIM designated router (DR) in the domain joins to the closest RP. The RPs share (S, G) information with each other by sending SA messages. Each logical RP must use a separate originator ID.

Note There are two MSDP mesh groups on RouterA. The routes for the loopback interfaces are in OSPF. Loopback 0 is the Router ID and is used as the connect source/update source for MBGP/MSDP. Loopback 10 is the same on all routers in the example.

All networks are 171.69.0.0. The RP address is 10.10.10.10 on Loopback 10 on all RPs. BGP connections are 192.168.1.x on Loopback 0. Loopback 0 is put into BGP with network 192.168.1.3 mask 255.255.255.255 NLRI unicast multicast.

Figure 80 Logical RP Using MSDP



RouterA Configuration

```
!
hostname RouterA
!
ip routing
!
ip subnet-zero
ip multicast-routing
!
!
interface Loopback0
 ip address 192.168.1.2 255.255.255.255
 no shutdown
!
interface Loopback10
 ip address 10.10.10.10 255.255.255.255
 no ip directed-broadcast
 ip pim sparse-dense-mode
 no shutdown
!
interface Ethernet1/2
 description LANethernet2
```

```
 ip address 171.69.2.2 255.255.255.0
ip pim sparse-dense-mode
no  shutdown
!
interface Ethernet4/0/0
 description LANethernet3
 ip address 171.69.3.2 255.255.255.0
ip pim sparse-dense-mode
no shutdown
!
router ospf 10
 network 171.69.0.0 0.0.255.255 area 0
 network 10.10.10.10 0.0.0.0 area 0
 network 192.168.1.2 0.0.0.0 area 0
!
router bgp 1
 no synchronization
 network 171.69.0.0 nlri unicast multicast
 network 192.168.1.2 mask 255.255.255.255 nlri unicast multicast
 neighbor 192.168.1.3 remote-as 1 nlri unicast multicast
neighbor description routerB
 neighbor 192.168.1.3 next-hop-self
neighbor 192.168.1.3 update-source loopback0
neighbor 192.168.1.4 remote-as 1 nlri unicast multicast
neighbor  description routerC
neighbor 192.168.1.4 update-source loopback0
neighbor 192.168.1.5 remote-as 1 nlri unicast multicast
neighbor  description routerD
 neighbor 192.168.1.5 next-hop-self
neighbor 192.168.1.5 update-source loopback0
neighbor 192.168.1.6 remote-as 1 nlri unicast multicast
neighbor description routerE
 neighbor 192.168.1.6 update-source Loopback0
 neighbor 192.168.1.6 next-hop-self
!
!
ip msdp peer 192.168.1.3 connect-source loopback 0
ip msdp peer 192.168.1.5 connect-source loopback 0
ip msdp peer 192.168.1.4 connect-source loopback 0
ip msdp peer 192.168.1.6 connect-source Loopback0
ip msdp mesh-group inside-test 192.168.1.3
ip msdp mesh-group inside-test 192.168.1.4
ip msdp mesh-group inside-test 192.168.1.5
ip msdp mesh-group outside-test 192.168.1.6
ip msdp cache-sa-state
ip msdp originator-id loopback0
!
ip classless
ip pim send-rp-disc scope 10
ip pim send-rp-anno loopback 10 scope 10
!
```

RouterB Configuration

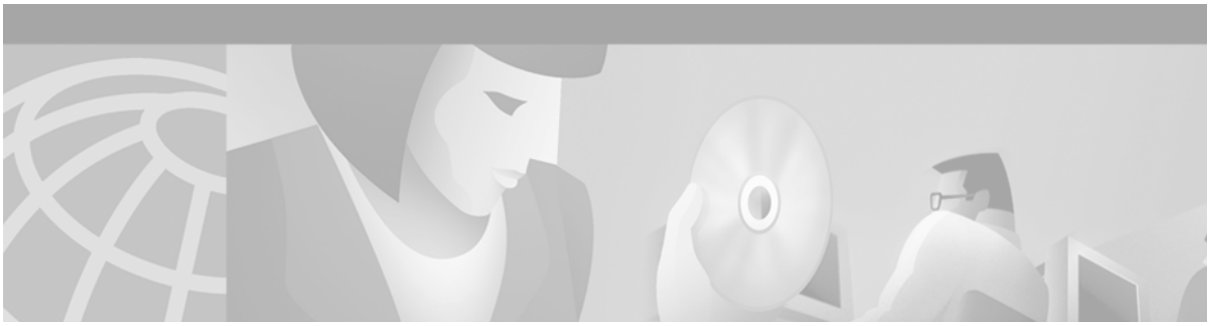
```
!
hostname RouterB
!
ip routing
!
ip multicast-routing
ip dvmrp route-limit 20000
!
interface Loopback0
 ip address 192.168.1.3 255.255.255.255
```

```
 no shutdown
!
interface Loopback10
 ip address 10.10.10.10 255.255.255.255
ip pim sparse-dense-mode
 no shutdown
!
interface Ethernet2
 description LANethernet 0
 ip address 171.69.0.3 255.255.255.0
ip pim sparse-dense-mode
no shutdown
!
interface Ethernet3
 description LANethernet 2
 ip address 171.69.2.3 255.255.255.0
ip pim sparse-dense
!
router ospf 10
 network 171.69.0.0 0.0.255.255 area 0
 network 10.10.10.10 0.0.0.0 area 0
 network 192.168.1.3 0.0.0.0 area 0
!
router bgp 1
 no synchronization
 network 171.69.0.0 nlri unicast multicast
 network 192.168.1.3 mask 255.255.255.255 nlri unicast multicast
 neighbor 192.168.1.2 remote-as 1 nlri unicast multicast
neighbor  description routerA
neighbor 192.168.1.2 update-source loopback0
neighbor 192.168.1.4 remote-as 1 nlri unicast multicast
neighbor  description routerC
neighbor 192.168.1.4 update-source loopback0
neighbor 192.168.1.5 remote-as 1 nlri unicast multicast
neighbor  description routerD
neighbor 192.168.1.5 update-source loopback0
neighbor 192.168.1.5 soft-recon in
!
ip msdp peer 192.168.1.2 connect-source loopback 0
ip msdp peer 192.168.1.5 connect-source loopback 0
ip msdp peer 192.168.1.4 connect-source loopback 0
ip msdp mesh-group inside-test 192.168.1.2
ip msdp mesh-group inside-test 192.168.1.4
ip msdp mesh-group inside-test 192.168.1.5
ip msdp cache-sa-state
ip msdp originator-id loopback0
!
ip classless
ip pim send-rp-disc scope 10
ip pim send-rp-anno loopback 10 scope 10
!
```

RouterE Configuration

```
!
hostname RouterE
!
ip routing
!
ip subnet-zero
ip routing
ip multicast-routing
ip dvmrp route-limit 20000
!
```

```
interface Loopback0
 ip address 192.168.1.6 255.255.255.255
no shutdown
!
interface Ethernet2
 description LANethernet 3
 ip address 171.69.3.6 255.255.255.0
ip pim sparse-dense-mode
no shutdown
!
interface Ethernet5
 description LANethernet 6
 ip address 192.169.1.6 255.255.255.0
ip pim sparse-dense-mode
 ip multicast boundary 20
no shutdown
!
router ospf 10
 network 171.69.0.0 0.0.255.255 area 0
 network 192.168.1.6 0.0.0.0 area 0
 default-information originate metric-type 1
!
router bgp 1
 no synchronization
 network 171.69.0.0 nlri unicast multicast
 network 192.168.1.6 mask 255.255.255.255 nlri unicast multicast
 network 192.168.1.0
 neighbor 192.168.1.2 remote-as 1 nlri unicast multicast
 neighbor 192.168.1.2 update-source Loopback0
 neighbor 192.168.1.2 next-hop-self
neighbor 192.168.1.2 route-map 2-intern out
neighbor 192.169.1.7 remote-as 2 nlri unicast multicast
neighbor 192.169.1.7 route-map 2-extern out
 neighbor 192.169.1.7 default-originate
!
ip classless
ip msdp peer 192.168.1.2 connect-source Loopback0
ip msdp peer 192.169.1.7
ip msdp mesh-group outside-test 192.168.1.2
ip msdp cache-sa-state
ip msdp originator-id Loopback0
!
access-list 1 permit 192.168.1.0
access-list 1 deny 192.168.1.0 0.0.0.255
access-list 1 permit any
!
route-map 2-extern permit 10
 match ip address 1
!
route-map 2-intern deny 10
 match ip address 1
!
```



Configuring PGM Host and Router Assist

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

This chapter describes the PGM Host and Router Assist feature. PGM Host and Router Assist enables Cisco routers to support multicast applications that operate at the PGM transport layer and the PGM network layer, respectively.

The PGM Reliable Transport Protocol itself is implemented on the hosts of the customer. For information on PGM Reliable Transport Protocol, refer to the Internet Engineering Task Force (IETF) protocol specification draft named *PGM Reliable Transport Protocol Specification*.

For a complete description of the PGM Host and Router Assist commands in this chapter, refer to the "PGM Host and Router Assist Commands" chapter of the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

PGM Overview

Pragmatic General Multicast (PGM) is a reliable multicast transport protocol for multicast applications that require reliable, ordered, duplicate-free multicast data delivery from multiple sources to multiple receivers. PGM guarantees that a receiver in a multicast group either receives all data packets from transmissions and retransmissions, or can detect unrecoverable data packet loss. PGM is intended as a solution for multicast applications with basic reliability requirements. PGM has two main parts: a host element (also referred to as the transport layer of the PGM protocol) and a network element (also referred to as the network layer of the PGM protocol).

The transport layer of the PGM protocol has two main parts: a source part and a receiver part. The transport layer defines how multicast applications send and receive reliable, ordered, duplicate-free multicast data from multiple sources to multiple receivers. PGM Host is the Cisco implementation of the transport layer of the PGM protocol.

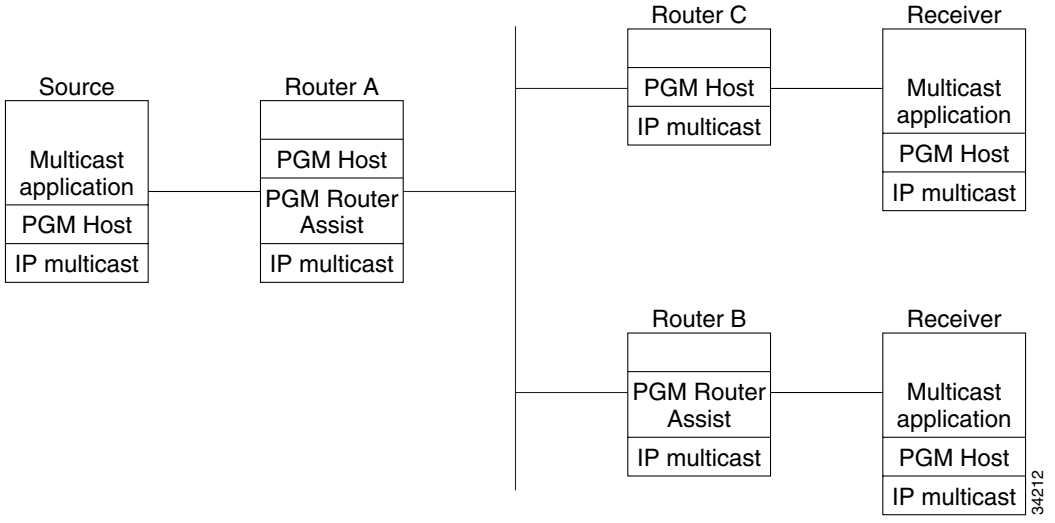
The network layer of the PGM protocol defines how intermediate network devices (such as routers and switches) handle PGM transport data as the data flows through a network. PGM Router Assist is the Cisco implementation of the network layer of the PGM protocol.

Note PGM contains an element that assists routers and switches in handling PGM transport data as it flows through a network. Unlike the Router Assist element, the Host element does not have a current practical application.

PGM is network-layer independent; PGM Host and Router Assist in the Cisco IOS software support PGM over IP. Both PGM Host and Router Assist use a unique transport session identifier (TSI) that identifies each individual PGM session.

Figure 81 shows a simple network topology using the PGM Host and Router Assist feature.

Figure 81 Network Topology Using PGM Host and Router Assist



When the router is functioning as a network element (PGM Router Assist is configured) and PGM Host is configured (Router A in Figure 81), the router can process received PGM packets as a virtual PGM Host, originate PGM packets and serve as its own first hop PGM network element, and forward received PGM packets.

When the router is functioning as a network element and PGM Host is not configured (Router B in Figure 81), the router forwards received PGM packets as specified by PGM Router Assist parameters.

When the router is not functioning as a network element and PGM Host is configured (Router C in Figure 81), the router can receive and forward PGM packets on any router interface simultaneously as specified by PGM Host feature parameters. Although this configuration is supported, it is not recommended in a PGM network because PGM Host works optimally on routers that have PGM Router Assist configured.

PGM Host Configuration Task List

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

To configure PGM Host, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining section are optional.

- Enabling PGM Host (Required)
- Verifying PGM Host Configuration (Optional)

See the end of this chapter for the section "PGM Host and Router Assist Configuration Examples."

Prerequisites

Before you configure PGM Host, ensure that the following tasks are performed:

- PGM Reliable Transport Protocol is configured on hosts connected to your network.
- PGM Router Assist is configured on intermediate routers and switches connected to your network.
- IP multicast routing is configured on all devices connected to your network that will be processing IP multicast traffic, including the router on which you are configuring PGM Host.
- Protocol Independent Multicast (PIM) or another IP multicast routing protocol is configured on each PGM interface in your network that will send and receive IP multicast packets.
- A PGM multicast virtual host interface (vif) is configured on the router (if you do not plan to source PGM packets through a physical interface installed on the router). The vif enables the router to send and receive IP multicast packets on several different interfaces at once, as dictated by the multicast routing tables on the router.

Enabling PGM Host

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

When enabling PGM Host on your router, you must source PGM packets through a vif or out a physical interface installed in the router.

Sourcing PGM packets through a vif enables the router to send and receive PGM packets through any router interface. The vif also serves as the interface to the multicast applications that reside at the PGM network layer.

Sourcing IP multicast traffic out a specific physical or logical interface type (for example, an Ethernet, serial, or loopback interface) configures the router to send PGM packets out that interface only and to receive packets on any router interface.

