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A Study on Integrated IP-Optical Networks for Better Network Performance

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Abstract: Increasing network convergence has accelerated the network architecture evolution. IP + OTN network architecture can be used to creatively collaborate IP switching and optical cross-connection to improve the network reliability, efficiency, and ROI and overall network performance across the system. This research paper examines the various challenges of integrating IP and optical networks and road ahead.

I. INTRODUCTION

The volume of IP and data traffic is growing at up to 70% per year. Given the high growth, but low profit margin for IP services there is a challenge as well as an opportunity for a service provider to deliver most of these services over a unified IP network to reduce capital and operations cost. Current IP networks, which have been perfectly suitable for best effort services, however, must be enhanced to provide the same level of resiliency and service quality well established in the traditional service domains.

The emergence of multi-service data aware access and edge platforms with intelligent network functions (such as automatic topology discovery, routing, and signaling) will enable the integration of multiple services closer to the customer reducing the access cost and providing fast service delivery capability. The second component is the resilient high-capacity core IP routers forming the backbone of the integrated service network. At the lowest layer is the third component, the optical switch, which interconnects the core routers via a switched optical layer over WDM links. While new high-availability (so called “non-stop routing”) core routers provide service resiliency at the packet layer, the optical layer provides lowest cost and highest level of resiliency at the physical layer against catastrophic network events such as optical amplifier failure and fiber cuts.

Complexity of Today’s Networks: Multi-layer, multi-technology, multi-vendor networks being created by the cumulative addition of advances over the years have multiplied the complexity of the networks. The difficulties of scalability and interworking between, and even within, layers makes it increasingly difficult to manage today’s networks. In addition, complexity also threatens the ability of networks and services to provide an excellent customer experience at the right cost. Clearly, network architecture needs to be simplified. The answer is to optimize the layers within networks by integrating high-capacity optical infrastructure with the IP/MPLS and the associated control layers.

Such an approach enables operators to:

- Take advantage of the efficiency of IP/MPLS
- Enjoy the cost advantages of optical transport for high-speed links
- Maintain the highest levels of network resiliency
- Support legacy and next-generation services as markets evolve.

Transponder based approach: Transponders and muxponders are used by DWDM systems today to provide the required adaptation of client interfaces from networking equipment, such as IP routers, Ethernet switches and MSPPs, to DWDM wavelengths for metro and long reach transport. Transponders provide optical and OAM demarcation points between equipment types and muxponders also provide for sub-wavelength aggregation of multiple client interfaces to increase network efficiency and lower costs. However, with the increasing deployment of networking platforms with 10Gbit/s interfaces there is increasing drive for direct wavelength termination on these platforms with transparent transport across the DWDM transport layer - or the integrated IP-optical solution. There are cost savings in the integrated solutions compared with a transponder-based approach, and these have been deployed for some years with SONET ADM and MSPP as well as IP router platforms. Core IP routers are a prime example of this application where multiple 10Gbit/s interfaces may need to be terminated in a particular location and transported long distances across the DWDM core optical network. Further, with the migration towards 40Gbit/s interfaces on core routers, where the interface costs are greater, there is additional motivation for the integrated solution in avoiding additional OEO functions.

In parallel, there has been an increasing trend in networking equipment towards pluggable optical interfaces

with the specification of MSAs such as XENPAK, X2, XPAK and XFP at 10Gbit/s rates. Pluggable interfaces provide standardized optical layer specifications, and form factors, which enable equipment vendors to provide a smaller number of line cards while still being able to offer the various flavors of optical interfaces needed for network optimization. Common specifications enable economies of scale for component suppliers, thus lowering the cost of network deployments. Pluggable optics MSAs are however constrained in terms of physical footprint, power consumption and thermal dissipation. Although short reach 10Gbit/s DWDM pluggable interfaces are now commercially available, to date there has not been a DWDM optical interface provided in a pluggable footprint, along with G.709 OAM functions required for long reach applications. The availability of such a component with integrated G.709 framer allows the network operator the greatest flexibility in enabling long reach transport interfaces without variation of line cards.

