Integrated Optical Transport Systems & Convergence

It's more than photons

There has been a lot of focus on 100Gbps capabilities, coherent optical systems, and OTN. However, less focus has been placed on understanding the implication of the rich set of other capabilities, such as integrated packet switching, that these systems present to the network service provider. New thinking and organizational changes are likely to be needed to realize systems convergence opportunities for reduced costs and improved service delivery.

Author: Dr. Wesley K. Kaplow, CTO and VP Solutions

14900 Conference Center Drive
Site 280
Chantilly, VA 20151
703-955-7770

1 Introduction

It has been true, and continues to be true today, that there is a networking box for "anything". If you have one protocol or technology and you need to connect to another, there is always a box. This reality reflects the "tyranny" of the Open Systems Interconnect (OSI) networking model – which divided-up the data networking landscape into several bite-sized chunks. When realized in traditional network deployments, it is manifested in a box for every layer, and many boxes to buy and operate:

- Optical Transport Box, for 2.5Gbps and 10Gbps optical paths
- Synchronous Optical Networking (SONET) Multiplexors, big ones and little ones (rings and rings and rings…)
- Asynchronous Transfer Mode (ATM) Switches, eventually replaced by Multi-Protocol Label Switched (MPLS) "Provider" routers for bandwidth management and path protection
- Internet Protocol (IP) Edge and Boarder Routers for Routed Services making the Wide Area Network (WAN)
- Ethernet Switches for making the Local Area Network (LAN)

For the most part, this box madness continues today, with well-known consequences:

- Complexity in engineering, with separate groups engineering each layer
- Complexity in planning, with separate planning groups that require coordination
- Complexity in operations, with stovepipe operations that yields a lack of end-to-end service views and a significant increase in network management systems development costs, not to mention a more complex capacity management and budget estimation problem
- Complexity in the network, with many more failure modes, and many more failure points, not to mention the very significant constraints created by each added layer

The bottom line is that the current approach costs both time and money, and more importantly slows the delivery (i.e., Service Velocity) of high-quality services to customers.

The paper outlines some of the recent past service convergence concepts and approaches against the emerging set of new optical transport and service convergence platforms.

In summary:

1. *Traditional Optical Transport Vendors are Enabling Robust Data Networking Features in their New Systems*
2. *Walls Between Typical Service Provider Engineering Organizations Must be Broken Down to Take Advantage of these New Capabilities*

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

3. *Significant Operations Improvements are Possible, Enabling the Combining of Traditionally Separate Groups to Merge*

To be successful, the management of the Service Provider has to have an Enterprise Architect and access to staff that understands the technical landscape and can help drive change into the affected engineering and operations organizations.

2 Optical Technology

Optical transport technology has come a long way in the last 15 years. What is achievable today is nearly fantastic compared to the recent past:

- In the 1980's moving towards SONET and 2.5Gbps line systems
- In the early and mid-1990's moving towards SONET and Dense Wavelength Division Multiplexed (DWDM) networks of 8 channels x 2.5Gbps
- In the late 1990's introducing 10Gbps and 16 channels of 10Gbps with fixed wavelength transponders
- In the mid 2000's creating high-performance optical lines systems and the beginnings of so-called Ultra Long Haul (ULH) systems with up to 128 channels of 10Gbps, and the emergence of 40Gbps SONET with full band-tunable transponders

The complexity of the deployment of these systems has also evolved. The care and feeding of the optical layer initially required specialized skills, significant modeling (e.g., for the location of chromatic Dispersion Compensation Fiber, DCF, units), and field operations staff to balance optical amplifiers in the field. Improvements in the optical control plane and optical amplifier technology reduced the need for visiting dozens of optical amplifier locations.

This paper is not meant to be a tutorial or complete exposition on optical transport physics or technology, but it is important to contrast the above recent past with where we stand (approximately) today:

- Coherent Optical Transmission and its associated Electronic Dispersion Compensation technology has virtually eliminated the need for costly and performance limiting DCF
- Full band-tunable transponders as well as tunable receivers (enabled by coherent detection) significantly reduce the complexity of the DWDM de-multiplexing
- 100Gbps transponders (and some with 200Gbps capability) in systems with 80 or more wavelengths

So, just in the period from around 2000 to 2013, the line capability of commercially available systems has gone from 160Gbps to over 8Tbps, or more than a factor of 50.

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

The bottom line is that the current and future generations of optical networking equipment significantly reduced the complexity of designing and deploying an optical network with a dramatic increase in capability.