Enabling PGM Host with a Virtual Host Interface

To enable PGM Host globally on the router and to configure the router to source PGM packets through a vif, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip pgm host`	Enables PGM Host (both the source and receiver parts of the PGM network layer) globally on the router and configures the router to source PGM packets through a vif. **Note** You must configure a vif by using the **interface vif** *number* global configuration command on the router before enabling PGM Host on the router; otherwise, the router will not know to use the vif to source PGM packets and PGM Host will not be enabled on the router.

See the "PGM Host with a Virtual Interface Example" section later in this chapter for an example of enabling PGM Host with a virtual interface.

Enabling PGM Host with a Physical Interface

To enable PGM Host globally on the router and to configure the router to source PGM packets through a physical interface, use the following commands in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# ip pgm host`	Enables PGM Host (both the source and receiver part of the PGM network layer) globally on the router.
Step 2	`Router(config)# ip pgm host source-interface` *type number*	Configures the router to source PGM packets through a physical (or logical) interface.

See the "PGM Host with a Physical Interface Example" section later in this chapter for an example of enabling PGM Host with a physical interface.

Verifying PGM Host Configuration

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

To verify that PGM Host is configured correctly on your router, use the following **show** commands in EXEC mode:

- Use the **show ip pgm host sessions** command to display information about current open PGM transport sessions:

```
Router> show ip pgm host sessions

Idx  GSI           Source Port  Type     State   Dest Port  Mcast Address
1    000000000000  0            receiver listen  48059      224.3.3.3
```

```
2    9CD72EF099FA  1025         source   conn    48059      224.1.1.1
```

Specifying a traffic session number or a multicast IP address with the **show ip pgm host sessions** command displays information specific to that PGM transport session:

```
Router> show ip pgm host sessions 2

Idx  GSI           Source Port  Type     State   Dest Port  Mcast Address
2    9CD72EF099FA  1025         source   conn    48059      224.1.1.1

    stream-type (apdu), ttl (255)

    spm-ambient-ivl (6000), txw-adv-secs (6000)
    txw-adv-timeout-max (3600000), txw-rte (16384), txw-secs (30000)
    ncf-max (infinite), spm-rpt-ivl (3000), ihb-min (1000)
    ihb-max (10000), join (0), tpdu-size (16384)
    txw-adv-method (time), tx-buffer-mgmt (return)

    ODATA packets sent                      0
          bytes sent                        0
    RDATA packets sent                      0
          bytes sent                        0
    Total bytes sent                        0
    ADPUs sent                              0
    APDU  transmit memory errors            0
    SPM   packets sent                      6
    NCF   packets sent                      0
    NAK   packets received                  0
          packets received in error         0
    General bad packets                     0
    TX window lead                          0
    TX window trail                         0
```

- Use the **show ip pgm host traffic** command to display traffic statistics at the PGM transport layer:

```
Router> show ip pgm host traffic

General Statistics :

    Sessions in                             0
             out                            0
    Bytes    in                             0
             out                            0

Source Statistics :

    ODATA packets sent                      0
          bytes sent                        0
    RDATA packets sent                      0
          bytes sent                        0
    Total bytes sent                        0
    ADPUs sent                              0
    APDU  transmit memory errors            0
    SPM   packets sent                      0
    NCF   packets sent                      0
    NAK   packets received                  0
          packets received in error         0

Receiver Statistics :

    ODATA packets received                  0
          packets received in error         0
          valid bytes received              0
    RDATA packets received                  0
```

```
      packets received in error          0
      valid bytes received               0
Total valid bytes received               0
Total bytes received in error            0
ADPUs received                           0
SPM   packets received                   0
      packets received in error          0
NCF   packets received                   0
      packets received in error          0
NAK   packets received                   0
      packets received in error          0
      packets sent                       0
Undeliverable packets                    0
General bad packets                      0
Bad checksum packets                     0
```

PGM Router Assist Configuration Task List

To configure PGM Router Assist, perform the required task described in the following section:

- Enabling PGM Router Assist (Required)

Prerequisites

Before you enable PGM Router Assist, ensure that the following tasks are completed:

- PGM Reliable Transport Protocol is configured on hosts connected to your network.
- IP multicast is configured on the router upon which you will enable PGM Router Assist.
- PIM is configured on each PGM interface.

Enabling PGM Router Assist

When enabling PGM Router Assist on your router, you must set up your router to forward PGM packets through a vif or out a physical interface installed in the router.

Setting up your router to forward PGM packets through a vif enables the router to forward PGM packets through any router interface. The vif also serves as the interface to the multicast applications that reside at the PGM network layer.

Setting up your router to forward PGM packets out a specific physical or logical interface type (for example, an Ethernet, serial, or loopback interface) configures the router to forward PGM packets out that interface only.

Enabling PGM Router Assist with a Virtual Host Interface

To enable PGM Router Assist on a vif, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pgm router`	Enables the router to assist PGM on this interface. **Note** You must configure a vif by using the **interface vif** *number* global configuration command on the router before enabling PGM Assist on the router; otherwise, PGM Assist will not be enabled on the router.

See the "PGM Router Assist with a Virtual Interface Example" section later in this chapter for an example of enabling PGM Router Assist with a virtual interface.

Enabling PGM Router Assist with a Physical Interface

To enable PGM Router Assist on the router and to configure the router to forward PGM packets through a physical interface, use the following commands in interface configuration mode:

Command	Purpose
`Router(config-if)# ip pgm router`	Enables the router to assist PGM on this interface.

See the "PGM Router Assist with a Physical Interface Example" section later in this chapter for an example of enabling PGM Router Assist with a physical interface.

Monitoring and Maintaining PGM Host and Router Assist

This section provides information on monitoring and maintaining the PGM Host and Router Assist feature.

Monitoring and Maintaining PGM Host

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

To reset PGM Host connections, use the following command in privileged EXEC mode:

Command	Purpose
`Router# clear ip pgm host {defaults | traffic}`	Resets PGM Host connections to their default values and clears traffic statistics.

To enable PGM Host debugging, use the following command in privileged EXEC mode:

Command	Purpose
`Router# debug ip pgm host`	Displays debug messages for PGM Host.

To display PGM Host information, use the following commands in user EXEC mode, as needed:

Command	Purpose
`Router> show ip pgm host defaults`	Displays the default values for PGM Host traffic.
`Router> show ip pgm host sessions [session-number | group-address]`	Displays open PGM Host traffic sessions.
`Router> show ip pgm host traffic`	Displays PGM Host traffic statistics.

Monitoring and Maintaining PGM Router Assist

To clear PGM traffic statistics, use the following command in privileged EXEC mode:

Command	Purpose
`Router# clear ip pgm router [[traffic [type number]] | [rtx-state [group-address]]]`	Clears the PGM traffic statistics. Use the **rtx-state** keyword to clear PGM retransmit state.

To display PGM information, use the following command in privileged EXEC mode:

Command	Purpose
`Router# show ip pgm router [[interface [type number]] | [state [group-address]] | [traffic [type number]]] [verbose]`	Displays information about PGM traffic statistics and TSI state. The TSI is the transport-layer identifier for the source of a PGM session. Confirms that PGM Router Assist is configured, although there might not be any active traffic. Use the **state** or **traffic** keywords to learn whether an interface is actively using PGM.

PGM Host and Router Assist Configuration Examples

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

This section provides the following configuration examples:

- PGM Host with a Virtual Interface Example
- PGM Host with a Physical Interface Example
- PGM Router Assist with a Virtual Interface Example
- PGM Router Assist with a Physical Interface Example

Note For clarity, extraneous information has been omitted from the examples in the following sections.

PGM Host with a Virtual Interface Example

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

The following example shows PGM Host (both the source and receiver part of the PGM network layer) enabled globally on the router and PGM packets sourced through virtual host interface 1 (vif1). PGM packets can be sent and received on the vif and on the two physical interfaces (ethernet1 and ethernet2) simultaneously.

```
ip multicast-routing
ip routing
ip pgm host

interface vif1
ip address 10.0.0.1 255.255.255.0
ip pim dense-mode
no ip directed-broadcast
no ip mroute-cache

interface ethernet1
ip address 10.1.0.1 255.255.255.0
ip pim dense-mode
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT

interface ethernet2
ip address 10.2.0.1 255.255.255.0
ip pim dense-mode
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT
```

PGM Host with a Physical Interface Example

Note Support for the PGM Host feature has been removed. Use of this feature is not recommended.

The following example shows PGM Host (both the source and receiver part of the PGM network layer) enabled globally on the router and PGM packets sourced out of physical Ethernet interface 1. PGM packets can be received on physical Ethernet interfaces 1 and 2 simultaneously.

```
ip multicast-routing
ip routing
ip pgm host
ip pgm host source-interface ethernet1
ip pgm host source-interface ethernet2

interface ethernet1
ip address 10.1.0.1 255.255.255.0
ip pim dense-mode
```

```
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT

interface ethernet2
ip address 10.2.0.1 255.255.255.0
ip pim dense-mode
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT
```

PGM Router Assist with a Virtual Interface Example

The following example shows PGM Router Assist (the PGM network layer) enabled on the router and the router set up to forward PGM packets on virtual host interface 1 (vif1). PGM packets can be received on interfaces vif1, ethernet1, and ethernet2 simultaneously.

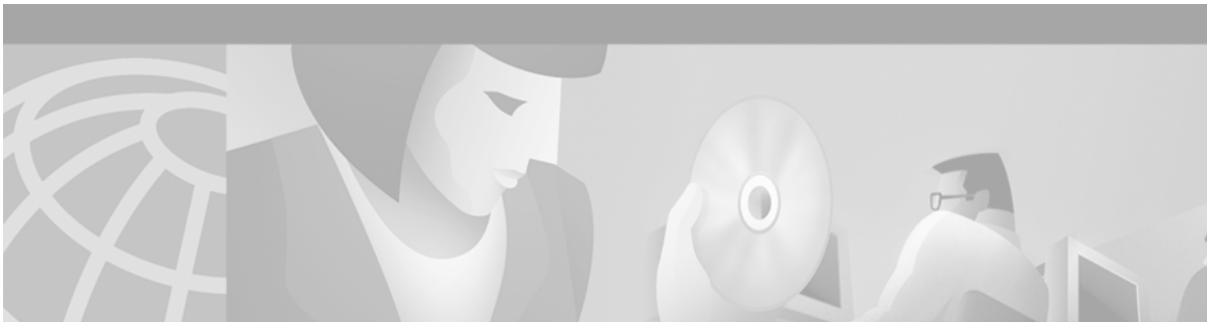
```
ip multicast-routing
ip routing

interface vif1
ip address 10.0.0.1 255.255.255.0
ip pim dense-mode
ip pgm router
no ip directed-broadcast
no ip mroute-cache

interface ethernet1
ip address 10.1.0.1 255.255.255.0
ip pim dense-mode
ip pgm router
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT

interface ethernet2
ip address 10.2.0.1 255.255.255.0
ip pim dense-mode
ip pgm router
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT
```

PGM Router Assist with a Physical Interface Example

The following example shows PGM Router Assist (the PGM network layer) enabled on the router and the router set up to forward PGM packets out of physical Ethernet interfaces 1 and 2. PGM packets can be received on physical Ethernet interfaces 1 and 2 simultaneously.

```
ip multicast-routing
ip routing

interface ethernet1
ip address 10.1.0.1 255.255.255.0
ip pim dense-mode
ip pgm router
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT
```

```
interface ethernet2
ip address 10.2.0.1 255.255.255.0
ip pim dense-mode
ip pgm router
no ip directed-broadcast
no ip mroute-cache
media-type 10BaseT
```



Configuring Unidirectional Link Routing

This chapter describes the unidirectional link routing (UDLR) feature. UDLR provides mechanisms for a router to emulate a bidirectional link to enable the routing of unicast and multicast packets over a physical unidirectional interface, such as a broadcast satellite link. However, there must be a back channel or other path between the routers that share a physical unidirectional link (UDL). A UDLR tunnel is a mechanism for unicast and multicast traffic; Internet Group Management Protocol (IGMP) UDLR and IGMP Proxy are mechanisms for multicast traffic.

For information about tunnel interfaces, refer to the "Configuring Logical Interfaces" chapter in the *Cisco IOS Interface Configuration Guide*. For information about IGMP, refer to the chapter "Configuring IP Multicast Routing" in the *Cisco IOS IP Configuration Guide*.

For a complete description of the UDLR commands used in this chapter, refer to the "Unidirectional Link Routing Commands" chapter in the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast.* To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

UDLR Overview

Both unicast and multicast routing protocols forward data on interfaces from which they have received routing control information. This model works only on bidirectional links for most existing routing protocols. However, some networks use broadcast satellite links, which are unidirectional. For networks that use broadcast satellite links, accomplishing two-way communication over broadcast satellite links presents a problem in terms of discovering and sharing knowledge of a network topology.

Specifically, in unicast routing, when a router receives an update message on an interface for a prefix, it forwards data for destinations that match that prefix out that same interface. This is the case in distance vector routing protocols. Similarly, in multicast routing, when a router receives a join message for a multicast group on an interface, it forwards copies of data destined for that group out that same interface. Based on these principles, existing unicast and multicast routing protocols cannot be supported over UDLs. UDLR is designed to enable the operation of routing protocols over UDLs without changing the routing protocols themselves.

UDLR enables a router to emulate the behavior of a bidirectional link for IP operations over UDLs. UDLR has three complementary mechanisms for bidirectional link emulation, which are described in the following sections:

- UDLR Tunnel
- IGMP UDLR
- IGMP Proxy

You can use each mechanism independently or in conjunction with the others.

UDLR Tunnel

The UDLR tunnel mechanism enables IP and its associated unicast and multicast routing protocols to treat the UDL as being logically bidirectional. A packet that is destined on a receive-only interface is picked up by the UDLR tunnel mechanism and sent to an upstream router using a generic routing encapsulation (GRE) tunnel. The control traffic flows in the opposite direction as the user data flow. When the upstream router receives this packet, the UDLR tunnel mechanism makes it appear that the packet was received on a send-only interface on the UDL.

The purpose of the unidirectional GRE tunnel is to move control packets from a downstream node to an upstream node. The one-way tunnel is mapped to a one-way interface (that goes in the opposite direction). Mapping is performed at the link layer, so the one-way interface appears bidirectional. When the upstream node receives packets over the tunnel, it must make the upper-layer protocols act as if the packets were received on the send-capable UDL.

UDLR tunnel supports the following features:

- Address Resolution Protocol (ARP) and Next Hop Resolution Protocol (NHRP) over a UDL
- Emulation of bidirectional links for all IP traffic (as opposed to only control-only broadcast/multicast traffic)
- Support for IP GRE multipoint at a receive-only tunnel

Note A UDL router can have many routing peers, for example, routers interconnected via a broadcast satellite link. As with bidirectional links, the number of peer routers a router has must be kept relatively small to limit the volume of routing updates that must be processed. For multicast operation, we recommend using the IGMP UDLR mechanism when interconnecting more than 20 routers.