For an integrated IP-optical DWDM solution, it is critical to provide management and control functions that enable seamless end-to-end provisioning of circuits across the transport network and to provide OAM functions for network monitoring and troubleshooting. Without transponder demarcation, the end-to-end service should then be provisioned across platforms and should also provide an end-to-end circuit view for OAM functionality – between the IP platforms and across

II. INTEGRATION OF IP AND OTN NETWORKS

Figure 1 shows a generic integrated IP-Optical network consisting of IP routers with integrated DWDM optical interfaces interworking with an optical layer. The optical layer consists of an arbitrary mix of OADM, ROADMs and Multi-Degree ROADMs providing wavelength aggregation, amplification and switching. Wavelengths are terminated on the routers, with end-to-end G.709 functionality providing transport OAM and FEC functions. RS (255/239) FEC enables long distance transport, minimizing requirements for intermediate regeneration. In this example, wavelengths are routed across the network to provide logical connectivity between the routers with alternate paths providing re-routing capability in the case of network failures. The routers may be of the same type or different types and even from different vendors.

Key to the optimization of costs in long distance transport networks is the minimization of intermediate node transit costs. Implementing the most effective means for optical-bypass, the ROADM enabled network is the ideal solution for this, providing local add/drop termination to routers only where traffic planning dictates and not for intermediate regeneration. Implementation of a generic wavelength mesh, using combinations of ROADM and Multi-Degree ROADMs gives the most flexibility for optimization of the wavelength routing and hence transport bandwidth resources.

GMPLS provides the most efficient means for resource provisioning across the network in a multi-vendor environment. A user will initiate a service request on the router platform which then translates to resource reservation and signaling across the network via Control Plane interface between platforms. In the case of colorless

ROADM configurations, this includes the flexibility to assign wavelengths according to channel availability as well as wavelength routing across the network.

End-to-end OAM of the wavelength paths across the network, including fault and performance monitoring is supported via combination of optical performance monitoring in the optical network along with G.709 termination and digital monitoring in the IP networking equipment.

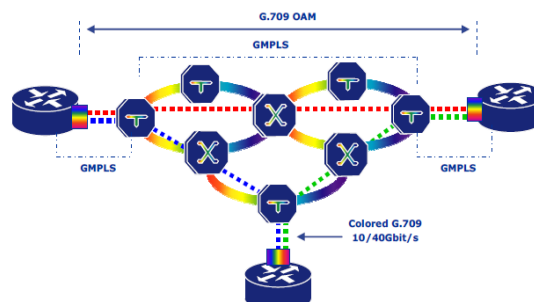


Fig. 1. Integrated IP-Optical Network

High availability IP services in the integrated network are enabled in various ways. The key requirement is to have diverse paths from each router as shown in Fig.1. In the case of network faults, fast IP re-route, or other IP-

based protection mechanisms, may be used to restore services. Going forward, optical restoration may be used to provide wavelength level restoration in the case of network failures enabled by Control Plane and the dynamic optical layer.

III. IP-OPTICAL INTEGRATION USING MC-LB

Large-scale IP networks have associated risks such as routing black holes which are dangerous and can cause wide-area impact across the entire network. Because these problems are hidden, troubleshooting is extremely difficult and the network can be affected for several hours or days

Such risks are inherent with the IP routing mechanism. The more complex a network, the harder it is for the network to avoid them. They are often triggered basically in the same way: A single-point failure leads to node routing convergence, causing severe risks such as routing black holes.

MC-LB takes advantage of multiple-route transmission of data traffic to dramatically increase network reliability. In case there is a port or link failure, routing convergence is not needed and a single point fault can be isolated without triggering potential risks, significantly boosting network reliability.

Due to MC-LB technology, when reasonable network architecture is adopted, the effective transmission of data traffic on the upper IP network will not be affected by any fault in the bottom-layer optical network, and route shocking will not occur on the IP network either. MC-LB can tremendously increase network reliability without the need to deploy extra redundant resources, and achieve real IP/Optical integration.

