Network Time Protocol (NTP) General Overview

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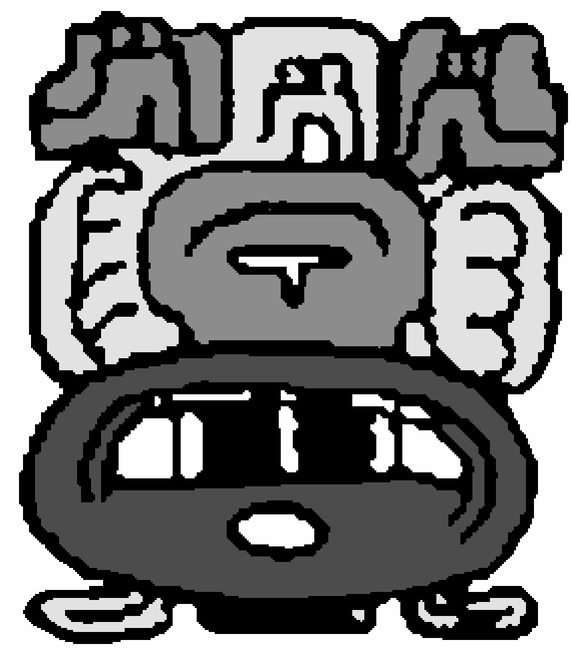

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Introduction

- Network Time Protocol (NTP) synchronizes clocks of hosts and routers in the Internet
- Well over 100,000 NTP peers deployed in the Internet and its tributaries all over the world
- Provides nominal accuracies of low tens of milliseconds on WANs, submilliseconds on LANs, and submicroseconds using a precision time source such as a cesium oscillator or GPS receiver
- Unix NTP daemon ported to almost every workstation and server platform available today - from PCs to Crays - Unix, Windows, VMS and embedded systems

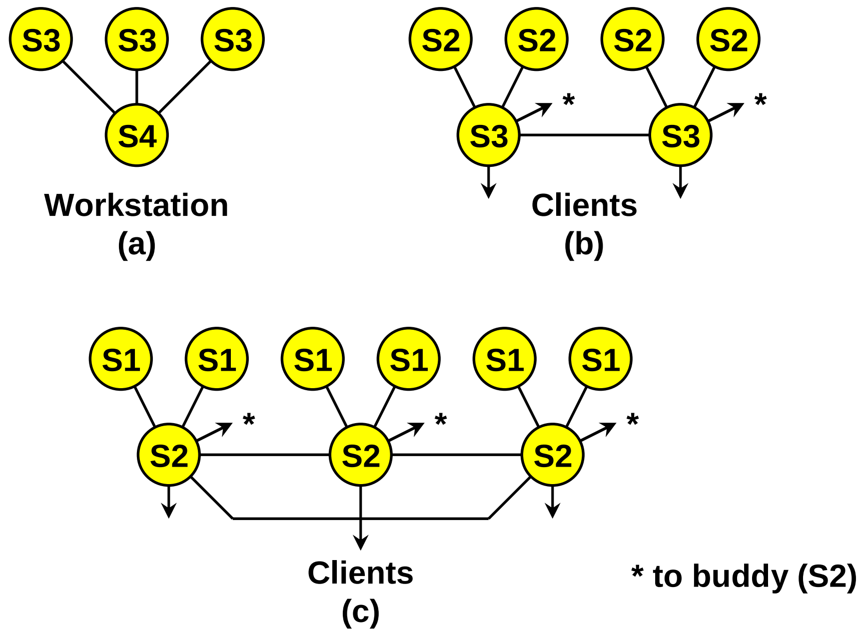
Needs for synchronized time

- Distributed database journal and transaction ordering
- Stock market buy and sell orders
- Cryptographic timestamping services
- Intrusion detection, isolation and logging
- Network monitoring, measurement and control
- Distributed multimedia stream synchronization
- RPC at-most-once transactions; replay defenses; sequence-number disambiguation
- Research experiment setup, measurement and control
- Cryptographic key management and lifetime control