IGMP UDLR

Another mechanism that enables support of multicast routing protocols over UDLs is using IP multicast routing with IGMP, which has been enhanced to accommodate UDLR. This mechanism scales well for many broadcast satellite links.

With IGMP UDLR, an upstream router sends periodic queries for members on the UDL. The queries include a unicast address of the router that is not the unicast address of the unidirectional interface. The downstream routers forward IGMP reports received from directly connected members (on interfaces configured to helper forward IGMP reports) to the upstream router. The upstream router adds the unidirectional interface to the (*, G) outgoing interface list, thereby enabling multicast packets to be forwarded down the UDL.

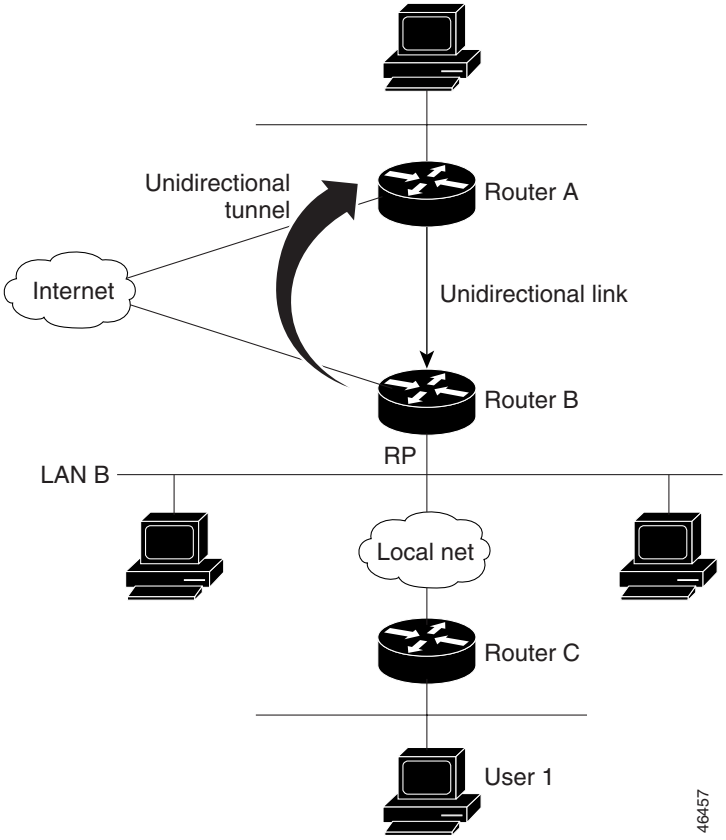
In a large enterprise network, it is not possible to be able to receive IP multicast traffic via satellite and forward the traffic throughout the network. This limitation exists because receiving hosts must be directly connected to the downstream router. However, you can use the IGMP Proxy mechanism to overcome this limitation. See the "IGMP Proxy" section later in this chapter for more information on this mechanism.

For information on IGMP, refer to the "Configuring IP Multicast Routing" chapter in the *Cisco IOS IP Configuration Guide*.

IGMP Proxy

The IGMP Proxy mechanism enables hosts that are not directly connected to a downstream router to join a multicast group sourced from an upstream network. Figure 82 illustrates this mechanism.

Figure 82 IGMP Mroute Proxy Mechanism



In the scenario in Figure 82, the following sequence of events occurs:

1. User 1 joins multicast group G.
2. Router C sends a Protocol Independent Multicast (PIM) join message hop-by-hop to the rendezvous point (Router B).
3. Router B receives the PIM join message and adds a forwarding entry for group G on LAN B.
4. Router B periodically checks its mroute table, and forwards an IGMP report for each multicast group in which it is the reporter.
5. Router A creates and maintains a forwarding entry on the UDL.

In an enterprise network, for example, it is desirable to be able to receive IP multicast traffic via satellite and forward the traffic throughout the network. With IGMP UDLR alone, this scenario is not possible because receiving hosts must be directly connected to the downstream router. IGMP Proxy overcomes this limitation by creating an IGMP report for (*, G) entries in the multicast forwarding table. To make this scenario functional, you must configure PIM sparse mode (PIM-SM) in the network, make the UDL downstream router the rendezvous point (RP) for a select set of addresses, and configure mroute proxy on interfaces leading to PIM-enabled networks with potential members. When the UDL downstream router has a (*, G) forwarding entry for an mroute proxy interface, an IGMP report for the group is created and sent to a loopback interface (IGMP Proxy interface). The loopback interface then uses the same mechanism as IGMP UDLR to forward reports upstream.

Note Because PIM messages are not forwarded upstream, each downstream network and the upstream network has a separate domain.

UDLR Tunnel Configuration Task List

To configure a UDLR tunnel, perform the required tasks described in the following section:

- Configuring UDLR Tunnel (Required)

Prerequisite

Before configuring UDLR tunnel, ensure that all routers on the UDL have the same subnet address. If all routers on the UDL cannot have the same subnet address, the upstream router must be configured with secondary addresses to match all the subnets that the downstream routers are attached to.

Configuring UDLR Tunnel

When configuring a UDLR tunnel, you must configure both the upstream and downstream routers to meet the following conditions:

- You need not assign an IP address to the tunnel (you need not use the **ip address** or **ip unnumbered** interface configuration commands).
- You must configure the tunnel endpoint addresses.
- The tunnel mode defaults to GRE.

- On the upstream router, where the UDL can only send, you must configure the tunnel to receive. When packets are received over the tunnel, the upper-layer protocols treat the packet as though it is received over the unidirectional, send-only interface.
- On the downstream router, where the UDL can only receive, you must configure the tunnel to send. When packets are sent by upper-layer protocols over the interface, they will be redirected and sent over this GRE tunnel.

To configure a UDLR tunnel on the upstream router, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Configures the unidirectional send-only interface.
Step 2	`Router(config-if)# interface tunnel number`	Configures the receive-only tunnel interface.
Step 3	`Router(config-if)# tunnel udlr receive-only type number`	Configures the UDLR tunnel. Use the same *type* and *number* values as the unidirectional send-only interface *type* and *number* values specified with the **interface** *type number* command.
Step 4	`Router(config-if)# tunnel source {ip-address | type number}`	Configures the tunnel source.
Step 5	`Router(config-if)# tunnel destination {hostname | ip-address}`	Configures the tunnel destination.

To configure a UDLR tunnel on the downstream router, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Configures the unidirectional receive-only interface.
Step 2	`Router(config-if)# interface tunnel number`	Configures the send-only tunnel interface.
Step 3	`Router(config-if)# tunnel udlr send-only type number`	Configures the UDLR tunnel. Use the same *type* and *number* values as the unidirectional receive-only interface *type* and *number* values specified with the **interface** *type number* command.
Step 4	`Router(config-if)# tunnel source {ip-address | type number}`	Configures the tunnel source.
Step 5	`Router(config-if)# tunnel destination {hostname | ip-address}`	Configures the tunnel destination.
Step 6	`Router(config-if)# tunnel udlr address-resolution`	Enables the forwarding of ARP and NHRP.

See the "UDLR Tunnel Example" section later in this chapter for an example of how to configure a UDLR tunnel. See the "Integrated UDLR Tunnel, IGMP UDLR, and IGMP Proxy Example" section later in this chapter for an example of how to set up all three UDLR mechanisms in the same configuration.

IGMP UDLR Configuration Task List

To configure IGMP UDLR, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Configuring the IGMP UDL (Required)
- Changing the Distance for the Default RPF Interface (Optional)
- Monitoring IGMP UDLR (Optional)

Prerequisites

Before configuring IGMP UDLR, ensure that the following conditions exist:

- All routers on the UDL have the same subnet address. If all routers on the UDL cannot have the same subnet address, the upstream router must be configured with secondary addresses to match all the subnets that the downstream routers are attached to.
- Multicast receivers are directly connected to the downstream routers.

Configuring the IGMP UDL

To configure an IGMP UDL, you must configure both the upstream and downstream routers to meet the following conditions:

- You need not specify whether the direction is sending or receiving; IGMP learns the direction by the nature of the physical connection.
- When the downstream router receives an IGMP report from a host, the router helpers the report to the IGMP querier associated with the UDL interface identified in the **ip igmp helper-address** interface configuration command.

To configure the IGMP UDL on the upstream router, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip igmp unidirectional-link`	Configures IGMP on the interface to be unidirectional.

To configure the IGMP UDL on the downstream router, use the following commands in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# ip igmp unidirectional-link`	Configures IGMP on the interface to be unidirectional.
Step 2	`Router(config-if)# ip igmp helper-address udl` *type number*	Configures the interface to be an IGMP helper. Use this command on every downstream router, on every interface to a potential multicast receiver. Specify the *type* and *number* values that identify the UDL interface.

See the "IGMP UDLR Example" section later in this chapter for an example of how to configure IGMP UDLR. See the "Integrated UDLR Tunnel, IGMP UDLR, and IGMP Proxy Example" section later in this chapter for an example of how to set up all three UDLR mechanisms in the same configuration.

Changing the Distance for the Default RPF Interface

By default, the distance for the default Reverse Path Forwarding (RPF) interface is 15. Any explicit sources learned by routing protocols will take preference if their distance is less than the distance configured by the **ip multicast default-rpf-distance** global configuration command.

If you want IGMP to prefer the UDLR link, set the distance to be less than the distances of the unicast routing protocols. If you want IGMP to prefer the non-UDLR link, set the distance to be greater than the distances of the unicast routing protocols. This task might be required on downstream routers if you want some sources to use RPF to reach the UDLR link and others to use the terrestrial paths.

To change the distance for the default RPF interface, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip multicast default-rpf-distance` *distance*	Changes the distance for the default RPF interface.

Monitoring IGMP UDLR

To display UDLR information for directly connected groups on interfaces that have a UDL helper address configured, use the following command in EXEC mode:

Command	Purpose
`Router# show ip igmp udlr` [*group-name* | *group-address* | *type number*]	Displays UDLR information for directly connected multicast groups on interfaces that have a UDL helper address configured.

IGMP Proxy Configuration Task List

To configure IGMP Proxy, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining section are optional.

- Configuring IGMP Proxy (Required)
- Verifying IGMP Proxy (Optional)

Prerequisites

Before configuring IGMP Proxy, ensure that the following conditions exist:

- All routers on the UDL have the same subnet address. If all routers on the UDL cannot have the same subnet address; the upstream router must be configured with secondary addresses to match all the subnets that the downstream routers are attached to.
- PIM-SM is configured in the network, the UDL downstream router is the RP for a select set of addresses, and mroute proxy is configured on interfaces leading to PIM-enabled networks with potential members.

Configuring IGMP Proxy

To configure IGMP Proxy, use the following commands in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# ip igmp mroute-proxy` *`type number`*	When used with the **ip igmp proxy-service** command, enables forwarding of IGMP reports to a proxy service interface for all (*, G) forwarding entries for this interface in the multicast forwarding table.
Step 2	`Router(config-if)# ip igmp proxy-service`	Enables the mroute proxy service. Based on the IGMP query interval, the router periodically checks the mroute table for (*, G) forwarding entries that match interfaces configured with the **ip igmp mroute-proxy** command. Where there is a match, one IGMP report is created and received on this interface. This command was intended to be used with the **ip igmp helper-address udl** command, in which case the IGMP report would be forwarded to an upstream router.

See the "IGMP Proxy Example" section later in this chapter for an example of how to configure IGMP Proxy. See the "Integrated UDLR Tunnel, IGMP UDLR, and IGMP Proxy Example" section later in this chapter for an example of how to set up all three UDLR mechanisms in the same configuration.

Verifying IGMP Proxy

To verify that IGMP Proxy is configured properly, use the **show ip igmp interface** EXEC command. The following sample output shows that IGMP Proxy is configured on Ethernet interface 1/0/6.

```
router# show ip igmp udlr

IGMP UDLR Status, UDL Interfaces:Ethernet1/0/6
Group Address    Interface            UDL Reporter     Reporter Expires
239.1.1.2        Ethernet1/0/6        10.10.0.3        00:02:59
239.1.1.1        Ethernet1/0/6        10.10.0.2        00:02:40
```

UDLR Configuration Examples

This section provides the following UDLR examples:

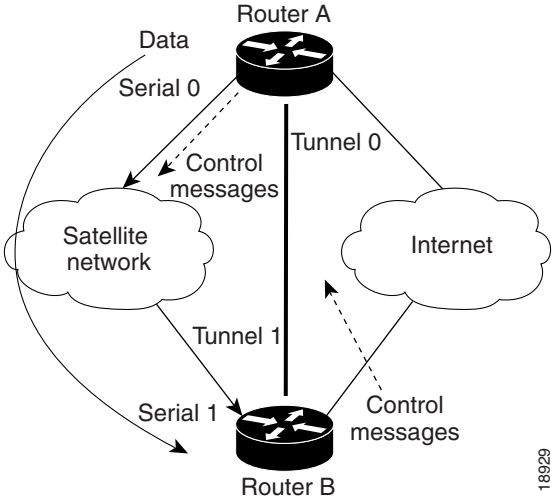
- UDLR Tunnel Example
- IGMP UDLR Example
- IGMP Proxy Example
- Integrated UDLR Tunnel, IGMP UDLR, and IGMP Proxy Example

UDLR Tunnel Example

The following example shows how to configure a UDLR tunnel. In the example, Router A (the upstream router) is configured with Open Shortest Path First (OSPF) and PIM. Serial interface 0 has send-only capability. Therefore, the UDLR tunnel is configured as receive only, and points to serial 0.

Router B (the downstream router) is configured with OSPF and PIM. Serial interface 1 has receive-only capability. Therefore, the UDLR tunnel is configured as send-only, and points to serial 1. The forwarding of ARP and NHRP is enabled. Figure 83 illustrates the example.