Prevention of traffic congestion: In a router network, the ideal networking method is one that can ensure direct connections between heavy-traffic nodes. This is because of the presence of many transit routers, which not only dramatically reduce the profitable bandwidth of the routers and the ROI, but also seriously deteriorate the QoS, making it hard to guarantee network performance.

It is very difficult for existing technologies to realize direct connections between nodes in a large or medium sized IP network, mainly due to two limiting factors. One is the limited number of router ports and the other is limited optical network resources.

The typical backbone router, for example, can ensure the mesh connection of 32 nodes at most (assuming the uplink and downlink ports are 50% respectively) at a speed of 10 Gbps. With cOTN and MC-LB technologies, the number of mesh-connected nodes can be increased by up to eight times to reach 256 depending on the application without the need to add any port and fiber resource to the optical network. These two technologies can markedly improve network efficiency.

The networking efficiency of MC-LB is also reflected in balanced IP network traffic, effectively utilized network bandwidth and lowered CAPEX. Generally, network traffic distribution is highly imbalanced in different directions for geographical and other reasons. Traffic is heavy in some directions causing bandwidth congestion, whereas it is very small in other directions resulting in idle bandwidth. MC-LB solves this situation by balancing traffic and improving network efficiency. It uses the idle bandwidth to offload the traffic from the congested directions.

Reducing O&M Expenses: The connection between two routers in a network requires the same physical ports. In the real-world network, different network layers require different transmission rates for router ports. The nodes at the access and aggregation layers require many GE and 10GE ports, whereas the backbone core layer requires high-rate 40G POS/OTN ports.

The high rate and low-rate cards of the same router are often mixed for connection requirements. These cause a series of problems: Configuring high-rate cards for access layer nodes is a waste of investment; configuring low-rate cards for backbone layer nodes reduces slot efficiency, and preparing all the high-rate and low-rate spare cards increases maintenance costs.

cOTN and MB-LB technologies realize the connection between routers with different physical ports. The technologies enable the access layer's routers to directly connect to the 40G OTN ports of the backbone layer's routers through the GE ports, dramatically increasing router connection flexibility. Unifying the ports configured for the nodes of different network layers reduces the maintenance complexity and spare-parts cost to improve the ROI.

End to End Fault Protection: A backbone network often spans several thousand kilometers, and equipment-

level operation, administration, and maintenance (OAM) is far from being able to meet the needs of end-to-end applications.

As backbone IP and optical networks involve applications carried over long distances and large amounts of equipment of varied types, it is important to locate link failures and provide effective protection. The MCX-LB solution extends, through cOTN technology, the advantages of the optical layer's OAM to the IP devices. In this way, end to end application management and control can be easily achieved.

Enhanced Network maintainability: Rapid business growth has left many operators with excessive network layers. Due to poor network architecture, network expansion often results in an increased proportion of non-profitable bandwidth. Therefore it has become a top priority for operators to optimize their networks by flattening the structure, reducing the number of transit ports, and increasing the proportion of profitable bandwidth.

The solution with cOTN and MC-LB is well-suited for network restructuring and can solve problems such as increased connection directions and the resulting traffic decrease in each direction. As the traffic analysis for an operator's backbone networks shows, compared with ordinary solutions, the solution can slash the number of router ports and transmission equipment by 3~50%, resulting in considerable CAPEX savings.

Many world leading operators are engaged in lean operations that are focused on high-value services like VPN, while providing Internet and other services as well. What they have in common is that they run different applications on a single physical network. However, they still need to design different architecture for different services.

With their unique features, cOTN and MC-LB serve this need well by realizing the separation of the logic network from the physical network and carrying different services over different paths. This can dramatically lower network TCO while enhancing network maintainability.

Interoperability between routers and optical network: In the FMC era, network convergence and service integration are improving interoperability between network equipment from different vendors and require technological openness and interface standardization. In the application of a new technology, network compatibility and equipment interoperability must be addressed so as to protect network investment and guarantee a smooth technological transition.

