

OPTICAL COMMUNICATION

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ABSTRACT

Networks today are the product of reactive evolution to demand. Circuit-switched networks built for providing POTS (Plain Old Telephone Service) evolved into the current multi-layered networks in reaction to pressures for new services and increased capacity. Growth of data traffic in particular has consistently outstripped the most aggressive projections, forcing service providers to continuously build out their networks using this inefficient and costly network model.

Responding to these pressures, the telecommunications industry has built networks, which may well be reaching the end of their viability. Multi-layered networks have become so complex that the cost of continuous development to meet demands is becoming prohibitive. This section presents three key issues that have brought traditional networks architectures to a crossroads: complexity, cost and the need to protect investments.

Keywords- Optical Communication, Optical Networking and Optical Switching, POTS etc

1. INTRODUCTION

Today's telecommunications service providers are faced with what appears to be an insoluble problem. They must maintain and even increase profitability, while responding to an exponential growth in demand with networks that are even more complex and costly to deploy and maintain.

Since the requirements for both profitability and the ability to offer new, revenue-rich services are given, the solution must be found in the networks. Service providers must find a way to build networks with the flexibility of IP, the reliability of SONET/SDH, and the scalability of optics at costs that will allow them to offer services at competitive prices. Photonic Service Switching (PSS) offers exactly that: a new network model that permits graceful evolution to simpler, more cost-effective core networks.

This article describes key enablers of the Photonic Service Switching intelligent core network solution. It begins with a very brief overview of some of the

reasons layered network architecture has reached a crossroads. It then briefly examines network architectures that have been proposed as evolutionary alternatives to traditional layered network architecture. The final section outlines how a Photonic Service Switching network is managed, focusing on specific challenges and benefits, such as traffic engineering, protection and restoration, and possible new services. This section briefly reviews some approaches, including Photonic Service Switching, proposed to move network design out of the current impasse.

(i) MESH TOPOLOGIES

The ring versus mesh debate is all but closed. SONET rings are reliable, but they lack the flexibility required by today's market, are costly, and are inefficient. They do not make best use of available bandwidth. 1+1 protection, for example, uses only half the available bandwidth, with the other half on reserve as protection against failures.

Mesh topologies, on the other hand, can offer great flexibility and more efficient use of resources. They can optimize bandwidth use of Differentiated Services. There is little doubt, therefore, that SONET rings will be replaced by more flexible topologies. Support for pure meshed environments will soon be the norm. Evolution to mesh topologies alone is not a complete solution, however. Traditional layered networks with mesh topologies are still complex, costly and difficult to scale. A more complete solution requires consolidation of network layers.

(ii) CONSOLIDATING LAYERS

Two important alternatives have been proposed to the traditional layered network model. The first, IP over optics, separates services from the optical transport but must maintain separate network elements for the various services carried. The second, Photonic Service Switching brings together services and transport through one core network element.

(iii) LAYERED NETWORKS

Overlay networks require management of their different layers, such as the IP and ATM layers, as though they were separate networks. Intelligence can be implemented for some layers, but is limited to the specific layers where it is implemented. Layers do not communicate with each other, so management and scalability of the network as a whole are severely compromised.

(iv) IP over DWDM

IP over DWDM uses IP addressing and routing over DWDM networks. Though it appears attractive, IP over DWDM is not a complete architecture and leaves many key issues unresolved.

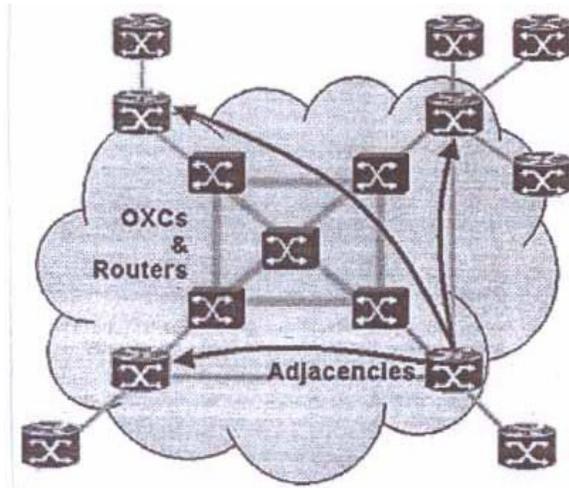
First, since IP over DWDM uses packet line cards for all traffic, network operators deploying this solution are obliged to pay premium price for all traffic. They cannot benefit from the lower cost of using wavelength cards for transit traffic.