Figure 83 UDLR Tunnel Example



Router A Configuration

```
ip multicast-routing
!
! Serial0 has send-only capability
!
interface serial 0
 encapsulation hdlc
 ip address 10.1.0.1 255.255.0.0
 ip pim sparse-dense-mode
!
! Configure tunnel as receive-only UDLR tunnel.
!
interface tunnel 0
 tunnel source 11.0.0.1
 tunnel destination 11.0.0.2
```

```
 tunnel udlr receive-only serial 0
!
! Configure OSPF.
!
router ospf <pid>
 network 10.0.0.0 0.255.255.255 area 0
```

Router B Configuration

```
ip multicast-routing
!
! Serial1 has receive-only capability
!
interface serial 1
 encapsulation hdlc
 ip address 10.1.0.2 255.255.0.0
 ip pim sparse-dense-mode

!
! Configure tunnel as send-only UDLR tunnel.
!
interface tunnel 0
 tunnel source 11.0.0.2
 tunnel destination 11.0.0.1
 tunnel udlr send-only serial 1
 tunnel udlr address-resolution
!
! Configure OSPF.
!
router ospf <pid>
 network 10.0.0.0 0.255.255.255 area 0
```

IGMP UDLR Example

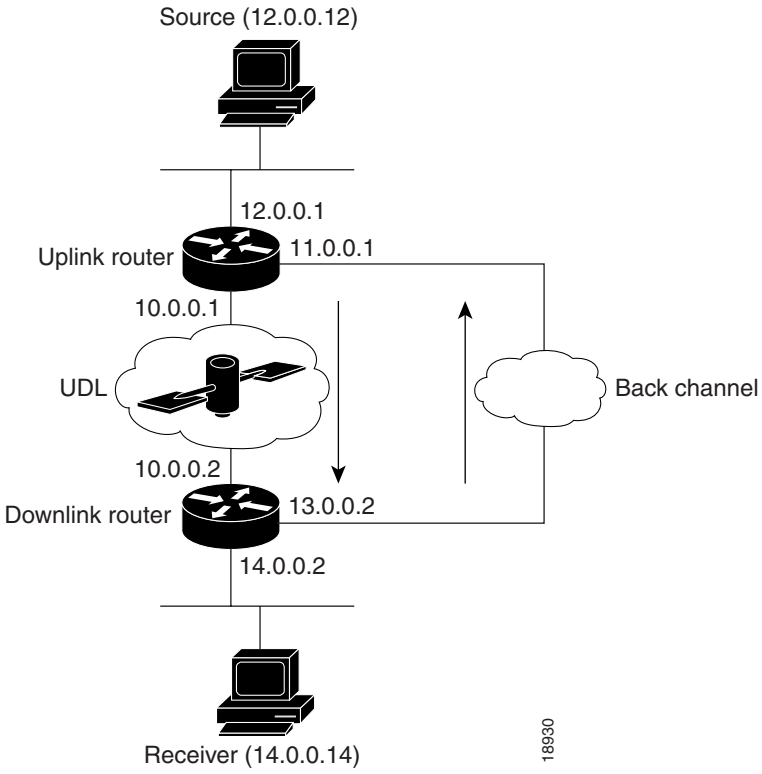
The following example shows how to configure IGMP UDLR. In this example, uplink-rtr is the local upstream router and downlink-rtr is the downstream router. Figure 84 illustrates the example.

Both routers are also connected to each other by a back channel connection. Both routers have two IP addresses: one on the UDL and one on the interface that leads to the back channel. The back channel is any return route and can have any number of routers.

Note Configuring PIM on the back channel interfaces on the uplink router and downlink router is optional.

All routers on a UDL must have the same subnet address. If all routers on a UDL cannot have the same subnet address, the upstream router must be configured with secondary addresses to match all the subnets that the downstream routers are attached to.

Figure 84 IGMP Unidirectional Link Routing Example



Uplink Router (uplink-rtr) Configuration

```
ip multicast-routing
!
! Interface that source is attached to
!
interface ethernet 0
 description Typical IP multicast enabled interface
 ip address 12.0.0.1 255.0.0.0
 ip pim sparse-dense-mode
!
! Back channel
!
interface ethernet 1
 description Back channel which has connectivity to downlink-rtr
 ip address 11.0.0.1 255.0.0.0
 ip pim sparse-dense-mode
!
! Unidirectional link
!
interface serial 0
 description Unidirectional to downlink-rtr
 ip address 10.0.0.1 255.0.0.0
 ip pim sparse-dense-mode
 ip igmp unidirectional-link
 no keepalive
```

Downlink Router (downlink-rtr) Configuration

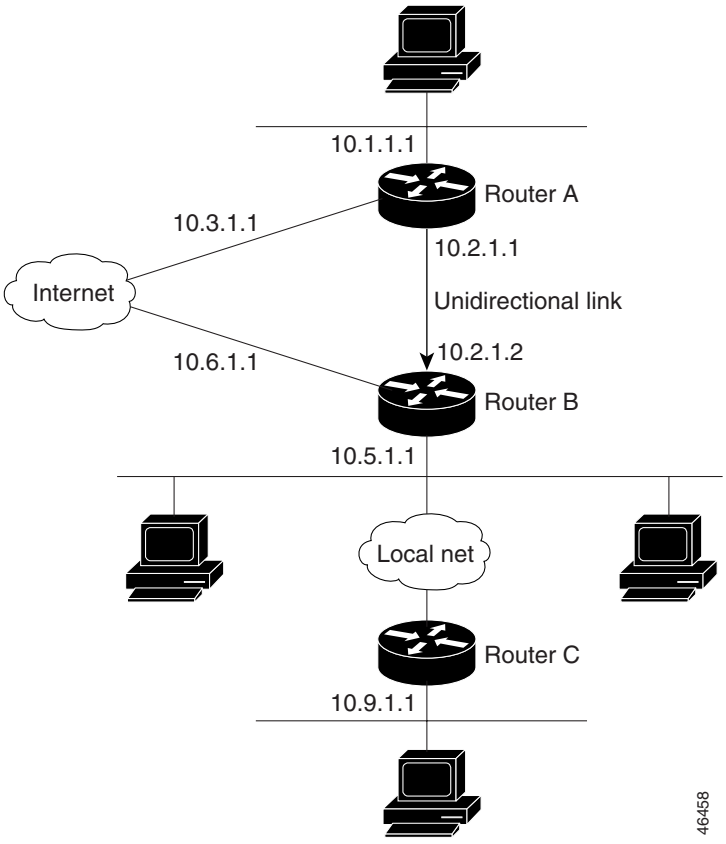
```
ip multicast-routing
!
! Interface that receiver is attached to, configure for IGMP reports to be
```

```
! helpered for the unidirectional interface.
!
interface ethernet 0
 description Typical IP multicast-enabled interface
 ip address 14.0.0.2 255.0.0.0
 ip pim sparse-dense-mode
 ip igmp helper-address udl serial 0
!
! Back channel
!
interface ethernet 1
 description Back channel that has connectivity to downlink-rtr
 ip address 13.0.0.2 255.0.0.0
 ip pim sparse-dense-mode
!
! Unidirectional link
!
interface serial 0
 description Unidirectional to uplink-rtr
 ip address 10.0.0.2 255.0.0.0
 ip pim sparse-dense-mode
 ip igmp unidirectional-link
 no keepalive
```

IGMP Proxy Example

The following example shows how to configure IGMP Proxy. In this example, Router C sends a PIM-SM join message to Router B for multicast group G. Router B will send a request to Router A for an IGMP report for group G. Router A will then forward group G multicast traffic over the UDL. Figure 85 illustrates this example.

Figure 85 IGMP Mroute Proxy Topology



Router A Configuration

```
interface ethernet 0
ip address 10.1.1.1 255.255.255.0
ip pim dense-mode
!
interface ethernet 1
ip address 10.2.1.1 255.255.255.0
ip pim dense-mode
ip igmp unidirectional link
!
interface ethernet 2
ip address 10.3.1.1 255.255.255.0
```

Router B Configuration

```
ip pim rp-address 10.5.1.1 5
access-list 5 permit 239.0.0.0 0.255.255.255
!
interface loopback 0
ip address 10.7.1.1 255.255.255.0
ip pim dense-mode
ip igmp helper-address udl ethernet 0
ip igmp proxy-service
!
interface ethernet 0
ip address 10.2.1.2 255.255.255.0
ip pim dense-mode
ip igmp unidirectional link
```

```
!
interface ethernet 1
ip address 10.5.1.1 255.255.255.0
ip pim sparse-mode
ip igmp mroute-proxy loopback 0
!
interface ethernet 2
ip address 10.6.1.1 255.255.255.0
```

Router C Configuration

```
ip pim rp-address 10.5.1.1 5
access-list 5 permit 239.0.0.0 0.255.255.255
!
interface ethernet 0
ip address 10.8.1.1 255.255.255.0
ip pim sparse-mode
!
interface ethernet 1
ip address 10.9.1.1 255.255.255.0
ip pim sparse-mode
```

Integrated UDLR Tunnel, IGMP UDLR, and IGMP Proxy Example

The following example shows how to configure UDLR tunnels, IGMP UDLR, and IGMP Proxy on both the upstream and downstream routers sharing a UDL:

Upstream Configuration

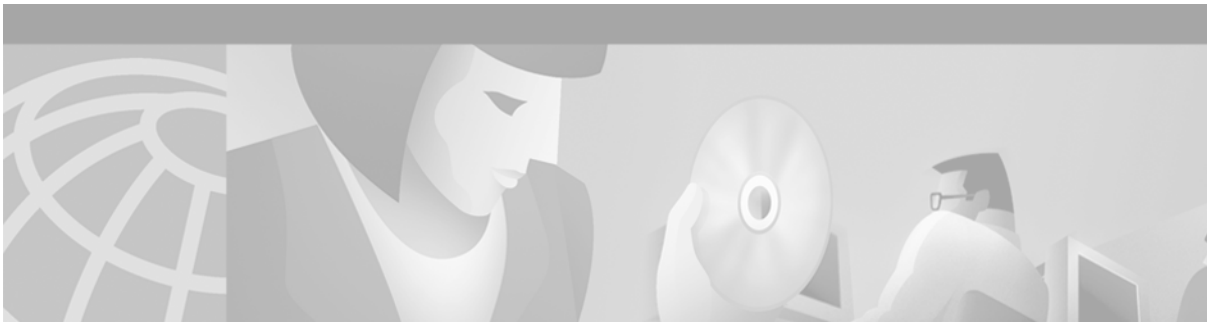
```
ip multicast-routing
!
!
!
interface Tunnel0
  ip address 9.1.89.97 255.255.255.252
  no ip directed-broadcast
  tunnel source 9.1.89.97
  tunnel mode gre multipoint
  tunnel key 5
  tunnel udlr receive-only Ethernet2/3
!
interface Ethernet2/0
  no ip address
  shutdown
!
! user network
interface Ethernet2/1
  ip address 9.1.89.1 255.255.255.240
  no ip directed-broadcast
  ip pim dense-mode
  ip cgmp
  fair-queue 64 256 128
  no cdp enable
  ip rsvp bandwidth 1000 100
!
interface Ethernet2/2
  ip address 9.1.95.1 255.255.255.240
  no ip directed-broadcast
!
! physical send-only interface
interface Ethernet2/3
  ip address 9.1.92.100 255.255.255.240
```

```
  no ip directed-broadcast
  ip pim dense-mode
  ip nhrp network-id 5
  ip nhrp server-only
  ip igmp unidirectional-link
  fair-queue 64 256 31
  ip rsvp bandwidth 1000 100
!
router ospf 1
  network 9.1.92.96 0.0.0.15 area 1
!
ip classless
ip route 9.1.90.0 255.255.255.0 9.1.92.99
!
```

Downstream Configuration

```
ip multicast-routing
!
!
!
interface Loopback0
  ip address 9.1.90.161 255.255.255.252
  ip pim sparse-mode
  ip igmp helper-address udl Ethernet2/3
  ip igmp proxy-service
!
interface Tunnel0
  ip address 9.1.90.97 255.255.255.252
  ip access-group 120 out
  no ip directed-broadcast
  no ip mroute-cache
  tunnel source 9.1.90.97
  tunnel destination 9.1.89.97
  tunnel key 5
  tunnel udlr send-only Ethernet2/3
  tunnel udlr address-resolution
!
interface Ethernet2/0
  no ip address
  no ip directed-broadcast
  shutdown
  no cdp enable
!
! user network
interface Ethernet2/1
  ip address 9.1.90.1 255.255.255.240
  no ip directed-broadcast
  ip pim sparse-mode
  ip igmp mroute-proxy Loopback0
  no cdp enable
!
! Backchannel
interface Ethernet2/2
  ip address 9.1.95.3 255.255.255.240
  no ip directed-broadcast
  no cdp enable
!
! physical receive-only interface
interface Ethernet2/3
  ip address 9.1.92.99 255.255.255.240
  no ip directed-broadcast
  ip pim sparse-mode
  ip igmp unidirectional-link
```

```
  no keepalive
  no cdp enable
!
router ospf 1
  network 9.1.90.0 0.0.0.255 area 1
  network 9.1.92.96 0.0.0.15 area 1
!
ip classless
ip route 0.0.0.0 0.0.0.0 9.1.95.1
! set rpf to be the physical receive-only interface
ip mroute 0.0.0.0 0.0.0.0 9.1.92.96
ip pim rp-address 9.1.90.1
!
! permit ospf, ping and rsvp, deny others
access-list 120 permit icmp any any
access-list 120 permit 46 any any
access-list 120 permit ospf any any
```



Using IP Multicast Tools

This chapter describes IP multicast tools that allow you to trace a multicast path or test a multicast environment. For a complete description of the commands in this chapter, refer to the "IP Multicast Tools Commands" chapter in the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast* publication. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

Multicast Routing Monitor Overview

The Multicast Routing Monitor (MRM) feature is a management diagnostic tool that provides network fault detection and isolation in a large multicast routing infrastructure. It is designed to notify a network administrator of multicast routing problems in near real time.

MRM has three components that play different roles: the Manager, the Test Sender, and the Test Receiver. To test a multicast environment using test packets, perhaps before an upcoming multicast event, you need all three components.

You create a test based on various test parameters, name the test, and start the test. The test runs in the background and the command prompt returns.

If the Test Receiver detects an error (such as packet loss or duplicate packets), it sends an error report to the router configured as the Manager. The Manager immediately displays the error report. (Also, by issuing a certain **show** EXEC command, you can see the error reports, if any.) You then troubleshoot your multicast environment as normal, perhaps using the **mtrace** command from the source to the Test Receiver. If the **show** EXEC command displays no error reports, the Test Receiver is receiving test packets without loss or duplicates from the Test Sender.

The Cisco implementation of MRM supports Internet Draft of *Multicast Routing Monitor (MRM)*, Internet Engineering Task Force (IETF), March 1999.

Benefits

The benefits of the MRM feature are as follows:

- Find fault in multicast routing in near real time—If a problem exists in the multicast routing environment, you will find out about it right away.