By channelizing router ports, cOTN and MC-LB enable the interoperability between routers and the optical network, without requiring any new feature for optical equipments. Any optical equipment that complies with OTN standard is interoperable with the routers through cOTN and MC-LB. In this way cOTN and MC-LB ensure the interoperability of optical NEs.

The flexibility in port configuration ensures the interoperability between new equipment and traditional equipment from other vendors. In connecting routers, MC-LB technology can best demonstrate its value. Furthermore, routers that incorporate this technology are interoperable with those that do not.

IV. CONCLUSION

Without depending on such complex protocols as GMPLS, MC-LB achieves synergy between IP and optical equipment and creates future-proof networks. Once GMPLS matures, it can be deployed on these networks to improve their flexibility and operability.

An IP network is an intelligent network driven by routers. Any change in the routing protocol can have a big impact on the existing network and make deployment difficult. When implemented through physical and data link layers, MC-LB technology will not affect the routing protocol and makes for an easy deployment on the existing IP network without even changing the routing policy.

Integrated IP-Optical DWDM networks have clear benefits in reducing the number of components in the network for providing end-to-end IP connectivity and routing. Converged IP and DWDM networks provide significant benefits to service providers. Router-integrated transponders eliminate transponder shelves, thus providing both CAPEX and OPEX savings.

Using pluggable DWDM OTN interfaces on networking platforms is an attractive means to enable interworking between different equipment types and vendors. For core applications, this requires G.709 functionality and

FEC to support long-distance transmission with standardized end-to-end wavelength monitoring functions. In addition, standardized management interfaces provide end-to-end network monitoring and performance management. Control plane integration facilitates faster introduction of new services, and integrated management simplifies network operations, while improving the network availability, utilization and performance.

REFERENCES

- [1] An OTN Pluggable Interface Providing IP over DWDM in Router-Router IP Transport - An Application Note Created by Juniper Networks, ADVA Optical Networking and Menara Networks for NFOEC'08
- [2] Tim Nagy, "Integrating Optical Networking Into the Packet Core", 2012
- [3] K.G. Coffman and A.M. Odlyzko, "Growth of the Internet", Optical Fiber Telecommunications IV B: Systems and Impairments, I. P. Kaminow and T. Li, eds. Academic Press, 2002, pp. 17-56.
- [4] S. Chaudhuri and E. Goldstein, "On the Value of Optical-Layer Reconfigurability in IP-over-WDM Lightwave Networks", Photonics Technology Letters, 12, August 2000
- [5] P. Charalambous et al., "National Mesh Network using Optical Cross-Connect Switches", Proc. OFC 2003, Atlanta, GA. Design of Reliable Communication Networks (DRCN) 2003, Banff, Alberta, Canada, October 19-22, 2003
- [6] T.E. Stern and K. Bala, "Multi-wavelength Optical Networks: A Layered Approach", Reading, MA: Addison Wesley, 1999.
- [7] G. Ellinas et. al., "Routing and Restoration in Mesh Optical Networks", Optical Network Magazine, Jan-Feb 2003.
- [8] J-F. Labourdette et al., "Routing Strategies for Capacity-Efficient and Fast-restorable Mesh Optical Networks", Photonic Network Communications, June-Dec 2002.
- [9] Jean-François Labourdette, "Role of Optical Network and Spare Router Strategy in Resilient IP Backbone Architecture", 2003
- [10] Shaheedul Huq, "Integrated Packet Optical Transport - An Optimal Solution for Converging IP Networks", 2012
- [11] Andrew Schmitt, "Integrated OTN Switching Virtualizes Optical Networks"
- [12] Juniper Networks, "Integrated Packet Transport Network: Combining IP and transport for lower costs and more efficient operations"
- [12] Iyad A. Katib, "IP/MPLS over OTN over DWDM Multilayer Networks: Optimization Models, Algorithms and Analyses", 2012
- [13] Kent Wong, "Converged Backbone Transformation", 2010
- [14] Liu Hongli, "IP and OTN synergy creates enhanced backbone networks", 2010