NTP capsule summary

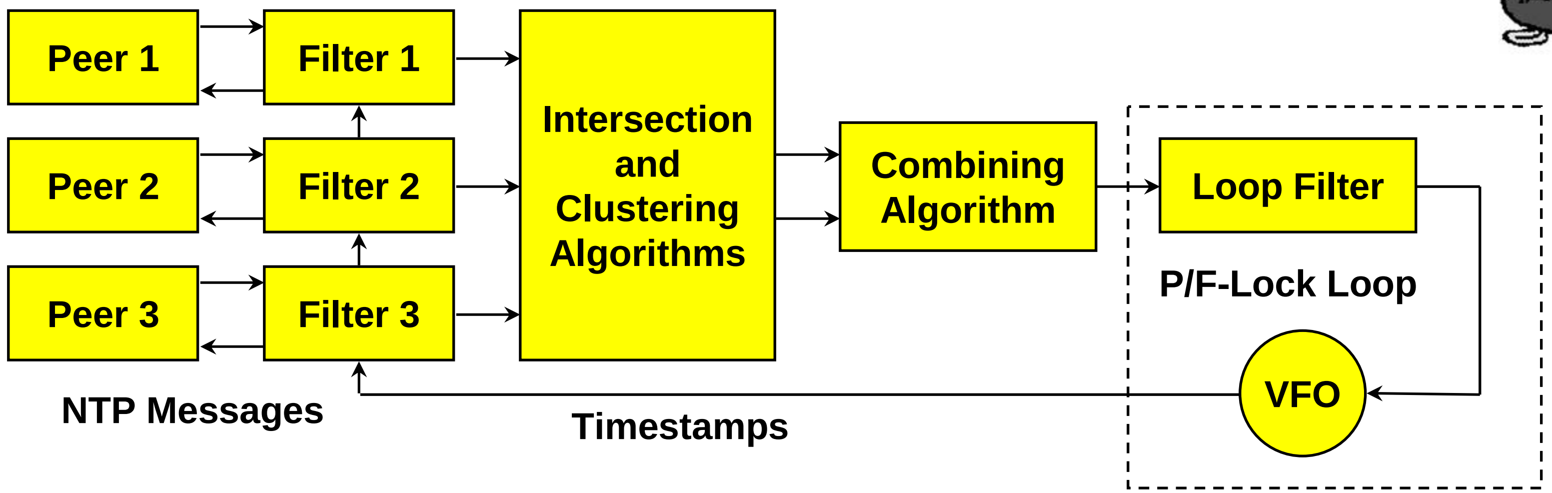
- Primary (stratum 1) servers synchronize to national time standards via radio, satellite and modem
- Secondary (stratum 2, ...) servers and clients synchronize to primary servers via hierarchical subnet
- Clients and servers operate in master/slave, symmetric or multicast modes with or without cryptographic authentication
- Reliability assured by redundant servers and diverse network paths
- Engineered algorithms reduce jitter, mitigate multiple sources and avoid improperly operating servers
- System clock is disciplined in time and frequency using an adaptive algorithm responsive to network time jitter and clock oscillator frequency wander