- Can verify a multicast environment prior to an event—You need not wait for real multicast traffic to fail in order to find out that a problem exists. You can test the multicast routing environment before a planned event.
- Easy diagnostics—The error information is easy for the user to understand.
- Scalable—This diagnostic tool works well for many users.

Restrictions

You must make sure the underlying multicast forwarding network being tested has no access lists or boundaries that deny the MRM data and control traffic. Specifically, consider the following factors:

- MRM test data are User Datagram Protocol (UDP) and Real-Time Transport Protocol (RTP) packets addressed to the configured multicast group address.
- MRM control traffic between the Test Sender, Test Receiver, and Manager is addressed to the 224.0.1.111 multicast group, which all three components join.

MRM Configuration Task List

To configure and use the MRM feature, perform the required tasks described in the following sections:

- Configuring a Test Sender and Test Receiver (Required)
- Configuring a Manager (Required)
- Conducting an MRM Test (Required)

Configuring a Test Sender and Test Receiver

To configure a Test Receiver on a router or host, use the following commands beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies an interface.
Step 2	`Router(config-if)# ip mrm test-receiver`	Configures the interface to be a Test Receiver.
Step 3	`Router(config)# ip mrm accept-manager {access-list}`	Optionally, specifies that the Test Receiver can accept status report requests only from Managers specified by the access list.

To use MRM on test packets instead of actual IP multicast traffic, use the following commands beginning in global configuration mode to configure a Test Sender *on a different router or host* from where you configured the Test Receiver:

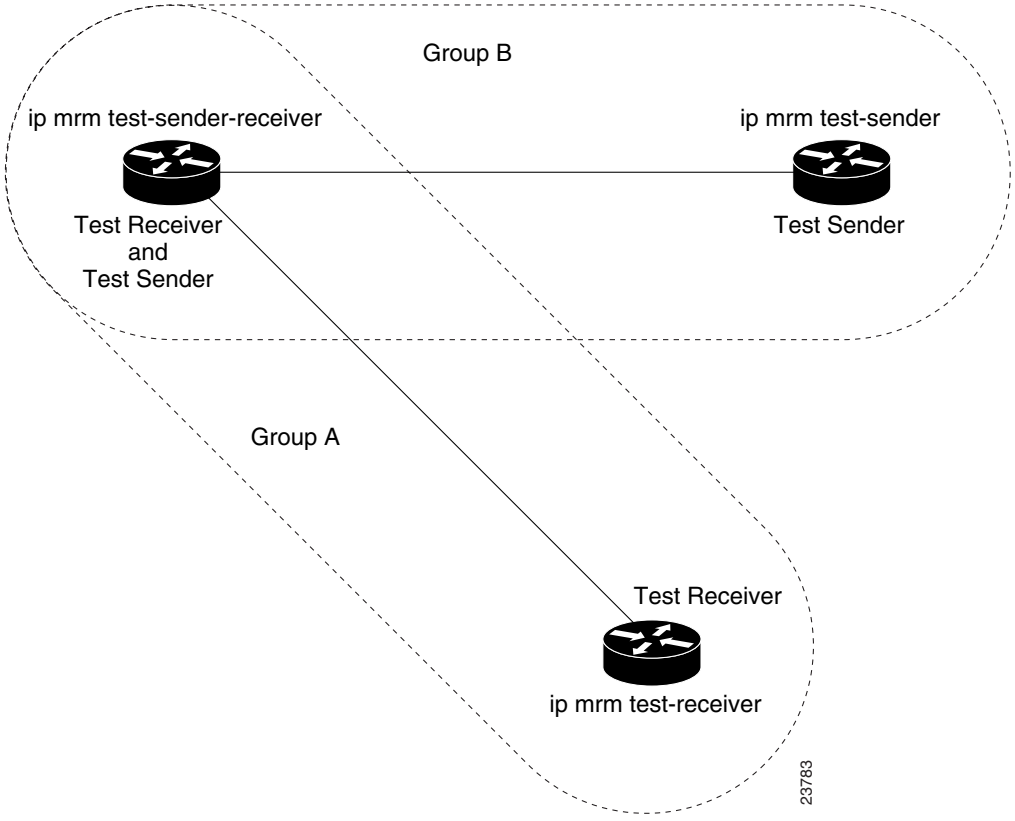
	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies an interface.
Step 2	`Router(config-if)# ip mrm test-sender`	Configures the interface to be a Test Sender.
Step 3	`Router(config)# ip mrm accept-manager {access-list}`	Optionally, specifies that the Test Sender can accept status report requests only from Managers specified by the access list.

Monitoring Multiple Groups

If you have more than one multicast group to monitor, you could configure an interface that is a Test Sender for one group and a Test Receiver for another group.

Figure 86 illustrates an environment where the router on the left is the Test Sender for Group A and the Test Receiver for Group B.

Figure 86 Test Sender and Test Receiver for Different Groups on One Router



To configure the routers in Figure 86 for monitoring more than one multcast group, configure the Test Sender in Group B and the Test Receiver in Group A separately, as already discussed, and configure the following commands beginning in global configuration mode on the router or host that belongs to both Group A and Group B (in the upper left of Figure 86):

	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies an interface.

	Command	Purpose
Step 2	`Router(config-if)# ip mrm test-sender-receiver`	Configures the interface to be a Test Sender for one group and a Test Receiver for another group.
Step 3	`Router(config)# ip mrm accept-manager {access-list} [test-sender | test-receiver]`	Optionally, specifies that the Test Sender or Test Receiver can accept status report requests only from Managers specified by the access list. By default, the command applies to both the Sender and Receiver. Because this device is both, you might need to specify that the restriction applies to only the Sender or only the Receiver.

Configuring a Manager

To configure a router as a Manager in order for MRM to function, use the following commands beginning in global configuration mode. A host cannot be a Manager.

	Command	Purpose
Step 1	`Router(config)# ip mrm manager test-name`	Identifies a test by name, and places the router in manager configuration mode. The test name is used to start, stop, and monitor a test.
Step 2	`Router(config-mrm-manager)# manager type number group ip-address`	Specifies which interface on the router is the Manager, and specifies the multicast group address the Test Receiver will listen to.
Step 3	`Router(config-mrm-manager)# beacon [interval seconds][holdtime seconds] [ttl ttl-value]`	Changes the frequency, duration, or scope of beacon messages that the Manager sends to the Test Sender and Test Receiver.
Step 4	`Router(config-mrm-manager)# udp-port [test-packet port-number] [status-report port-number]`	Changes UDP port numbers to which the Test Sender sends test packets or the Test Receiver sends status reports.
Step 5	`Router(config-mrm-manager)# senders {access-list} [packet-delay milliseconds] [rtp | udp] [target-only | all-multicasts | all-test-senders]`	Configures Test Sender parameters.
Step 6	`Router(config-mrm-manager)# receivers {access-list} [sender-list {access-list} [packet-delay]] [window seconds] [report-delay seconds] [loss percentage] [no-join] [monitor | poll]`	Establishes Test Receivers for MRM, specifies which Test Senders the Test Receivers will listen to, specifies which sources the Test Receivers monitor, specifies the packet delay, and changes Test Receiver parameters.

Conducting an MRM Test

To start and subsequently stop your MRM test, use the following command in EXEC mode:

Command	Purpose
`Router# mrm test-name {start | stop}`	Starts or stops the MRM test.

When the test begins, the Manager sends a unicast control packet to the Test Sender and Test Receiver, and then the Manager starts sending beacons. The Test Sender and Test Receiver send acknowledgments to the Manager and begin sending or receiving test packets. If an error occurs, the Test Receiver sends an error report to the Manager, which immediately displays the report.

You cannot change the Manager parameters while the test is in progress.

Monitoring IP Multicast Routing

To monitor IP multicast routers, packets, and paths, use the following commands in EXEC mode :

Command	Purpose
Router# **mrinfo** [*host-name* | *host-address*] [*source-address* | *interface*]	Queries a multicast router about which neighboring multicast routers are peering with it.
Router# **mstat** *source* [*destination*] [*group*]	Displays IP multicast packet rate and loss information.
Router# **mtrace** {*source-name* | *source-address*} [*destination-name* | *destination-address*][*group-name* | *group-address*]	Traces the path from a source to a destination branch for a multicast distribution tree for a given group.

Monitoring and Maintaining MRM

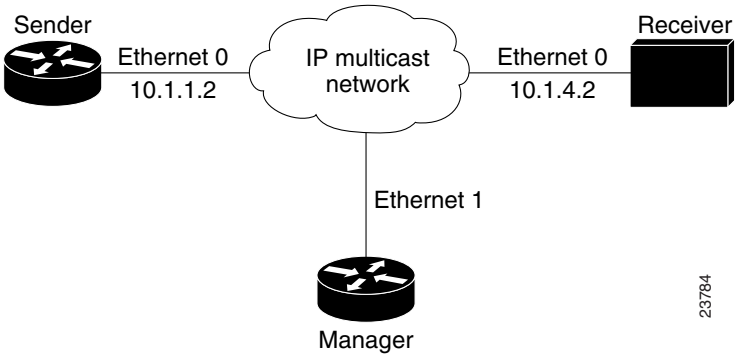
To monitor and maintain MRM, use the following commands in EXEC mode:

Command	Purpose
Router# **clear ip mrm status-report** [*ip-address*]	Clears the status report cache buffer.
Router# **show ip mrm interface** [*type number*]	Displays Test Sender and Test Receiver information.
Router# **show ip mrm manager** [*test-name*]	Displays MRM test information.
Router# **show ip mrm status-report** [*ip-address*]	Displays the status reports (errors) in the circular cache buffer.

MRM Configuration Example

Figure 87 illustrates a Test Sender, a Test Receiver, and a Manager in an MRM environment. The partial configurations for the three devices follow the figure.

Figure 87 Multicast Routing Monitor Example



Test Sender Configuration

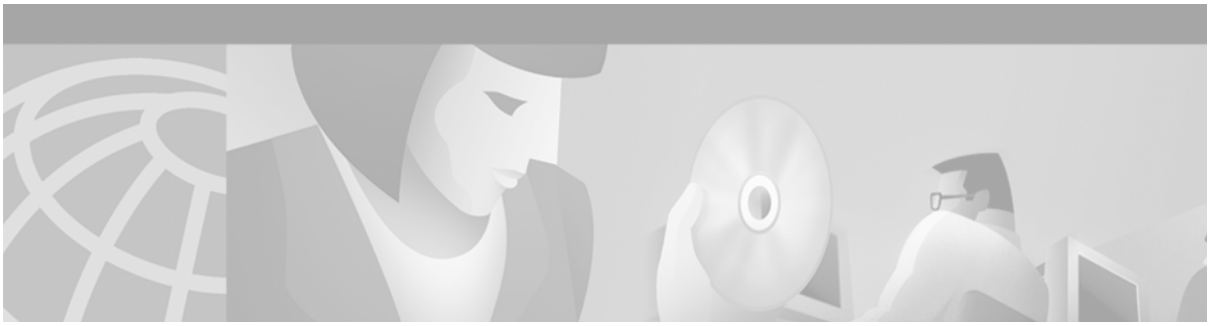
```
interface Ethernet 0
 ip mrm test-sender
```

Test Receiver Configuration

```
interface Ethernet 0
 ip mrm test-receiver
```

Manager Configuration

```
ip mrm manager test1
 manager Ethernet 1 group 239.1.1.1
 senders 1
 receivers 2 sender-list 1
!
access-list 1 permit 10.1.1.2
access-list 2 permit 10.1.4.2
```



Configuring Router-Port Group Management Protocol

This chapter describes the Router-Port Group Management Protocol (RGMP). RGMP is a Cisco protocol that restricts IP multicast traffic in switched networks. RGMP is a Layer 2 protocol that enables a router to communicate to a switch (or a networking device that is functioning as a Layer 2 switch) the multicast group for which the router would like to receive or forward traffic. RGMP restricts multicast traffic at the ports of RGMP-enabled switches that lead to interfaces of RGMP-enabled routers.

For a complete description of the RGMP commands in this chapter, refer to the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

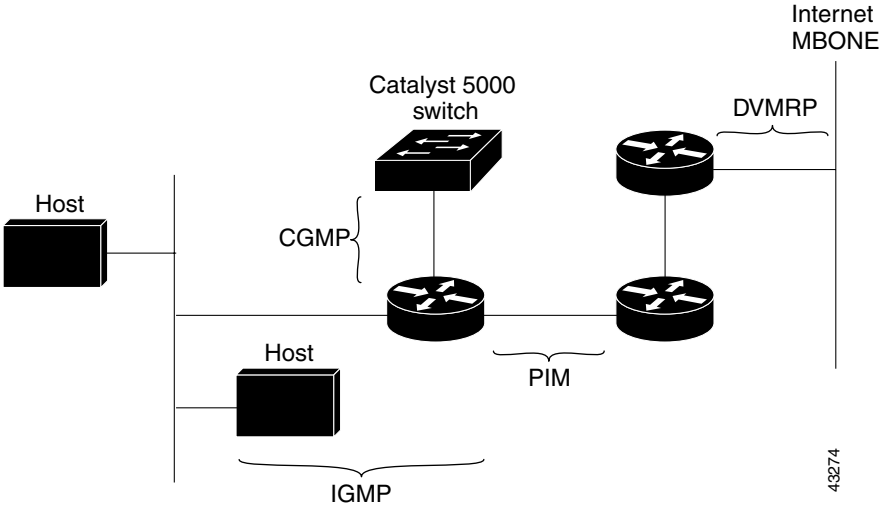
IP Multicast Routing Overview

The Cisco IOS software supports the following protocols to implement IP multicast routing:

- Internet Group Management Protocol (IGMP) is used between hosts on a LAN and the routers on that LAN to track the multicast groups of which hosts are members.
- Protocol Independent Multicast (PIM) is used between routers so that they can track which multicast packets to forward to each other and to their directly connected LANs.
- Distance Vector Multicast Routing Protocol (DVMRP) is the protocol used on the MBONE (the multicast backbone of the Internet). The Cisco IOS software supports PIM-to-DVMRP interaction.
- Cisco Group Management Protocol (CGMP) is a protocol used on routers connected to Catalyst switches to perform tasks similar to those performed by IGMP.
- RGMP is a protocol used on routers connected to Catalyst switches or networking devices functioning as Layer 2 switches to restrict IP multicast traffic. Specifically, the protocol enables a router to communicate to a switch the IP multicast group for which the router would like to receive or forward traffic.

Figure 88 shows where these protocols operate within the IP multicast environment.