Second, IP over DWDM requires separate network management systems for routing and wavelength.

Third, service types are limited: IP over DWDM cannot provide TDM, private line type connections for example. Since routers do not support TDM, it is

either necessary to run TDM over IP, or to maintain parallel TDM and IP networks.

Figure 1 : IP Over OXC/DWDM



(v) IP over OXC/DWDM

The IP over OXC/DWDM (in fact IP over OXC over DWDM) approach extends the IP over DWDM model to include wavelength services as shown in the Figure 1. It proposes using routers to aggregate traffic and wavelength switches to handle transit traffic. IP over OXC/DWDM requires additional core network devices to aggregate TDM traffic, and hence still relies on overlay network architecture for service integration. As such, it does not scale well.

2. PHOTONIC SERVICE SWITCHING (PSS)

Photonic Service Switching introduced in 2001 goes the final step to enabling an intelligent, peer-based core network solution. Using TOPS (TDM + Optical+ Packets) architecture enabled by G-MPLS (Generalized Multi-Label Switching Protocol), PSS supports the G-MPLS view of a common control plane for all layers of services.

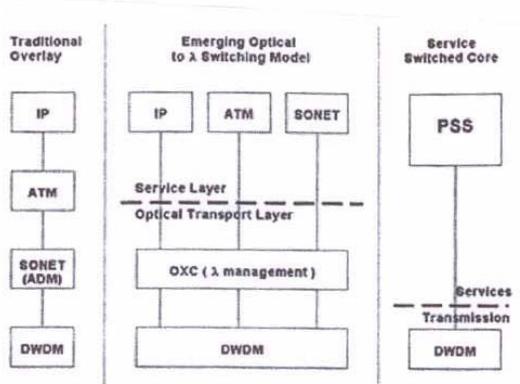
With Photonic Service Switching, service providers do not have to bet their capital investments against future demand for specific traffic types. PSS does not favor packet, for example, over other traffic types. It is, in fact, traffic-type neutral. Hence, it not only permits complete transition to a more efficient and cost-effective peer-based network model, but offers investment protection as well.

(i) PSS NETWORK (PSSN)

A Photonic Service Switching network is a peer-based intelligent optical core network. It applies the power of peering, traditionally found in data networks to transport services. All network elements peer with all other elements. Through an Inter-Gateway Protocol (IGP) they have network information (such as link type, link and bandwidth availability, and route reachability) and use this information dynamically and intelligently. The evolution to Photonic Service Switching networks is made possible by three recent innovations as shown in the Figure 2. G-MPLS, which extends the capabilities of MPLS to TDM and wavelength. TOPS architecture, which consolidates timeslot, wavelength and packet traffic onto one network layer.

Photonic Burst Switching technology, which has been used to build a new class of intelligent, optical core switch designed to handle packet, TDM and wavelength traffic simultaneously. Together, these innovations permit deployment of an intelligent, optical core network with a common control plane, and management of all network layers with the Photonics Core Manager.

Figure 2: PSS NETWORK



This section outlines how Photonic Service Switching achieves network layer consolidation and some key benefits of this consolidation, describes management of a PSS network with the Photonics Core Manager, and offers some examples of new revenue generating services made possible by PSS.

(ii) SERVICES AND TRANSPORT INTEGRATION

Layer integration is key to the efficiency and cost

effectiveness of a Photonic Service Switching network. Core network elements and links can be managed with a single management system and traffic can be directed through paths that make best use of network resources.

(iii) PROVISIONING

All layers of a Photonic Service Switching core network can be provisioned through a single management system. The architecture and intelligence of a PSS core network make possible restoration through the core. As well G-MPLS-aware edge devices outside the core can become peers of the PSS core devices for dynamic end-to-end provisioning. If the edge devices are not G-MPLS-aware, PSS can nonetheless use G-MPLS to create tunnels in the PSS network. Alternatively, an OSS can be used in concert with the Photonics Core Manager to provide end-to-end provisioning. Consolidation of layers in a Photonic Service Switching network does not mean that traffic can or should be managed in the same way for all layers. PSS manages each layer according to its unique attributes, and uses the inherent differences of the layers to ensure optimal use of network resources.

