CONVERTING RING-BASED ARCHTECTURES TO MESH

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Abstract: Research on survivable transport networking started in mid-80's when fiber network outages reached crisis proportions. Several ring and mesh-based protection schemes have been developed since then. This paper provides an overview of the current mesh protection technologies, the relative performance between ring and mesh architectures, and presents a ring-to-mesh evolution strategy.

1. INTRODUCTION

A decade of operating and maintaining ring-based survivable DWDM networks has shown that the multi-ring network is inefficient, inflexible and difficult to expand. In contrast, mesh-based architectures are inherently capacity efficient and flexible. Studies made in this area have provided insight in understanding the mesh based architectures and address the key questions with respect to their operational flexibility, capacity efficiency, survivability, and how mesh technology can be introduced in today's network infrastructure.

Many network operators today are convinced of the long-term benefits of establishing mesh-based shared protection architectures. Network operators' focus, rightly so, is on achieving flexible, capacity-efficient, survivable architectures that translate into cost efficiency as user demand increases and the network expands. Key expectations of the next generation optical networks are to support the emerging network features and services, provide fast restoration capabilities comparable to SONET/SDH rings and efficient utilization and flexibility in sharing network recourses.

Today's mesh protection schemes are far from achieving restoration performance comparable to rings. Mesh based path protection is highly unlikely to achieve this objective in the foreseeable future. The mesh based line protection appears promising, particularly the P-cycles [2], but not yet available for deployment in optical networks

The primary challenge facing operators today is defining the evolutionary path to a flexible and capacity efficient mesh network while maintaining restoration performance comparable to rings. One effective strategy is to overlay the rings on a mesh technology infrastructure, migrating eventually to all mesh as the technology evolves and the network grows.

2. MESH RESTORATION OVERVIEW

In mesh protection architectures, demands are shortest path routed and spare capacity is reserved to support end-to-end re-routing of all demands in a failed working path. Surviving portions of the failed working path can be re-used for restoration. A centralized or distributed re-routing control mechanism calculates and deploys the protection path for each demand. A single disjoined back-up route is pre-selected for each demand. Spare capacity on back-up routes is shared by working path demands that do not have spans or other physical layer dependencies in common.

The most widely considered types of mesh protection schemes follow two basic approaches: shared path mesh protection and shared line mesh protection.

<u>Shared Path Mesh Protection:</u> Restoration occurs by re-routing the failed demands between the end points of each demand (between their ingress and egress points to the network). A dynamic restoration mechanism can adaptively determine and construct the replacement path for each demand, or a single disjoined back-up route is pre-selected and reserved for each demand at the time of provisioning. Spare capacity on back-up routes is shared by working path demands that do not have spans or other physical layer dependencies in common.

<u>Shared Line Mesh Protection</u> Restoration occurs by re-routing the demands between the adjacent nodes of the failed span. A restoration mechanism can adaptively determine and construct the replacement paths on demand or the switching arrangements can be pre-planned within the same spare capacity (link protection). In the latter case, all demands in the failed span are aggregated and re-routed through the protection span(s).

Mesh protection schemes follow a trade-off between increasing capacity efficiency and speed of restoration. Greater capacity efficiency typically results in longer protection switching times. Capacity efficiency is best achieved in highly connected networks. However, the complexity of establishing the protection path in a network with high degree of connectivity directly affects the restoration time. The actual restoration times achieved in a mesh protected optical network are of stochastic nature and their statistics depended on the network topology and the particular implementation of the control and switching mechanisms. Typically shared path mesh protection architectures are more capacity efficient but have longer restoration times than the shared line mesh protection architectures.

3. RING-MESH ARCHITECTURES

As stated earlier, key expectations of the next generation optical networks are to support the emerging network features and services, provide fast restoration capabilities comparable to SONET/SDH rings and efficient utilization and flexibility in sharing network recourses.

A baseline strategy to address threes expectations in today's optical networks is to implement a Ring-Mesh architecture that provides mesh protection at path level (shared path mesh) and ring protection at line level (Figures 1).

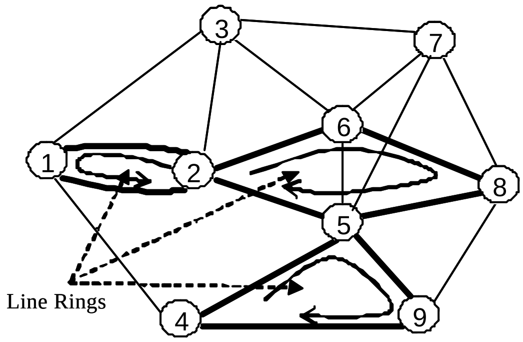

Figure 1: Shared Path-Mesh with embedded line rings

The line rings would provide the desired fast restoration of critical demands, and the path mesh protection would provide efficient capacity utilization for other demands. The path mesh architecture would also provide the infrastructure (control plane and signaling) needed to support the emerging features and services of the next generation networks, (e.g., dynamic routing and routing optimization, service flexibility, UNI/NNI communication, OVPN, etc.).

In the Ring-Mesh protection architecture, the mesh and ring protection schemes are functioning independently but their activities should be coordinated to avoid race conditions. The line ring protection should have priority over the path mesh protection. The coordination among the two protection schemes should not adversely affect the speed of ring protection.

The shared path-mesh provides demand restoration by sharing the available capacity in the network. All the network capacity is available for mesh protection, including the ring capacity. A mechanism should be provided (e.g., priority levels) to prevent non-critical demands from being mesh protected through the working lines of the rings. Mesh protection is optionally enabled for each demand at the time of its provisioning. All demands can be configured for mesh restoration including the demands that are ring protected. The latter will be mesh restored through the network in the event the ring protection fails.