Figure 88 IP Multicast Routing Protocols



Note CGMP and RGMP cannot interoperate on the same switched network. If RGMP is enabled on a switch or router interface, CGMP is automatically disabled on that switch or router interface; if CGMP is enabled on a switch or router interface, RGMP is automatically disabled on that switch or router interface.

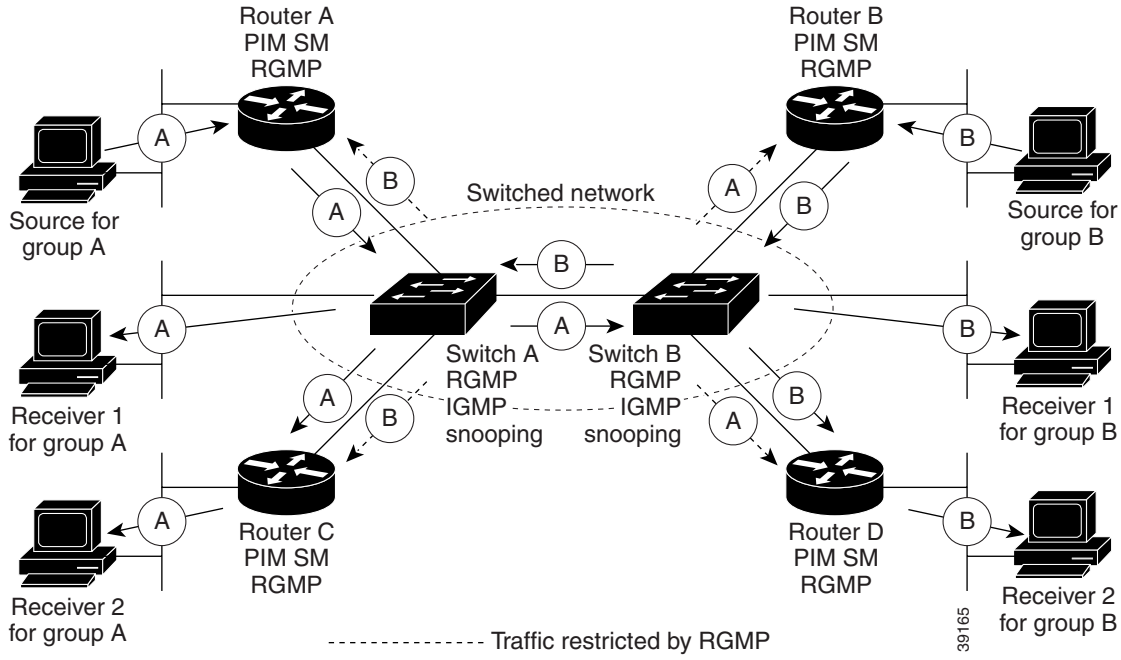
RGMP Overview

RGMP enables a router to communicate to a switch the IP multicast group for which the router would like to receive or forward traffic. RGMP is designed for switched Ethernet backbone networks running PIM sparse mode (PIM-SM) or sparse-dense mode.

Note RGMP-enabled switches and router interfaces in a switched network support directly connected, multicast-enabled hosts that receive multicast traffic. RGMP-enabled switches and router interfaces in a switched network do not support directly connected, multicast-enabled hosts that source multicast traffic. A multicast-enabled host can be a PC, a workstation, or a multicast application running in a router.

Figure 89 shows a switched Ethernet backbone network running PIM in sparse mode, RGMP, and IGMP snooping.

Figure 89 RGMP in a Switched Network

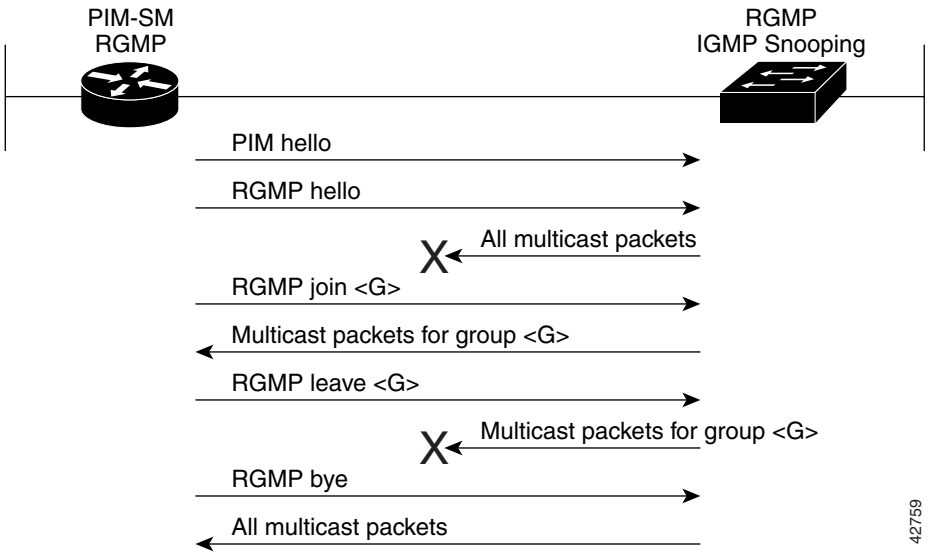


In Figure 89, the sources for the two different multicast groups (the source for group A and the source for group B) send traffic into the same switched network. Without RGMP, traffic from source A is unnecessarily flooded from switch A to switch B, then to router B and router D. Also, traffic from source B is unnecessarily flooded from switch B to switch A, then to router A and router C. With RGMP enabled on all routers and switches in this network, traffic from source A would not flood router B and router D. Also, traffic from source B would not flood router A and router C. Traffic from both sources would still flood the link between switch A and switch B. Flooding over this link would still occur because RGMP does not restrict traffic on links toward other RGMP-enabled switches with routers behind them.

By restricting unwanted multicast traffic in a switched network, RGMP increases the available bandwidth for all other multicast traffic in the network and saves the processing resources of the routers.

Figure 90 shows the RGMP messages sent between an RGMP-enabled router and an RGMP-enabled switch.

Figure 90 RGMP Messages



The router sends simultaneous PIM hello (or a PIM query message if PIM Version 1 is configured) and RGMP hello messages to the switch. The PIM hello message is used to locate neighboring PIM routers. The RGMP hello message instructs the switch to restrict all multicast traffic on the interface from which the switch received the RGMP hello message.

Note RGMP messages are sent to the multicast address 224.0.0.25, which is the local-link multicast address reserved by the Internet Assigned Numbers Authority (IANA) for sending IP multicast traffic from routers to switches.

If RGMP is not enabled on both the router and the switch, the switch automatically forwards all multicast traffic out the interface from which the switch received the PIM hello message.

The router sends the switch an RGMP join <G> message (where G is the multicast group address) when the router wants to receive traffic for a specific multicast group. The RGMP join message instructs the switch to forward multicast traffic for group <G> out the interface from which the switch received the RGMP hello message.

Note The router sends the switch an RGMP join <G> message for a multicast group even if the router is only forwarding traffic for the multicast group into a switched network. By joining a specific multicast group, the router can determine if another router is also forwarding traffic for the multicast group into the same switched network. If two routers are forwarding traffic for a specific multicast group into the same switched network, the two routers use the PIM assert mechanism to determine which router should continue forwarding the multicast traffic into the network.

The router sends the switch an RGMP leave <G> message when the router wants to stop receiving traffic for a specific multicast group. The RGMP leave message instructs the switch to stop forwarding the multicast traffic on the port from which the switch received the PIM and RGMP hello messages.

Note An RGMP-enabled router cannot send an RGMP leave <G> message until the router does not receive or forward traffic from any source for a specific multicast group (if multiple sources exist for a specific multicast group).

The router sends the switch an RGMP bye message when RGMP is disabled on the router. The RGMP bye message instructs the switch to forward the router all IP multicast traffic on the port from which the switch received the PIM and RGMP hello messages, as long as the switch continues to receive PIM hello messages on the port.

RGMP Configuration Task List

To configure RGMP, perform the tasks described in the following sections. The tasks in the first two section are required; the tasks in the remaining section are optional.

- Enabling RGMP (Required)
- Verifying RGMP Configuration (Optional)

See the end of this chapter for the section "RGMP Configuration Example."

Prerequisites

Before you enable RGMP, ensure that the following features are enabled on your router:

- IP routing
- IP multicast
- PIM in sparse mode, sparse-dense mode, source specific mode, or bidirectional mode

If your router is in a bidirectional group, make sure to enable RGMP only on interfaces that do not function as a designated forwarder (DF). If you enable RGMP on an interface that functions as a DF, the interface will not forward multicast packets up the bidirectional shared tree to the rendezvous point (RP).

You must have the following features enabled on your switch:

- IP multicast
- IGMP snooping

Note Refer to the Catalyst switch software documentation for RGMP switch configuration tasks and command information.

Enabling RGMP

To enable RGMP, use the following commands on all routers in your network beginning in global configuration mode:

	Command	Purpose
Step 1	`Router(config)# interface type number`	Specifies the router interface on which you want to configure RGMP and enters interface configuration mode.
Step 2	`Router(config-if)# ip rgmp`	Enables RGMP on a specified interface.

See the "RGMP Configuration Example" section later in this chapter for an example of how to configure RGMP.

Verifying RGMP Configuration

To verify that RGMP is enabled on the correct interfaces, use the **show ip igmp interface** EXEC command:

```
Router> show ip igmp interface

Ethernet1/0 is up, line protocol is up
  Internet address is 10.0.0.0/24
  IGMP is enabled on interface
  Current IGMP version is 2
→ RGMP is enabled
  IGMP query interval is 60 seconds
  IGMP querier timeout is 120 seconds
  IGMP max query response time is 10 seconds
  Last member query response interval is 1000 ms
  Inbound IGMP access group is not set
  IGMP activity: 1 joins, 0 leaves
  Multicast routing is enabled on interface
  Multicast TTL threshold is 0
  Multicast designated router (DR) is 10.0.0.0 (this system)
  IGMP querying router is 10.0.0.0 (this system)
  Multicast groups joined (number of users):
      224.0.1.40(1)
```

Note If RGMP is not enabled on an interface, no RGMP information is displayed in the **show ip igmp interface** command output for that interface.

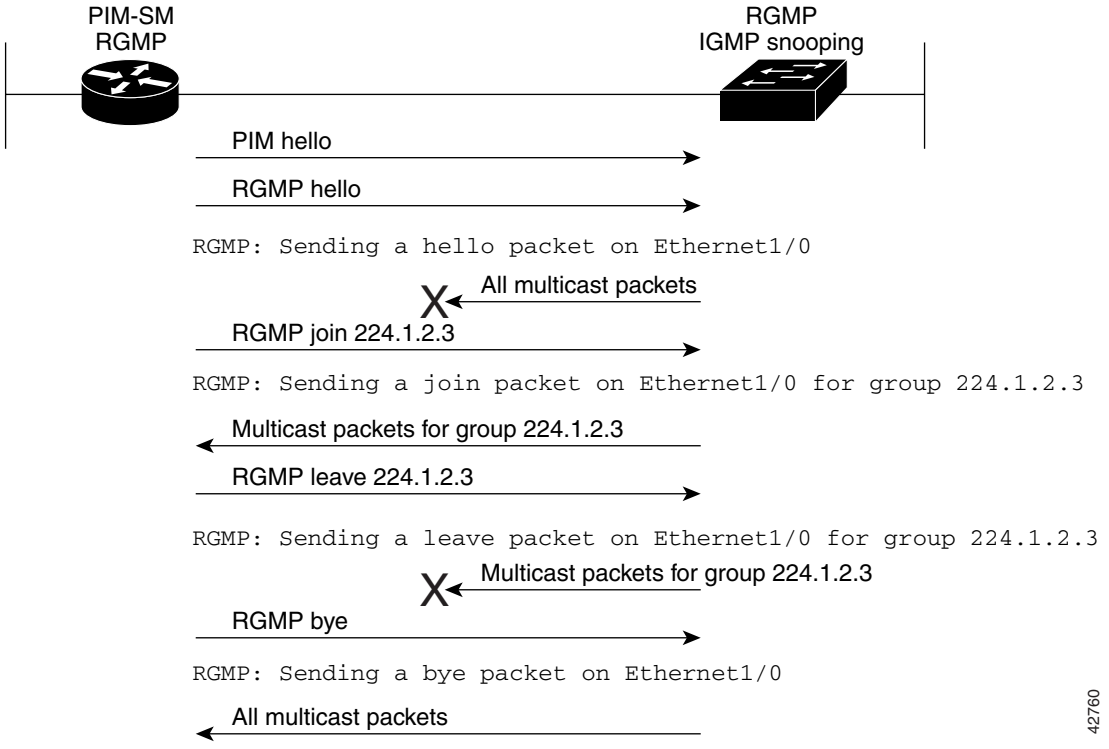
Monitoring and Maintaining RGMP

To enable RGMP debugging, use the following command in privileged EXEC mode:

Command	Purpose
`Router# debug ip rgmp [group-name | group-address]`	Logs debug messages sent by an RGMP-enabled router. Using the command without arguments logs RGMP Join <G> and RGMP leave <G> messages for all multicast groups configured on the router. Using the command with arguments logs RGMP join <G> and RGMP leave <G> messages for the specified group.

Figure 91 shows the debug messages that are logged by an RGMP-enabled router as the router sends RGMP join <G> and RGMP leave <G> messages to an RGMP-enabled switch.