For example to manage path allocation on the SONET/SDH and optical layers, Photonic Service Switching employs a hierarchy of Label Switched Paths (LSPs), developed within the framework of G-MPLS. The hierarchy defines simple rules that prevent, for instance, TDM LSPs from being created within packet LSPs. Within this hierarchy, links at all levels are visible to higher levels. Once they have been created, lower level links are made known to higher layer links through IGP advertisements. This visibility permits aggregation across layers: higher-level LSPs that have the same source and destination nodes can be optimized and their number reduced.

(iv) TRAFFIC MANAGEMENT

Photonic Service Switching offers network level Quality of Service (QoS). It offers sophisticated capabilities such as Weighted Random Early Discard (WRED) and Weighted Fair Queue (WFQ). Its QoS mappings permit flexibility in the selection of queuing mechanisms, which span the full range of Differentiated Services from those with guarantees to those without guarantees. Switches in the network can be configured to allow establishment of packet LSPs with or without guaranteed bandwidth, as needed. When an LSP requires guaranteed bandwidth, PSS employs the CAC mechanism that checks and reserves resources. Services

with guarantees can be maintained at the same time as services without guarantees, permitting great flexibility in design of SLAs.

(v) TRAFFIC ENGINEERING

Traffic Engineering (TE) is the task of optimizing use of network resources by provisioning LSPs as dedicated paths between two end points. The path an LSP takes in the network can be set up either though the manually specified routes from a management system. or through routes that are computed based on applying constraints to the topology calculation on a switch. Traffic engineering is necessary for delivery of optimal network performance, and it enhances service provides ability to offer Service Level Agreements (SLA). Effective traffic engineering is therefore one of the keys to maximizing return on investment while improving service offerings.

Photonic Service Switching extends traffic engineering from traditional packet traffic to include TDM and wavelength services as shown in the Table 1. APSS consolidated service-transport backbone uses G-MPLS TE and optical extensions for routing and signaling protocols. These protocols provide enhanced network information, intelligent path computation and common signaling to packet. TDM and wavelength services. Integration of these protocol extensions in the G-MPLS framework increases flexibility in network planning enables more intelligent decision and better use of resources.

Table 1: G-MPLS Optical Extensions

G-MPLS Optical Extensions	Hop Count
	Path Metric
	Resource Class/Color
	Bandwidth
	Shared Risk Link Group
	Include Node(s)
	Exclude Node(s)
	Priority

(vi) PROTECTION AND RESTORATION

One of the challenges facing network operators moving towards more efficient mesh networks is ensuring efficient and reliable fault detection, and adequate restoration times. For many services, 'adequate' means restoration speeds comparable to those supported by today's SONET ring networks, where service is typically restored in about 50 milliseconds. The recovery times measured in tens of seconds typical of IP networks using IGP hellos for fault detection are unacceptable for many critical services.

The ability to offer SONET level recovery times when they are necessary (but only when they are necessary) and without having in all cases to invest in 1+1 redundant protection will allow service providers to offer their customers tailor-made, comprehensive SLAs. Photonic Service Switching employs a multi-level protection and restoration strategy that leverages 'best of breed' protection from all network layers of a given LSP. This means that, depending on the level of protection required; an LSP can be protected at the SONET line layer (opaque wavelength), the SONET path layer or the MPLS layer.

The range of protection available at different network layers makes possible protection and restoration management according to QoS requirements. Service providers can adjust the balance of resources against protection required to achieve optimal use of their network.

For instance, a SONET LSP is set up with parameters specifying the required protection. If 1+1 protection is required the LSP is set up over 1+1 protected SONET links. In the event of failure, the entire SONET link is switched to the backup link. Restoration time is less than 50 milliseconds. 1+1 protection consumes significant network resources, however. Other options, which consume less resource, are also available. These include 1:1 shared, and 1:N shared protection and other mesh restoration schemes. Similarly, Photonic Service Switching makes possible LSP repair mechanisms for packet LSPs, with local and global repair working in concert to provide rapid network restoration.