Line rings are configured as needed by selecting the appropriate lines (wavelengths). Any number of rings can be configured in the network up to its full capacity. Figure 2 shows three line rings configured in the network. Rings can be configured or removed from the network at any time (i.e., can be setup or tear down in service). The switching nodes should support stacked rings and ring interworking.

The objective of the ring-mesh implementation is to eventually migrate from line ring protection to line mesh protection when emerging mesh technology meets the desired protection switching efficiency. The resulting network will have an all mesh protection architectures with both line and path mesh protection capabilities. It is expected that the path and line mesh protection schemes will operate independently and have similar operational features as in the ring-mesh. For example, any number of lines can be configured into a line mesh group, as needed. Figure 2 shows an example of a line mesh group on top of the path mesh infrastructure. To make the ring to mesh migration feasible, the underlying mesh infrastructure (control plane, and signaling) of the switching nodes should be implemented to support this migration.

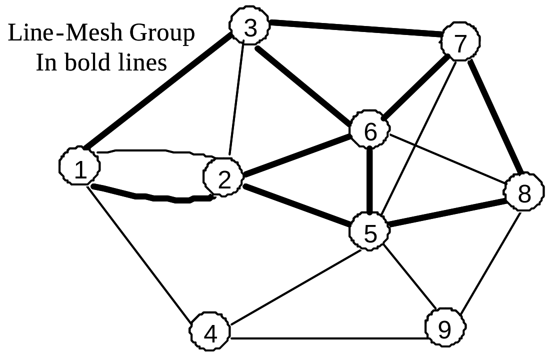

Figure 2: Shared Path-Mesh with a Line-Mesh group

The main benefits of the Ring-Mesh protection architecture are:

Service flexibility: It supports several classes of service. As a minimum it can support high priority services (fast restoration), low priority (mesh protected or best effort), and unprotected.

Next generation network features; The network infrastructure supports the emerging network technologies, such as, dynamic routing and routing optimization, service flexibility, UNI/NNI communication, OVPN

Automatic restoration: In the legacy networks, failure of the line protection results in manual service restoration through the available capacity. This typically takes several hours to be effected resulting in long outages. The mesh protection makes possible the automatic restoration of individual demands through the available capacity within the network within very short time, thus reducing outage.

Efficient utilization of Network resources The protected capacity of the network (line and path mesh) can be in service modified and/or built as revenue and complexity demand.

Ring-to-Mesh evolution. The Line-Ring protection will in-service migrates to line mesh as the technology evolves. This can be effected by in-service decommissioning the line rings, upgrade the switching software and enable line mesh as needed.

4. RING-MESH IMPLEMENTATION IN TGN

The Ring-Mesh protection architecture, as described in the previous section, was implemented in the Tyco Global Network (TGN). The TGN network is a global undersea optical DWDM network consisted of a set of switching nodes with average nodal degree of 4. The ring restoration times were within the ITU-G.841 & ITU-G841 Annex A objectives. Path mesh protection is used for non-critical demands and for service restoration in the event the ring protection fails. Mesh restoration times range from 200 msec to several seconds depending on the number of demands restored and the number of nodes involved.

The implementation of ring-mesh architecture had significant impact on the network planning and design, and traffic engineering. A summary of our experience in these areas is provided below:

Impact on Planning & Design: In Ring protected networks, the protection mechanism is deterministic. Consequently, the planning and design is relatively straightforward. Planning and design of a network and planning for network upgrades in a mesh network, is more complicated because optimization and failure analysis should take into account both the available free capacity and the utilized capacity with the existing traffic. Network connectivity and required capacity per link for a given traffic forecast should be optimized by some mesh protection design optimization tool that takes into account both the working and protection path of each demand in a global basis. Failure analysis has to be performed to verify that mesh restoration objectives are met, identify margins, potential bottlenecks, and make final capacity adjustments.

Impact on Traffic Engineering: The design optimization of a mesh-protection network is based on globally optimizing the forecasted demand routing and protection paths of the forecasted traffic. In real time, demands are routed through the network one at a time and the routing path is based on the routing protocol and constraints used by the control plane such as, shortest path routing, routing cost or protection diversity. These constraints often present challenges to maintain optimal traffic distribution on a global scale. To maintain an efficiently utilized network, the network utilization should be constantly monitored. Background analysis of capacity utilization should be performed periodically to determine the efficient use of capacity and the availability of resources for restoration. To perform this task, software tools are needed that closely model the network equipment routing and switching algorithms and constraints, and include advanced optimization algorithms tailored to the high-capacity ring-mesh optical networks.

5. CONCLUSION

We presented a Ring-Mesh protection architecture that is based on mesh network technology. The Ring-mesh architecture provides fast restoration capabilities comparable to SONET/SDH rings, efficient utilization of network recourses, and supports the emerging features and services of next generation networks. It also provides the infrastructure for in-service migration to all mesh protection. The protection architecture has been implemented in the Tyco Global Network and is now in operation.

6. REFERENCES

[1] W.D.Grover, J.Doucette, D.Leung, D.Stamatelakis, ”New Options and Insights for Survivable Transport Networks”, IEEE Communications Magazine, January 2002, pp 34-41

[2] W.D.Grover, D.Stamatelakis, ”Bridging the Ring-mesh Dichotomy with P-cycles”, DCRN 2000, April 2002, pp 92-104.

[3] G. Ellinas, A.G.Hailemarian, T.E.Stern, “Protection Cycles in Mesh WDM Networks”, IEEE JSAC, Vol. 18, [No.10, October 2000