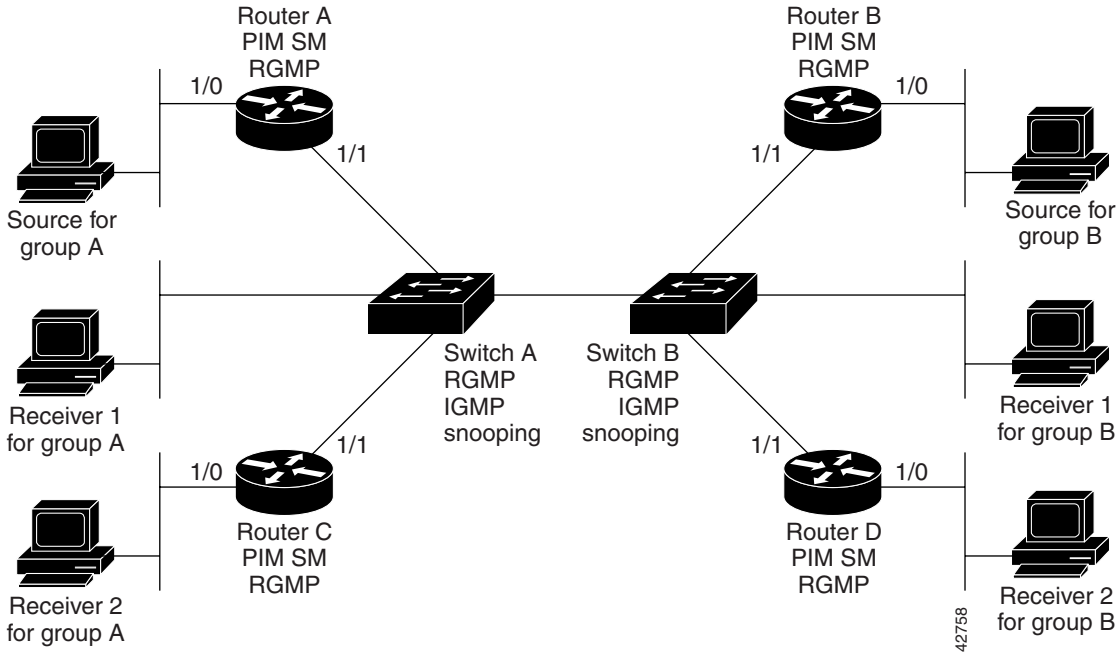
Figure 91 RGMP Debug Messages



RGMP Configuration Example

This section provides an RGMP configuration example that shows the individual configurations for the routers and switches shown in Figure 92.

Figure 92 RGMP Configuration Example



Router A Configuration

```
ip routing
ip multicast-routing

interface ethernet 1/0
  ip address 10.0.0.1 255.0.0.0
  ip pim sparse-dense-mode
  no shutdown

interface ethernet 1/1
  ip address 10.1.0.1 255.0.0.0
  ip pim sparse-dense-mode
  ip rgmp
  no shutdown
```

Router B Configuration

```
ip routing
ip multicast-routing

interface ethernet 1/0
  ip address 10.2.0.1 255.0.0.0
  ip pim sparse-dense-mode
  no shutdown

interface ethernet 1/1
  ip address 10.3.0.1 255.0.0.0
  ip pim sparse-dense-mode
  ip rgmp
```

```
  no shutdown
```

Router C Configuration

```
ip routing
ip multicast-routing

interface ethernet 1/0
  ip address 10.4.0.1 255.0.0.0
  ip pim sparse-dense-mode
  no shutdown

interface ethernet 1/1
  ip address 10.5.0.1 255.0.0.0
  ip pim sparse-dense-mode
  ip rgmp
  no shutdown
```

Router D Configuration

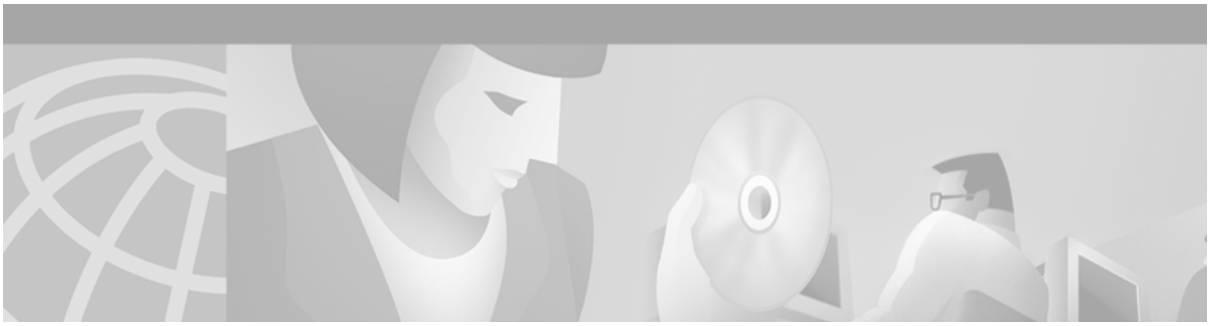
```
ip routing
ip multicast-routing

interface ethernet 1/0
  ip address 10.6.0.1 255.0.0.0
  ip pim sparse-dense-mode
  no shutdown

interface ethernet 1/1
  ip address 10.7.0.1 255.0.0.0
  ip pim sparse-dense-mode
  ip rgmp
  no shutdown
```

Switch A Configuration

```
Switch> (enable) set igmp enable
Switch> (enable) set rgmp enable
```

Switch B Configuration

```
Switch> (enable) set igmp enable
Switch> (enable) set rgmp enable
```



Configuring DVMRP Interoperability

This chapter describes the Distance Vector Multicast Routing Protocol (DVMRP) Interoperability feature. For a complete description of the DVMRP commands in this chapter, refer to the "IP Multicast Routing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast* publication. To locate documentation of other commands that appear in this chapter, use the command reference master index, or search online.

Cisco routers run Protocol Independent Multicast (PIM), and know enough about DVMRP to successfully forward multicast packets to and receive packets from a DVMRP neighbor. It is also possible to propagate DVMRP routes into and through a PIM cloud. The Cisco IOS software propagates DVMRP routes and builds a separate database for these routes on each router, but PIM uses this routing information to make the packet-forwarding decision. Cisco IOS software does not implement the complete DVMRP.

DVMRP builds a parent-child database using a constrained multicast model to build a forwarding tree rooted at the source of the multicast packets. Multicast packets are initially flooded down this source tree. If redundant paths are on the source tree, packets are not forwarded along those paths. Forwarding occurs until prune messages are received on those parent-child links, which further constrains the broadcast of multicast packets.

DVMRP is implemented in the equipment of many vendors and is based on the public-domain mrouted program. The Cisco IOS software supports dynamic discovery of DVMRP routers and can interoperate with them over traditional media such as Ethernet and FDDI, or over DVMRP-specific tunnels.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

Basic DVMRP Interoperability Configuration Task List

To configure basic interoperability with DVMRP machines, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Configuring DVMRP Interoperability (Required)
- Configuring a DVMRP Tunnel (Optional)
- Advertising Network 0.0.0.0 to DVMRP Neighbors (Optional)

For more advanced DVMRP interoperability features, see the section "Advanced DVMRP Interoperability Configuration Task List" later in this chapter.

Configuring DVMRP Interoperability

Cisco multicast routers using PIM can interoperate with non-Cisco multicast routers that use the DVMRP.

PIM routers dynamically discover DVMRP multicast routers on attached networks. Once a DVMRP neighbor has been discovered, the router periodically sends DVMRP report messages advertising the unicast sources reachable in the PIM domain. By default, directly connected subnets and networks are advertised. The router forwards multicast packets that have been forwarded by DVMRP routers and, in turn, forwards multicast packets to DVMRP routers.

You can configure which sources are advertised and which metrics are used by configuring the **ip dvmrp metric** interface configuration command. You can also direct all sources learned via a particular unicast routing process to be advertised into DVMRP.

The mrouted protocol is a public-domain implementation of DVMRP. It is necessary to use mrouted Version 3.8 (which implements a nonpruning version of DVMRP) when Cisco routers are directly connected to DVMRP routers or interoperate with DVMRP routers over an multicast backbone (MBONE) tunnel. DVMRP advertisements produced by the Cisco IOS software can cause older versions of mrouted to corrupt their routing tables and those of their neighbors. Any router connected to the MBONE should have an access list to limit the number of unicast routes that are advertised via DVMRP.

To configure the sources that are advertised and the metrics that are used when DVMRP report messages are sent, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp metric` *metric* [**list** *access-list*] [*protocol process-id*]	Configures the metric associated with a set of destinations for DVMRP reports.

A more sophisticated way to achieve the same results as the preceding command is to use a route map instead of an access list. Thus, you have a finer granularity of control. To subject unicast routes to route map conditions before they are injected into DVMRP, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp metric` *metric* [**route-map** *map-name*]	Subjects unicast routes to route map conditions before they are injected into DVMRP.

Responding to mrinfo Requests

The Cisco IOS software answers mrinfo requests sent by mrouted systems and Cisco routers. The software returns information about neighbors on DVMRP tunnels and all of the interfaces of the router. This information includes the metric (which is always set to 1), the configured TTL threshold, the status of the interface, and various flags. The **mrinfo** EXEC command can also be used to query the router itself, as in the following example:

```
mm1-7kd# mrinfo

  171.69.214.27 (mm1-7kd.cisco.com) [version cisco 11.1] [flags: PMS]:
  171.69.214.27 -> 171.69.214.26 (mm1-r7kb.cisco.com) [1/0/pim/querier]
  171.69.214.27 -> 171.69.214.25 (mm1-45a.cisco.com) [1/0/pim/querier]
  171.69.214.33 -> 171.69.214.34 (mm1-45c.cisco.com) [1/0/pim]
  171.69.214.137 -> 0.0.0.0 [1/0/pim/querier/down/leaf]
```

```
171.69.214.203 -> 0.0.0.0 [1/0/pim/querier/down/leaf]
171.69.214.18 -> 171.69.214.20 (mm1-45e.cisco.com) [1/0/pim]
171.69.214.18 -> 171.69.214.19 (mm1-45c.cisco.com) [1/0/pim]
171.69.214.18 -> 171.69.214.17 (mm1-45a.cisco.com) [1/0/pim]
```

See the "DVMRP Interoperability Example" section later in this chapter for an example of how to configure a PIM router to interoperate with a DVMRP router.

Configuring a DVMRP Tunnel

The Cisco IOS software supports DVMRP tunnels to the MBONE. You can configure a DVMRP tunnel on a router if the other end is running DVMRP. The software then sends and receives multicast packets over the tunnel. This strategy allows a PIM domain to connect to the DVMRP router in the case where all routers on the path do not support multicast routing. You cannot configure a DVMRP tunnel between two routers.

When a Cisco router runs DVMRP over a tunnel, it advertises sources in DVMRP report messages much as it does on real networks. In addition, the software caches DVMRP report messages it receives and uses them in its Reverse Path Forwarding (RPF) calculation. This behavior allows the software to forward multicast packets received over the tunnel.

When you configure a DVMRP tunnel, you should assign a tunnel an address in the following two cases:

- To enable the sending of IP packets over the tunnel
- To indicate whether the Cisco IOS software should perform DVMRP summarization

You can assign an IP address either by using the **ip address** interface configuration command, or by using the **ip unnumbered** interface configuration command to configure the tunnel to be unnumbered. Either of these two methods allows IP multicast packets to flow over the tunnel. The software will not advertise subnets over the tunnel if the tunnel has a different network number from the subnet. In this case, the software advertises only the network number over the tunnel.

To configure a DVMRP tunnel, use the following commands in interface configuration mode:

	Command	Purpose
Step 1	`Router(config-if)# interface tunnel number`	Specifies a tunnel interface in global configuration mode and puts the router into interface configuration mode.
Step 2	`Router(config-if)# tunnel source ip-address`	Sets the source address of the tunnel interface. This address is the IP address of the interface on the router.
Step 3	`Router(config-if)# tunnel destination ip-address`	Sets the destination adddress of the tunnel interface. This address is the IP address of the mrouted multitask router.
Step 4	`Router(config-if)# tunnel mode dvmrp`	Configures a DVMRP tunnel.

Step 5	`Router(config-if)# ip address address mask`
	or
	`Router(config-if)# ip unnumbered type number`
		Assigns an IP address to the interface.
		or
		Configures the interface as unnumbered.

Step 6	`Router(config-if)# ip pim [dense-mode | sparse-mode]`	Configures PIM on the interface.
Step 7	`Router(config-if)# ip dvmrp accept-filter access-list [distance | ip neighbor-list access-list]`	Configures an acceptance filter for incoming DVMRP reports.

See the "DVMRP Tunnel Example" section later in this chapter for an example of how to configure a DVMRP tunnel.

Advertising Network 0.0.0.0 to DVMRP Neighbors

The mrouted protocol is a public domain implementation of DVMRP. If your router is a neighbor to an mrouted Version 3.6 device, you can configure the Cisco IOS software to advertise network 0.0.0.0 to the DVMRP neighbor. Do not advertise the DVMRP default into the MBONE. You must specify whether only route 0.0.0.0 is advertised or if other routes can also be specified.

To advertise network 0.0.0.0 to DVMRP neighbors on an interface, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp default-information {originate | only}`	Advertises network 0.0.0.0 to DVMRP neighbors.

Advanced DVMRP Interoperability Configuration Task List

Cisco routers run PIM and know enough about DVMRP to successfully forward multicast packets to receivers and receive multicast packets from senders. It is also possible to propagate DVMRP routes into and through a PIM cloud. PIM uses this information; however, Cisco routers do not implement DVMRP to forward multicast packets.

The basic DVMRP interoperability features are described in the section "Basic DVMRP Interoperability Configuration Task List" earlier in this chapter. To configure more advanced DVMRP interoperability features on a Cisco router, perform the optional tasks described in the following sections:

- Enabling DVMRP Unicast Routing (Optional)
- Limiting the Number of DVMRP Routes Advertised (Optional)
- Changing the DVMRP Route Threshold (Optional)
- Configuring a DVMRP Summary Address (Optional)
- Disabling DVMRP Automatic summarization (Optional)
- Adding a Metric Offset to the DVMRP Route (Optional)
- Rejecting a DVMRP Nonpruning Neighbor (Optional)
- Configuring a Delay Between DVRMP Reports (Optional)

Enabling DVMRP Unicast Routing

Because policy for multicast routing and unicast routing requires separate topologies, PIM must follow the multicast topology to build loopless distribution trees. Using DVMRP unicast routing, Cisco routers and mrouted machines exchange DVMRP unicast routes, to which PIM can then reverse path forward.

Cisco routers do not perform DVMRP multicast routing among each other, but they can exchange DVMRP routes. The DVMRP routes provide a multicast topology that may differ from the unicast topology. These routes allow PIM to run over the multicast topology, thereby allowing PIM sparse mode over the MBONE topology.

When DVMRP unicast routing is enabled, the router caches routes learned in DVMRP report messages in a DVMRP routing table. PIM prefers DVMRP routes to unicast routes by default, but that preference can be configured.

DVMRP unicast routing can run on all interfaces, including generic routing encapsulation (GRE) tunnels. On DVMRP tunnels, it runs by virtue of DVMRP multicast routing. This feature does not enable DVMRP multicast routing among Cisco routers. However, if there is a DVMRP-capable multicast router, the Cisco router will do PIM/DVMRP multicast routing interaction.

To enable DVMRP unicast routing, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp unicast-routing`	Enables DVMRP unicast routing.