3. SCALABILITY

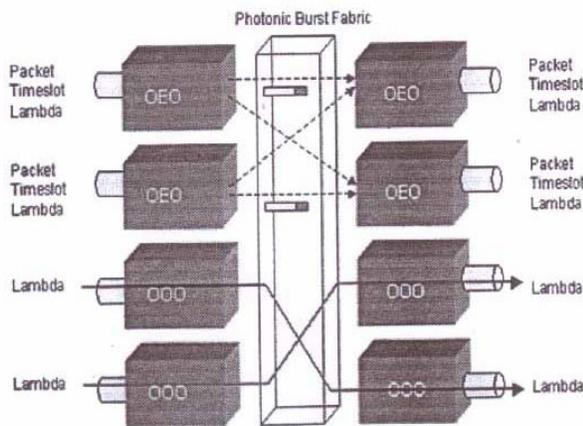
Evolution to a consolidated layer network elements capable of scaling to meet demand while

continuing to handle the various traffic types required. As well, a consolidated layer network will eventually require a means for managing the large number of links in a G-MPLS, meshed network.

(i) OPTICAL SCALABILITY

Photonic Service Switching uses Photonic Burst Switching (PBS) technology, Switches built with this patented technology can scale in three dimensions: space, wavelength and bit-rate as shown in the Fig.3.

Figure 3: Photonic Burst Switching



The PBS $n \times n$ design means fabric can be expanded spatially, with ports added when they are required. Everything between the ingress and egress line cards is optical, and wavelength and bit-rate independent, so switching capacity is virtually unlimited. Thus, PBS switches offer throughput scalability to petabit capacity while maintaining the 99.999 percent availability required of core grade, carrier-class network equipment.

(ii) LINK BUILDING

Photonic Service Switching greatly simplifies network management because G-MPLS extends the use of proven IP protocols for unique identification of elements, signaling, and routing and link to all network layers. However, the combination IP, SONET and wavelength means the number of links in a PSS network is higher than in a typical IP network.

The solution to this increase in the number of link bundling. To reduce the number of IP addresses managed in the network, Photonic Service Switching

uses G-MPLS to bundle multiple links between elements. As well as preserving IP interfaces throughout the network, link bundling reduces control traffic by replacing individual channels for each link with a single IP control channel for the bundle.

4. NETWORK MANAGEMENT

One of the most important benefits of the evolution to a single control plane for core networks is a simplification in network management -- an improvement with immediate positive implications for an operator's bottom line.

(i) COMMON CONNECTION MANAGEMENT

G-MPLS permits the inter-operability of IP routers, legacy SONET/SDH and TDM devices (ADM, BDCS) and optical devices (OXC, OADM, DWDM). G-MPLS provides the flexibility of IP for route advertisement, administration and link discovery while maintaining circuit-like LSPs for traffic across all these devices. Service connection with Photonic Service Switching is greatly simplified. The network operator has one interface for requesting connections at any layer of the network. He need only specify bandwidth, delay and jitter, and reliability required. The network has the intelligence to use lower layer LSPs to provide the requested bandwidth and return notification of successful completion or failure of the request.

(ii) A CONSOLIDATED NETWORK MANAGEMENT SYSTEM

Though next generation core networks will consolidate layers, service providers may continue to operate along traditional functional partitions. For example, a transport team may manage SONET/SDH, TDM and optical devices, while an IP team manages the core and aggregation routers. The challenge is twofold. Service providers will want to make provisioning of these consolidated networks seamless, while allowing network operators to maintain the expertise and efficiency of traditional teams managing specific network layers. They will also want to consider developing new teams to take advantage of PSS's network layer consolidation, and single system element and network management.

CONCLUSION

The layered network architecture under

development since the 1970s to meet demands for new traffic types has come to a crisis. The complexity, cost and inherent limitations of layered networks are such that service providers must begin moving towards simpler, more efficient architectures. Intelligent peer-based networks in which network elements at all layers have full information about all other network elements are the most viable option for future network architecture. Photonic Service Switching brings together the best of many worlds: IP flexibility, SONET/SDB reliability, and optical scalability. Because it enables evolution to a simpler, more efficient network architecture that includes packet, TDM and wavelength traffic, Photonic Service Switching offers a truly evolutionary solution, and true investment protection.

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