NTP configuration examples



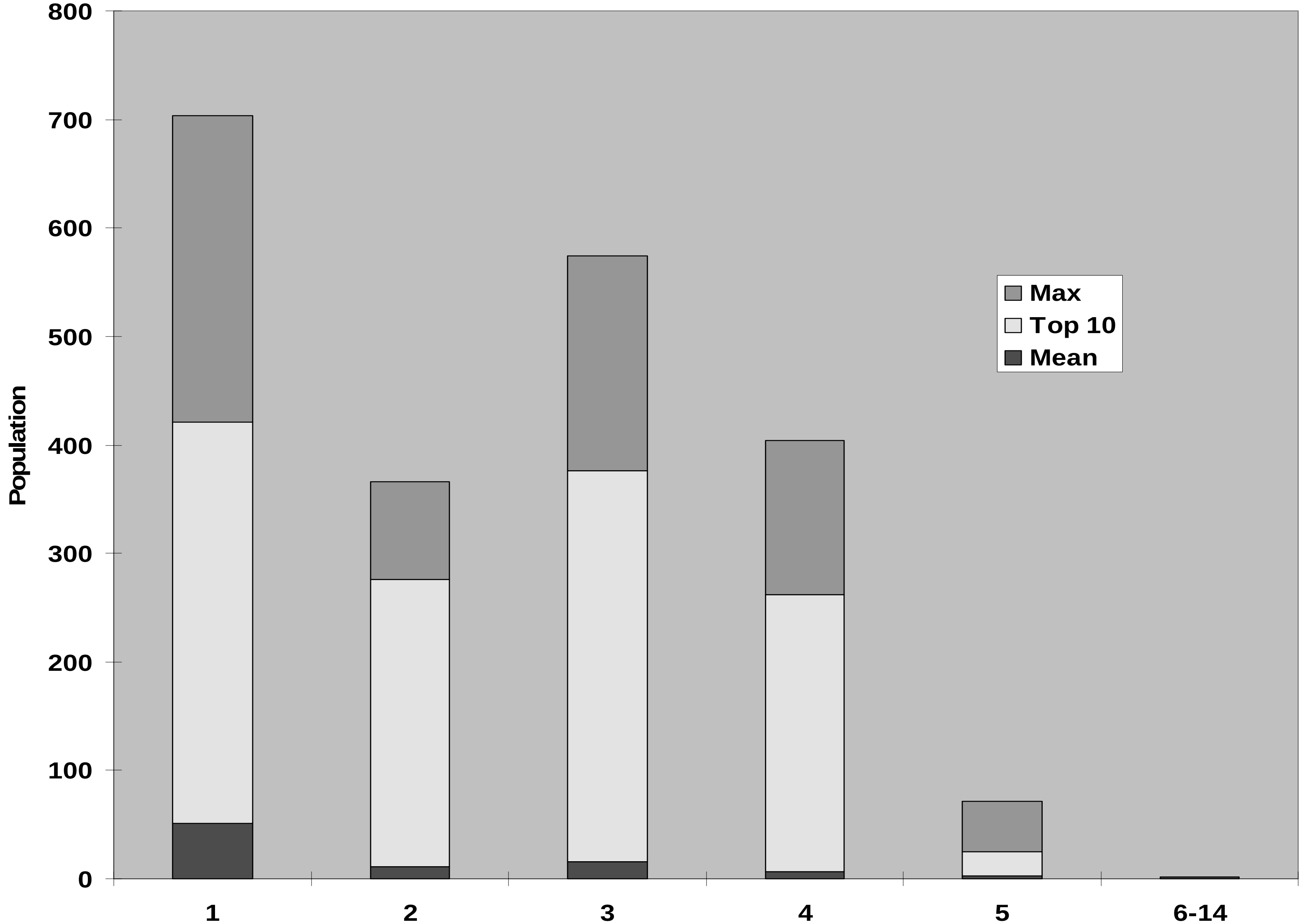
- (a) Workstations use multicast mode with multiple department servers
- (b) Department servers use client/server modes with multiple campus servers and symmetric modes with each other
- (c) Campus servers use client/server modes with up to six different external primary servers and symmetric modes with each other and external secondary (buddy) servers

