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Benefits of Metropolitan Mesh Optical Networks

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Introduction

The deployment of metropolitan optical networks will provide wavelength-based services to customers. These wavelengths will need to be optically managed between rings to provide services between end points that are not on the same ring. The current method to build these networks is to deploy multiple rings with wavelengths connected between back-to-back rings through opaque optical-electrical-optical (OEO) conversions. A more efficient method is to build a mesh metropolitan optical network using transparent optical pass-through between rings. This metropolitan mesh network would allow wavelengths to be managed optically end-to-end, thus minimizing the number of OEO conversions and reducing the overall network cost.

This paper compares opaque interconnection of dense wavelength-division multiplexing (DWDM) rings with suggested mesh interconnected rings. The differences between the two topologies are explored, taking into consideration the economics, protection, provisioning and scalability of each.

Evolution of Metropolitan Rings

The initial deployment of metropolitan DWDM was to solve fiber exhaust between large offices. Initially, these deployments were point-to-point, but have migrated toward optical ring configurations. As this evolution continues, metropolitan DWDM deployments will be used to build a scalable metropolitan optical network that provides interconnections between offices and delivers services to end customers.

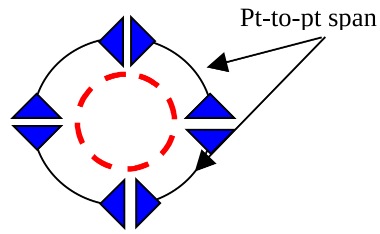

Figure 1 — Point-to-Point DWDM.

Early deployments of point-to-point metro DWDM were in interoffice facility (IOF) networks to solve fiber exhaust. Separate spans of a ring could be independently upgraded using point-to-point DWDM systems. However, these initial systems did not handle pass-through traffic well. To pass-through wavelengths, OEO conversion was required. This conversion was costly and removed the protocol independent advantage touted by DWDM proponents. Since there is a significant amount of pass-through traffic in metro networks, this barrier drove the evolution of ring-based DWDM systems. touted by DWDM proponents. Since there is a significant amount of pass-through traffic in metro networks, this barrier drove the evolution of ring-based DWDM systems.

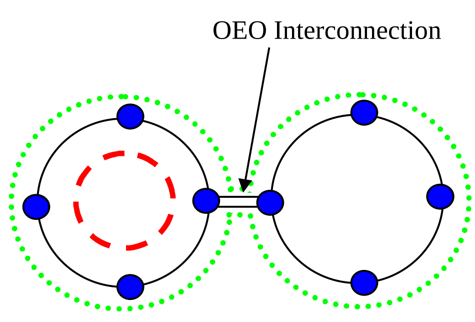

Figure 2 — Interconnected Rings.

Metro ring-based DWDM systems were introduced which more efficiently passed wavelengths between nodes than basic point-to-point systems. These systems were developed to solve both fiber exhaust in the metro IOF and to provide wavelength-based services to customers. The challenge came in when rings were interconnected (*Figure 2*). For ring-based systems, OEO regeneration is required to interconnect rings. As with point-to-point systems this removed the benefits gained through optical transparency.

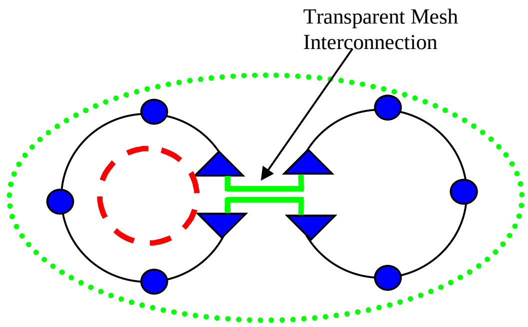

Figure 3 — Simple Mesh Configuration.

Now there are systems that support optical pass-through in both ring and mesh configurations. With these systems, interconnected rings can be viewed as a mesh network. Instead of physically connecting two rings, a simple mesh network can be created wherein logical rings can be overlaid. For wavelengths that need to be managed across both rings, a single logical ring is created (the dotted oval in *Figure 3*) while other wavelengths are managed on physical rings (the dashed circle in *Figure 3*).

Mesh network configurations are supported because wavelengths can be optically passed through either as single wavelengths or groups of wavelengths (bands). This flexibility allows service providers to build transparent optical networks by initially deploying point-to-point links to solve today's fiber exhaust and then evolving them to deliver end-to-end protected services.

Metropolitan Applications

While initial deployments of metropolitan DWDM may be single-ring configurations, network growth will drive the interconnection of disjoint rings. This evolution will be based on several metropolitan applications. The first application involves providing wavelength-based services between customer locations that are not located on the same optical ring. The second application is to back-haul traffic from the access ring to the hub office for grooming. A third application is used for the interconnection of another carrier, such as an Internet service provider (ISP) or an IXC, and a hub office.

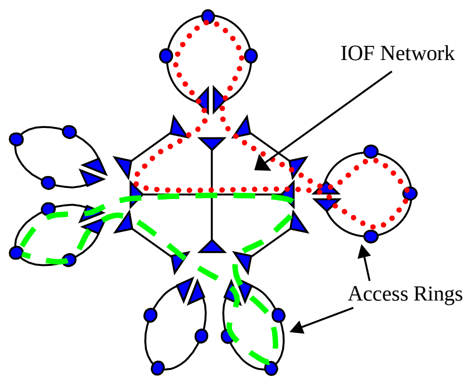

Figure 4 — Metropolitan Networks.

For any of the above applications, the network topologies are very similar. They center around an IOF network that interconnects multiple access rings.