Limiting the Number of DVMRP Routes Advertised

By default, only 7000 DVMRP routes will be advertised over an interface enabled to run DVMRP (that is, a DVMRP tunnel, an interface where a DVMRP neighbor has been discovered, or an interface configured to run the **ip dvmrp unicast-routing** interface configuration command).

To change this limit, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dvmrp route-limit` *count*	Changes the number of DVMRP routes advertised over an interface enabled to run DVMRP.

Changing the DVMRP Route Threshold

By default, 10,000 DVMRP routes may be received per interface within a 1-minute interval. When that rate is exceeded, a syslog message is issued, warning that a route surge might be occurring. The warning is typically used to quickly detect when routers have been misconfigured to inject a large number of routes into the MBONE.

To change the threshold number of routes that trigger the warning, use the following command in global configuration mode:

Command	Purpose
`Router(config)# ip dvmrp routehog-notification` *route-count*	Configures the number of routes that trigger a syslog message.

Use the **show ip igmp interface** EXEC command to display a running count of routes. When the count is exceeded, "*** ALERT ***" is appended to the line.

Configuring a DVMRP Summary Address

You can customize the summarization of DVMRP routes if the default classful automatic summarization does not suit your needs. To summarize such routes, specify a summary address by using the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp summary-address summary-address mask [metric value]`	Specifies a DVMRP summary address.

Note At least one, more-specific route must be present in the unicast routing table before a configured summary address will be advertised.

Disabling DVMRP Automatic summarization

By default, the Cisco IOS software performs some level of DVMRP summarization automatically. Disable this function if you want to advertise all routes, not just a summary. If you configure the **ip dvmrp summary-address** interface configuration command and did not configure the **no ip dvmrp auto-summary** command, you get both custom and automatic summaries.

To disable DVMRP automatic summarization, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# no ip dvmrp auto-summary`	Disables DVMRP automatic summarization.

Adding a Metric Offset to the DVMRP Route

By default, the router increments by 1 the metric of a DVMRP route advertised in incoming DVMRP reports. You can change the metric if you want to favor or not favor a certain route. The DVMRP metric is a hop count. Therefore, a very slow serial line of one hop is preferred over a route that is two hops over FDDI or another fast medium.

For example, perhaps a route is learned by Router A and the same route is learned by Router B with a higher metric. If you want to use the path through Router B because it is a faster path, you can apply a metric offset to the route learned by Router A to make it larger than the metric learned by Router B, allowing you to choose the path through Router B.

To change the default metric, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp metric-offset [in | out] increment`	Changes the metric added to DVMRP routes advertised in incoming reports.

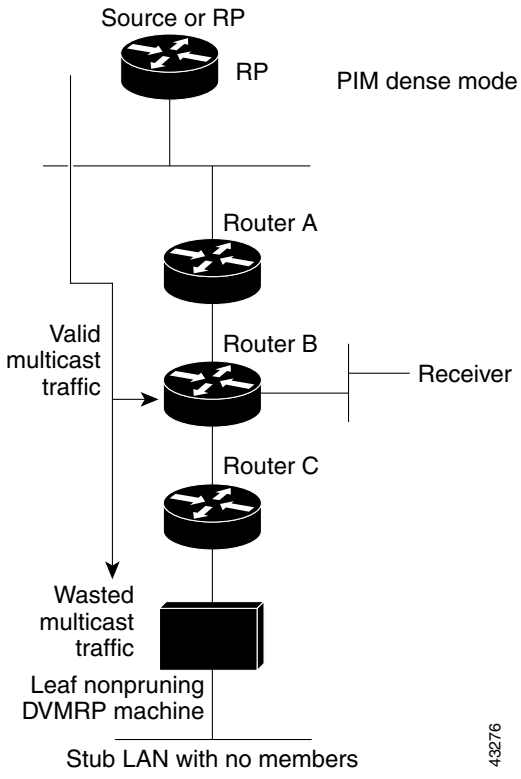
Similar to the **metric** keyword in mrouted configuration files, the following is true when using the **ip dvmrp metric-offset** interface configuration command:

- When you specify the **in** keywordor no keyword, the *increment* value is added to incoming DVMRP reports and is reported in mrinfo replies. The default value for the **in** keyword is 1.
- When you specify the **out** keyword, the *increment* is added to outgoing DVMRP reports for routes from the DVMRP routing table. The default value for the **out** keyword is 0.

Rejecting a DVMRP Nonpruning Neighbor

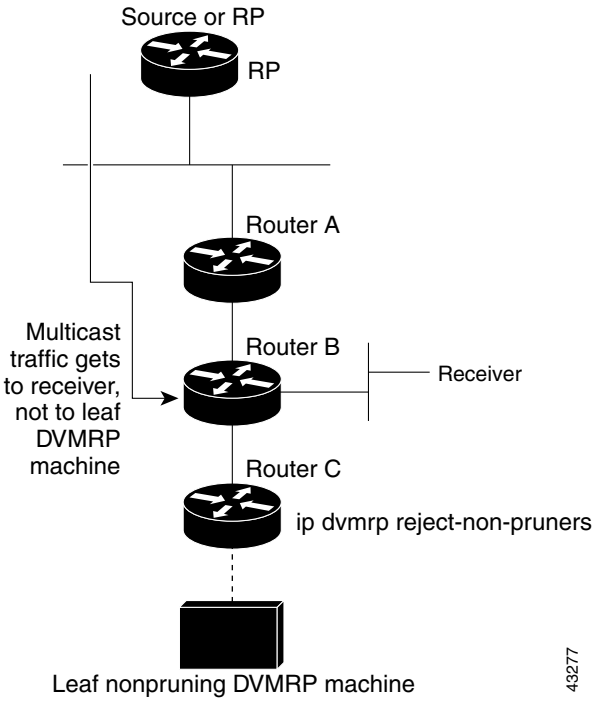
By default, Cisco routers accept all DVMRP neighbors as peers, regardless of their DVMRP capability or lack of. However, some non-Cisco machines run old versions of DVMRP that cannot prune, so they will continuously receive forwarded packets unnecessarily, wasting bandwidth. Figure 93 shows this scenario.

Figure 93 Leaf Nonpruning DVMRP Neighbor



You can prevent a router from peering (communicating) with a DVMRP neighbor if that neighbor does not support DVMRP pruning or grafting. To do so, configure Router C (which is a neighbor to the leaf, nonpruning DVMRP machine) with the **ip dvmrp reject-non-pruners** interface configuration command on the interface to the nonpruning machine. Figure 94 illustrates this scenario. In this case, when the router receives a DVMRP probe or report message without the Prune-Capable flag set, the router logs a syslog message and discards the message.

Figure 94 Router Rejects Nonpruning DVMRP Neighbor



Note that the **ip dvmrp reject-non-pruners** command prevents peering with neighbors only. If there are any nonpruning routers multiple hops away (downstream toward potential receivers) that are not rejected, then a nonpruning DVMRP network might still exist.

To prevent peering with nonpruning DVMRP neighbors, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp reject-non-pruners`	Prevents peering with nonpruning DVMRP neighbors.

Configuring a Delay Between DVRMP Reports

You can configure an interpacket delay of a DVMRP report. The delay is the number of milliseconds that elapse between transmissions of sets of packets that constitute a report. The number of packets in the set is determined by the *burst* value, which defaults to 2 packets. The *milliseconds* value defaults to 100 milliseconds.

To change the default values of the delay, use the following command in interface configuration mode:

Command	Purpose
`Router(config-if)# ip dvmrp output-report-delay` *milliseconds* [*burst*]	Configures an interpacket delay between DVMRP reports.

Monitoring and Maintaining DVMRP

To clear routes from the DVMRP routing table, use the following command in EXEC mode:

Command	Purpose
`Router# clear ip dvmrp route { * | route}`	Deletes routes from the DVMRP routing table.

To display entries in the DVMRP routing table, use the following command in EXEC mode:

Command	Purpose
`Router# show ip dvmrp route [name | ip-address | type number]`	Displays the entries in the DVMRP routing table.

DVMRP Configuration Examples

This section provides the following DVMRP configuration examples:

- DVMRP Interoperability Example
- DVMRP Tunnel Example

DVMRP Interoperability Example

The following example configures DVMRP interoperability for configurations when the PIM router and the DVMRP router are on the same network segment. In this example, access list 1 advertises the networks (198.92.35.0, 198.92.36.0, 198.92.37.0, 131.108.0.0, and 150.136.0.0) to the DVMRP router, and access list 2 is used to prevent all other networks from being advertised (the **ip dvmrp metric 0** interface configuration command).

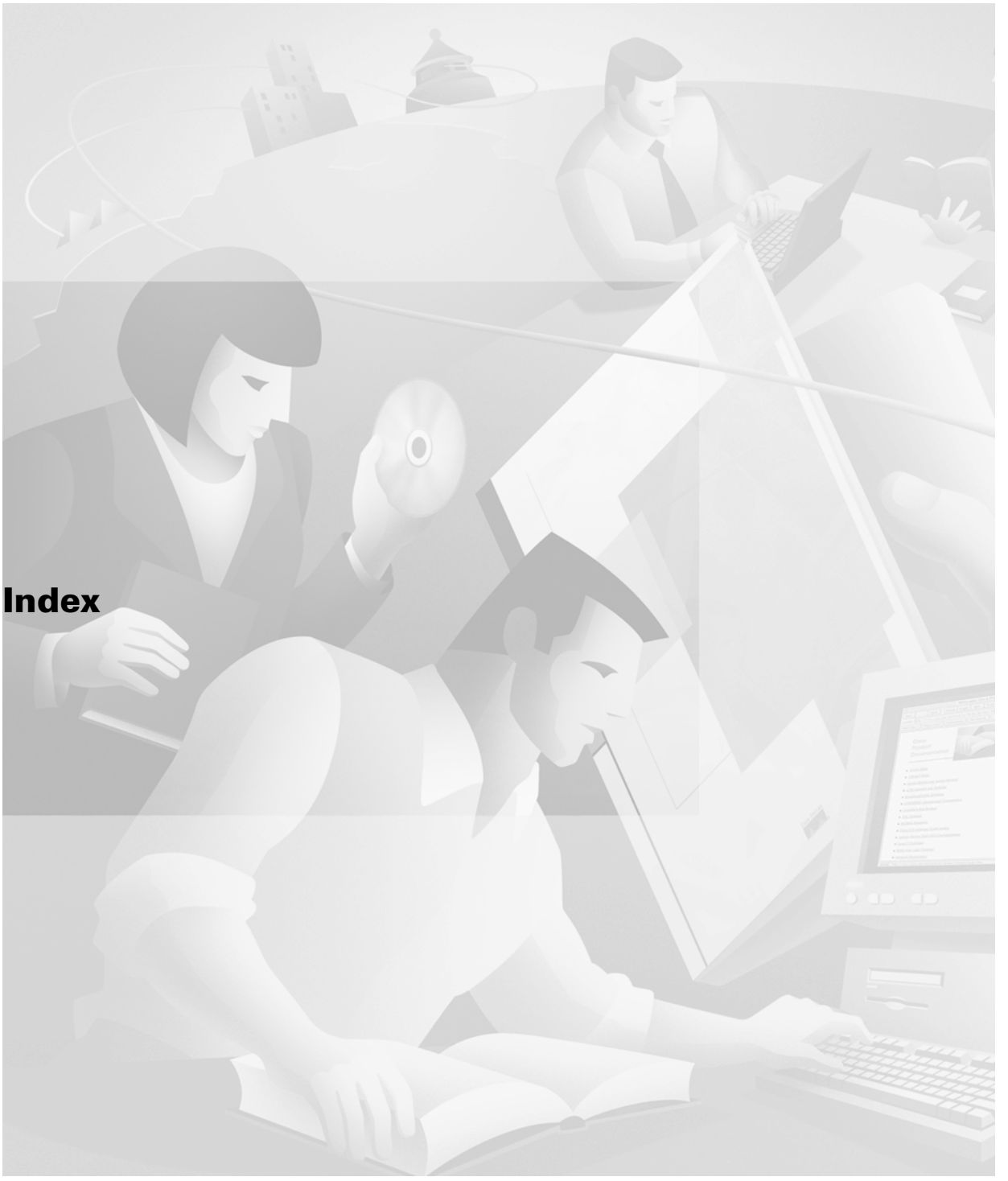
```
interface ethernet 0
 ip address 131.119.244.244 255.255.255.0
 ip pim dense-mode
 ip dvmrp metric 1 list 1
 ip dvmrp metric 0 list 2

access-list 1 permit 198.92.35.0 0.0.0.255
access-list 1 permit 198.92.36.0 0.0.0.255
access-list 1 permit 198.92.37.0 0.0.0.255
access-list 1 permit 131.108.0.0 0.0.255.255
access-list 1 permit 150.136.0.0 0.0.255.255
access-list 1 deny   0.0.0.0 255.255.255.255
access-list 2 permit 0.0.0.0 255.255.255.255
```

DVMRP Tunnel Example

The following example configures a DVMRP tunnel:

```
!
ip multicast-routing
!
interface tunnel 0
```

```
 ip unnumbered ethernet 0
 ip pim dense-mode
 tunnel source ethernet 0
 tunnel destination 192.70.92.133
 tunnel mode dvmrp
!
interface ethernet 0
 description Universitat DMZ-ethernet
 ip address 192.76.243.2 255.255.255.0
 ip pim dense-mode
```



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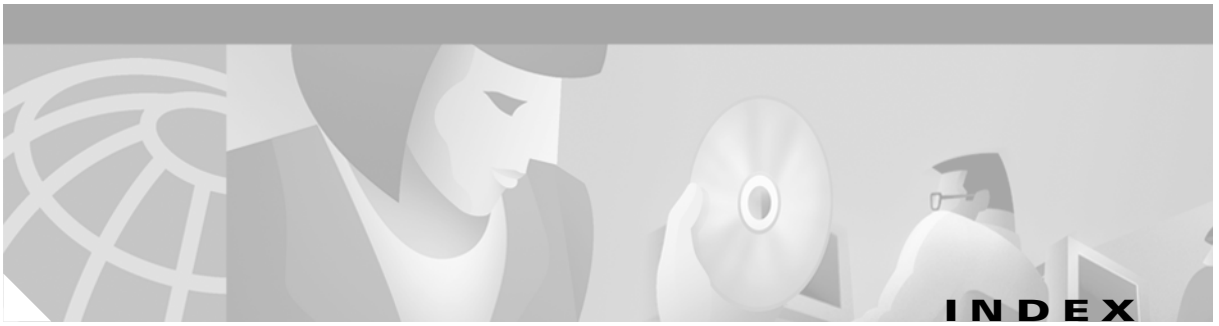

Symbols

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