How NTP works

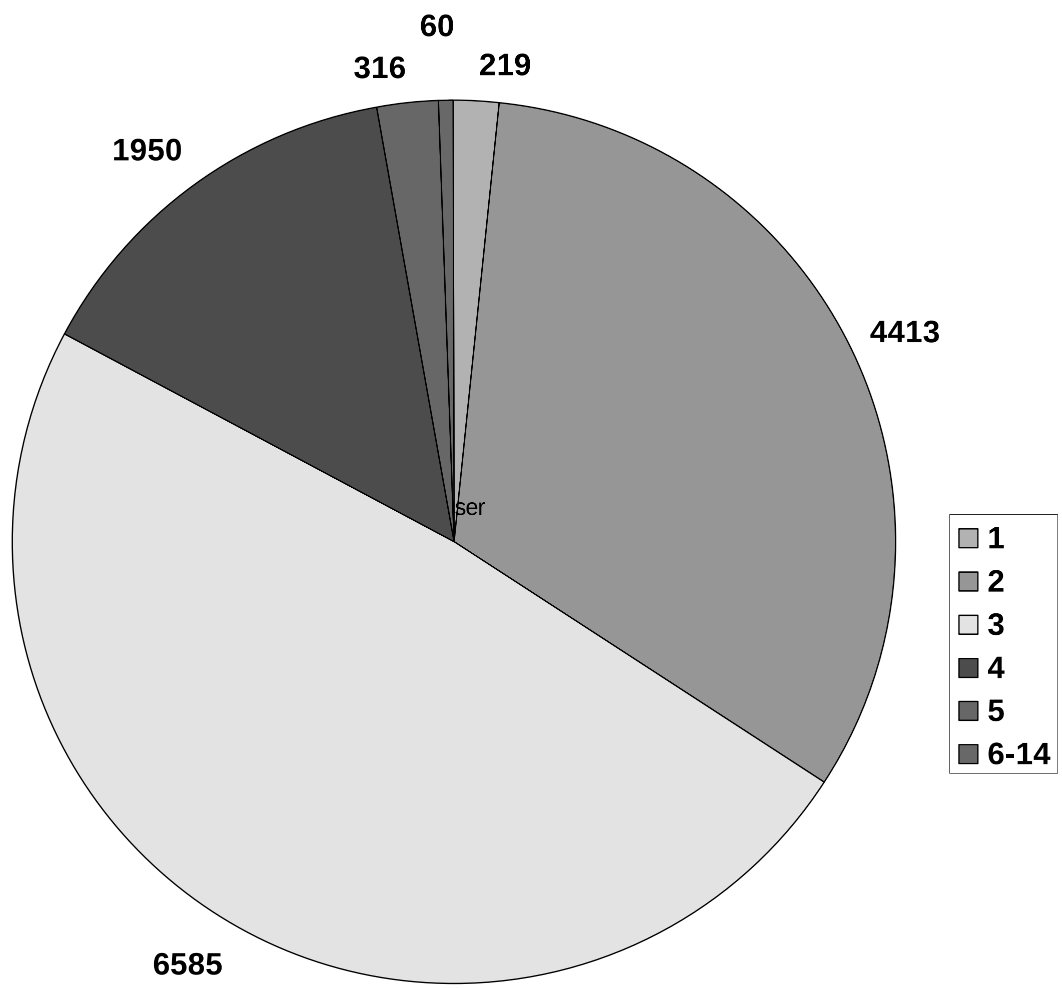


- Multiple synchronization peers provide redundancy and diversity
- Clock filters select best from a window of eight clock offset samples
- Intersection and clustering algorithms pick best subset of servers believed to be accurate and fault-free
- Combining algorithm computes weighted average of offsets for best accuracy
- Phase/frequency-lock feedback loop disciplines local clock time and frequency to maximize accuracy and stability

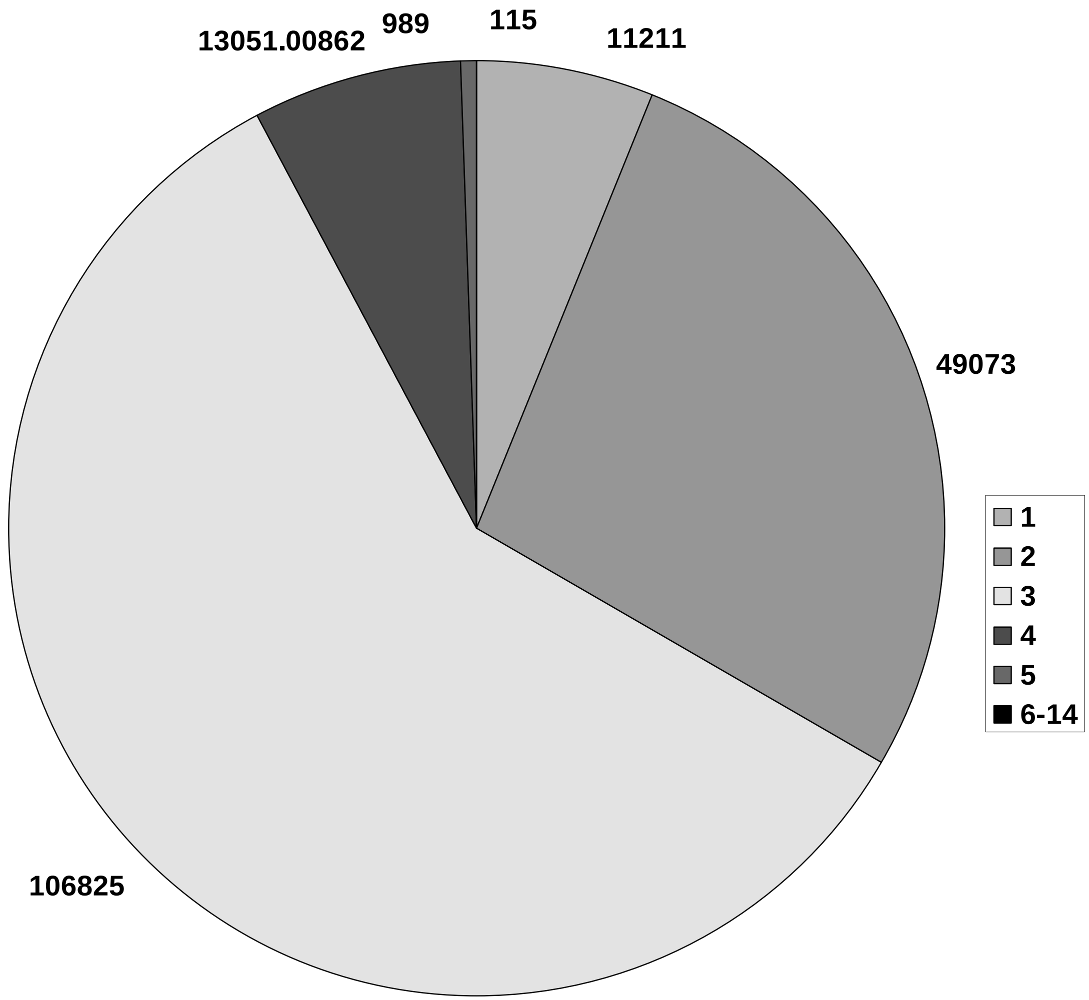
Clients per server population by stratum (1997 survey)