Economics

One of the drawbacks to metro DWDM that critics cite is the cost associated with deployments. To that end, mesh metropolitan networks are being proposed, as in long haul networks, to reduce the overall cost of building a DWDM network. Unlike long haul mesh networks, mesh-interconnected rings do not reduce the overall network cost based solely on a reduction in the number of required protection wavelengths. The cost reduction is based instead on the reduction in the number of required OEO conversions. This section will focus on the economic advantage (due only to reduce OEO conversions) of deploying opaque interconnection of DWDM rings as compared to transparent mesh interconnections of rings.

As described above, the basic topology of opaquely interconnected DWDM rings and a transparent mesh networking is very similar. The major difference between the approaches is the method for interconnecting rings, which in turn is based on the cost of optically passing wavelengths between elements and electrical regeneration (using back-to-back transponders) between rings. This comparison assumes that the common costs are roughly equivalent between solutions.

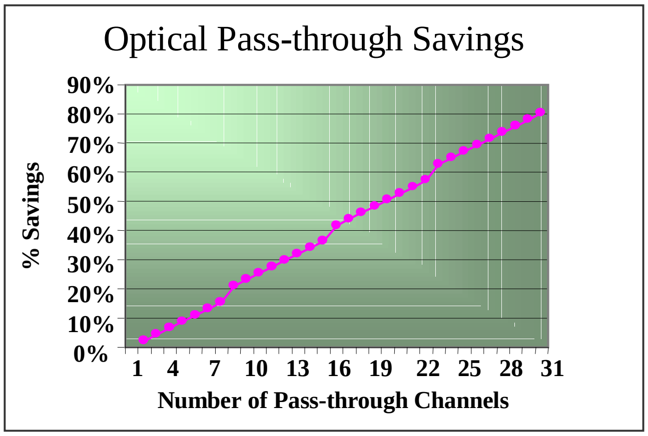

Table 1 — Pass-Through Savings.

Table 1 outlines the relative cost savings of optical pass-through as compared to back-to-back transponders. There is a direct relation in cost savings to the number of wavelengths optically passed through.

Simplified Provisioning

The rapid provisioning of services is another driver for metropolitan optical networking between, for example customer locations and/or carrier's offices. Mesh networking allows providers to easily provision end-to-end services and will therefore be the basis for future innovations that provide dynamically provisioned services.

The difference between provisioning opaquely interconnected DWDM rings and transparent mesh network is the fact that wavelengths are provisioned on each disjoint DWDM ring before the rings are interconnected. In contrast, mesh network connections are provisioned end-to-end across rings. This requires transparent optical pass-through functionality that allows the passing of individual wavelengths or bands (groups) of wavelengths between network elements in ring and mesh topologies, creating logical rings. Utilizing this ideology, multiple logical rings can be created over the mesh network topology (see *Figure 4* — Metropolitan Networks) whereas the physical ring governs wavelength provisioning with opaquely interconnected DWDM rings.

Transparent mesh networks provide the basis for future dynamic provisioning of wavelengths. Initially, wavelength pass-through is manually provisioned between network elements. Small optical cross-connects will be used to dynamically provision wavelengths that are optically passed through and will allow wavelengths to be provisioned through the network dynamically. The end points will still require manual provisioning and connections. However, the dynamic provisioning between end points reduces the number of manual steps required to turn up new services.

End-to-End Protection

Service-based protection is an area where metropolitan networks differ from long-haul networks. In long-haul networks, mesh restoration is being developed to reduce the bandwidth used for protection. Conversely in the metro networks, protection is being added to protect services that are unprotected (*i.e.*, gigabit Ethernet). For this application, wavelengths are provisioned from end-to-end as a protected service.

In some cases, this means that a wavelength may need to be provisioned across optical rings. If the interconnected rings are built in a transparent mesh configuration, the wavelength is simply provisioned from end-to-end. The protection exists only at the end points and the wavelength is optically passed through at the ring-interconnection point. Additionally, at the interconnection point, there are fewer points of failure (refer to *Figure 3* — Simple Mesh Configuration). For opaque interconnected rings, the network elements that interconnect the rings may serve as single points of failure (refer to *Figure 2* — Interconnected Rings).

Network Scalability

Scalability is one of the selling points for metropolitan DWDM rings. Individually, these rings can easily scale from one wavelength to many wavelengths. However, as the rings are interconnected to form true networks, they may not scale so easily.

Using opaque interconnections of DWDM, the capacity of a network of multiple rings will be limited by the smallest amount of available capacity on a single ring. By comparison, a mesh topology can be viewed as a collection of spans, each of which is individually upgradable in its capacity. This removes the lowest common denominator restriction found in opaquely interconnected DWDM rings and also reduces the cost of adding capacity between two points if the capacity is not needed around the entire ring or throughout the entire network.

Even though wavelengths are carried transparently between the end points, there are reasons that OEO conversions may be required. Two of the major drivers for OEO conversions are wavelength interchange and corrections of signal impairments. If the desired wavelength is not available on the required span, an OEO conversion may be used to change the wavelength to one that is. Additionally, optical signals may need regeneration after a specific distance or after signal degradation.

Overall, the mesh-interconnected rings enhance scalability at reduced cost as compared with interconnected DWDM rings. Most importantly, this scalability does not come at the expense of network flexibility. Within this framework, wavelengths can easily be regenerated due to impairments, or can be converted to different wavelengths, but only as necessary.

Conclusions

Viewing transparently interconnected rings as simple mesh networks is an alternative to an opaque interconnection of DWDM rings. Logical rings are provisioned over the physical mesh network which enables services can be managed from end-to-end. These services are carried transparently, reducing the number of OEO conversions while maintaining the flexibility to correct impairments, change wavelengths and scale the network.