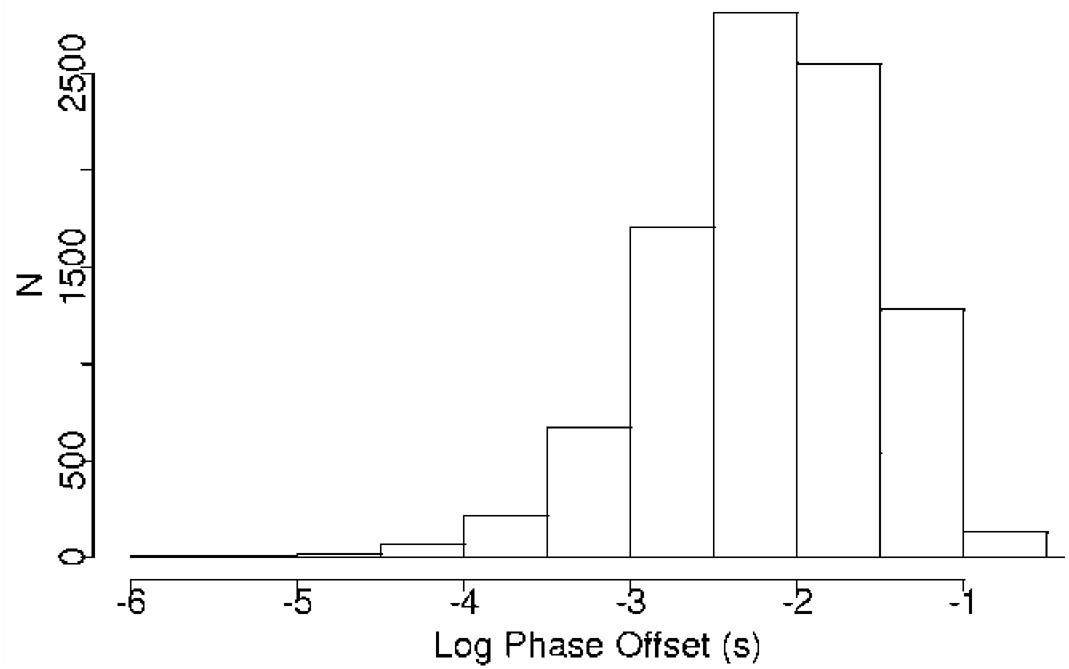
Server population by stratum (1997 survey)



Client population by stratum (1997 survey)

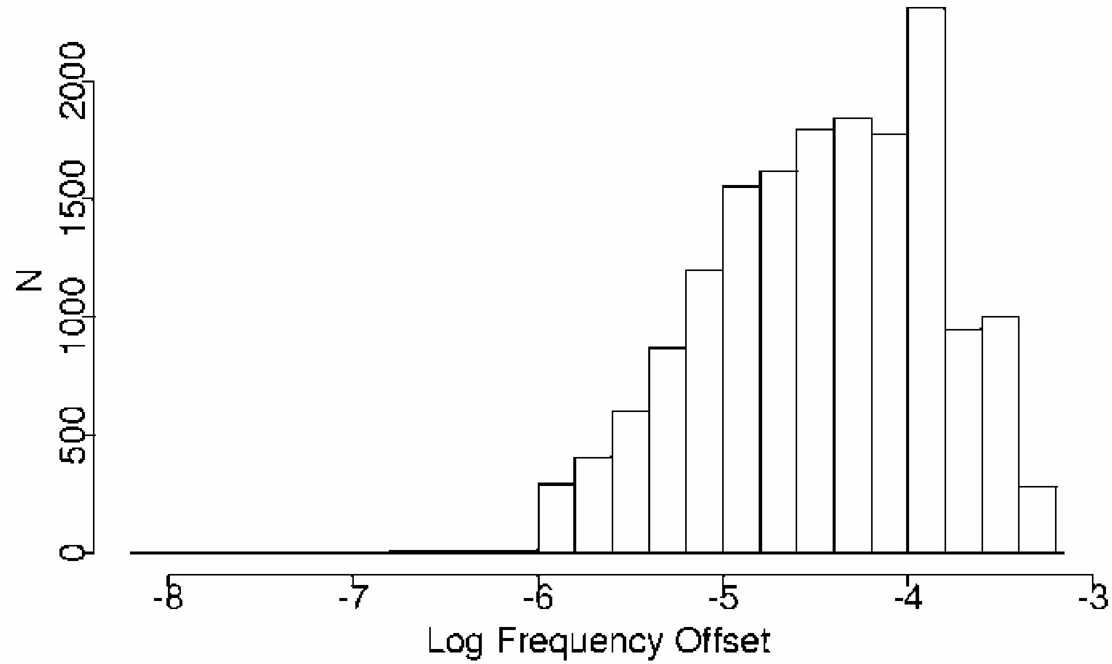


Typical local clock phase offsets (1997 survey)



- Histogram of local clock absolute phase offsets
  - 19,873 Internet peers surveyed running NTP Version 2 and 3
  - 530 offsets equal to zero deleted as probably unsynchronized
  - 664 offsets greater than 128 ms deleted as probably unsynchronized
  - Remaining 18,679 offsets: median 7.45 ms, mean 15.87 ms

Typical local clock frequency offsets (1997 survey)



- Histogram of local clock absolute frequency offsets
  - 19,873 Internet peers surveyed running NTP Version 2 and 3
  - 396 offsets equal to zero deleted as probably spurious (self synchronized)
  - 593 offsets greater than 500 PPM deleted as probably unsynchronized
  - Remaining 18,884 offsets: median 38.6 PPM, mean 78.1 PPM

Reference clock sources

- In a survey of 36,479 peers, found 1,733 primary and backup external reference sources
- 231 radio/satellite/modem primary sources
  - 47 GPS satellite (worldwide), GOES satellite (western hemisphere)
  - 57 WWVB radio (US)
  - 17 WWV radio (US)
  - 63 DCF77 radio (Europe)
  - 6 MSF radio (UK)
  - 5 CHU radio (Canada)
  - 7 modem time service (NIST and USNO (US), PTB (Germany), NPL (UK))
  - 25 other (precision PPS sources, etc.)
- 1,502 local clock backup sources (used only if all other sources fail)
- For some reason or other, 88 of the 1,733 sources appeared down at the time of the survey

Performance of typical NTP servers in the global Internet

NTP Server	Location	Days	Mean	RMS	Max	>1	>5	>10	>50
Austron GPS	DCnet	91	0.0	0.012	1.000	0	0	0	0
rackety	DCnet	95	0.066	0.053	2.054	11	0	0	0
mizbeaver	DCnet	17	0.150	0.171	1.141	2	0	0	0
churchy	DCnet	42	0.185	0.227	3.150	15	0	0	0
pogo	DCNet	88	0.091	0.057	1.588	8	0	0	0
beauregard	DCnet	187	0.016	0.108	2.688	30	0	0	0
umd1	U Maryland	78	4.266	2.669	35.89	29	29	28	0
swifty	Australia	84	2.364	56.70	3944	27	27	27	13
ntps1	Germany	70	0.810	10.86	490.9	12	12	12	6
time_a	NIST Boulder	85	1.511	1.686	80.56	28	19	11	2
fuzz	San Diego	77	3.889	2.632	47.59	27	27	23	0
la	Los Angeles	83	0.650	0.771	17.84	28	8	3	0
enss136	NSFnet WashDC	88	0.657	1.203	32.65	38	23	10	0

- Table shows number days surveyed, mean absolute offset, RMS and maximum absolute error and number of days on which the maximum error exceeded 1, 5, 10 and 50 ms at least once
- Servers represent LANs, domestic WANs and worldwide Internet
- Results show all causes, including software upgrades and reboots

A day in the life of a busy NTP server

- NTP primary (stratum 1) server rackety is a Sun IPC running SunOS 4.1.3 and supporting 734 clients scattered all over the world
- This machine supports NFS, NTP, RIP, IGMP and a mess of printers, radio clocks and an 8-port serial multiplexor
- The mean input packat rate is 6.4 packets/second, which corresponds to a mean poll interval of 157 seconds for each client
- Each input packet generates an average of 0.64 output packets and requires a total of 2.4 ms of CPU time for the input/output transaction
- In total, the NTP service requires 1.54% of the available CPU time and generates 10.5, 608-bit packets per second, or 0.41% of a T1 line
- The conclusion drawn is that even a slow machine can support substantial numbers of clients with no significant degradation on other network services

The Sun never sets on NTP

- NTP is arguably the longest running, continuously operating, ubiquitously available protocol in the Internet
- USNO and NIST, as well as equivalents in other countries, provide multiple NTP primary servers directly synchronized to national standard cesium clock ensembles and GPS
- Over 230 Internet primary servers in Australia, Canada, Chile, France, Germany, Israel, Italy, Holland, Japan, Norway, Spain, Sweden, Switzerland, UK, and US - the list goes on
- Over 100,000 Internet secondary servers and clients all over the world
- National and regional service providers BBN, MCI, Sprint, Alternet, etc.
- Agencies and organizations: US Weather Service, US Treasury Service, IRS, PBS, Merrill Lynch, Citicorp, GTE, Sun, DEC, HP, etc.
- Several private networks are reported to have over 10,000 NTP servers and clients; one (GTE) reports in the order of 30,000 NTP-equipped workstations and PCs

Current progress and status

- NTP Version 4 protocol, architecture and algorithms
  - Backwards compatible protocol algorithm implemented and tested
  - Improved local clock model completed and tested
  - Nanokernel precision time kernel modifications simulated, implemented and tested with SPARC, Alpha and Intel architectures
  - IETF pulse-per-second application program interface implemented and tested for SPARC and Intel architectures
- Autonomous configuration *autoconfigure*
  - Multicast discovery with propagation correction completed and tested
  - Manycast discovery largely completed
  - Distributed add/drop greedy heuristic designed and simulated
  - Span-limited, hierarchical multicast groups using NTP distributed mode and add/drop heuristics under study
- Autonomous authentication *autokey*
  - Implemented and in test

Future plans

- Complete *autoconfigure* and *autokey* implementation in NTP Version 4
- Deploy, test and evaluate NTP Version 4 daemon in DARTnet II testbed, then at friendly sites in the US, Europe and Asia
- Revise the NTP formal specification and launch on standards track
- Participate in deployment strategies with NIST, USNO, others
- Prosecute standards agenda in IETF, ANSI, ITU, POSIX
- Develop scenarios for other applications such as web caching, DNS servers and other multicast services

NTP online resources

- NTP specification documents
  - Internet (Draft) NTP standard specification RFC-1305
  - Simple NTP (SNTP) RFC-2030
  - NTP Version 4 papers and reports at http://www.eecis.udel.edu/~mills
  - Under consideration in ANSI, ITU, POSIX
- NTP web page http://www.ntp.org/
  - NTP Version 3 and Version 4 software and HTML documentation
    - Utility programs for remote monitoring, control and performance evaluation
    - Ported to over two dozen architectures and operating systems
  - Supporting resources
    - List of public NTP time servers (primary and secondary)
    - NTP newsgroup and FAQ compendia
    - Tutorials, hints and bibliographies
    - Links to other NTP software

Further information

- Network Time Protocol (NTP): http://www.ntp.org/
  - Current NTP Version 3 and 4 software and documentation
  - FAQ and links to other sources and interesting places
- David L. Mills: http://www.eecis.udel.edu/~mills
  - Papers, reports and memoranda in PostScript and PDF formats
  - Briefings in HTML, PostScript, PowerPoint and PDF formats
  - Collaboration resources hardware, software and documentation
  - Songs, photo galleries and after-dinner speech scripts
- FTP server ftp.udel.edu (`pub/ntp` directory)
  - Current NTP Version 3 and 4 software and documentation repository
  - Collaboration resources repository
- Related project descriptions and briefings
  - See "Current Research Project Descriptions and Briefings" at http://www.eecis.udel.edu/~mills/status.htm