3 Convergence Overview

As already indicated, there is another wave of convergence that is moving though the telecommunications landscape. This one, however, is a bit different than the "convergences" that may first come to mind. As a review, consider some previous convergence examples:

- Service Convergence: Converging voice and video services over Internet Protocol (IP)-based networks
- Private Networking Convergence: Move from Asynchronous Transfer Mode (ATM) and Frame Relay (FR) into Multi-Protocol Labeled Switching (MPLS)-based Virtual Private Network (VPN) services
- Provider Networking Convergence: The use of MPLS to provide a common "Provider" P core network to support all data services (i.e., Internet, and MPLS-based VPNs)

All three of these examples represent the convergence of technology, and each represents the elimination of a set of wide area networking hardware. The first represents the convergence of an application, making voice and video service just another IP user of an infrastructure, eliminating the traditional voice TDM network of switches (i.e., Integrated Services Digital Network – ISDN).

The last two examples represent a convergence that eliminates core data network switches or routers. In the first case, we benefit from the elimination of an ATM or FR network; and in the second case, we benefit from the convergence of managed IP services onto a common MPLS backplane. Note, however that this complete single P core convergence strategy is not universal, with some service providers separating their private VPN services from their Internet service.

Along with the actual hardware platform consolidation, the data network convergence changes the structure of the planning, engineering, and operations organizations and their tasks. These changes are further discussed below.

3.1 Application Convergence - Voice, Video, and Data

Service Convergence of voice and private data networking onto the same IP network infrastructure required new thinking on the organizations that support voice services. No longer an independent Time Division Multiplexed (TDM)-based voice backbone, the voice services organization transitioned to making requirements on the converged, and most likely MPLS-based. IP-service network.

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

However, there is one critical area that did not converge. The hardware devices that support the voice services are separate and distinct from the data networks. These devices include items like call processing servers, session boarder controllers, and TDM gateways. Therefore, with the exception of the actual IP bandwidth, the voice service planning, engineering, and operations teams still have a separate set of devices to lifecycle manage.

3.2 Data Transport Convergence – Transport, MPLS, and Ethernet

The next convergence on the infrastructure-based service provider horizon goes one step beyond data network convergence and starts the actual merging of data networking into the optical transport domain. Right now, the product roadmaps of companies such as Ciena, Juniper, Cisco, and Infinera show a merging of the functionality of both the DWDM optical layer and the functionality of a core MPLS provider P router in one device.

Currently, the optical and MPLS layers are designed, acquired, and engineered independently by separate internal organizations. This separation also extends into the operations environment (i.e., the Network Operations Centers – NOCs) which generally has separate transport, MPLS/IP, and voice groups.

It is important to understand the implications of these technology changes with respect to the organizations needed to create and operate the resulting new system architectures.

4 Operation Observations

Before we continue on the impact of convergence, a brief interlude of observations on the operations environment of different layers of the network is warranted:

- Transport Networks. Equipment and systems provided by virtually all optical transport vendors come with integrated network management platforms. In general, these systems provide for full systems visibility, configuration management, capacity control, and provisioning (in many cases with point-and-click simplicity)
- Routed Networks. Traditionally virtually nonexistent, the operation and operations support systems of the MPLS and IP layers of the network are left as an exercise for the network operator

Overall, the telecommunications service provider industry has traditionally demanded more complete solutions from optical transport vendors, and expects almost nothing from router vendors. Features that are demanded include:

- Capacity planning, both real-time and strategic
- Provisioning, for multiple types of services
- Service performance management and reporting, on a per customer basis

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

- Fault management

If this convergence trend continues, one would expect that transport equipment vendors will expand their point-and-click provisioning and configuration management systems to leverage the new data network capabilities in optical transport gear. If done correctly, it is likely to make a large contribution to cost reduction (due to staffing and operations systems development) and service velocity. At the very least, transport equipment vendors have a significant advantage on the development cycle over router vendors.

5 The Convergence Opportunity

This section provides an overview of the near-term technology changes and some of issues related to leveraging these new capabilities.

5.1 Now

Figure 1 shows an example of the recent data networking architecture past and the convergence that is here today. In the "Typical Today" environment, the MPLS P and PE layers are grouped together, and have a separate engineering and operations life-cycle. Similarly, the Synchronous Optical Networking (SONET) and associated Ethernet interfaces for Ethernet-line (ELINE) services are generally combined with the optical transport layer, with its own support environment. With this approach, there is a clear demarcation between transport operations and data network operations. Transport operations deals with SONET rings, DWDM-based wavelengths, and protected and unprotected private line services with SONET and Ethernet interfaces. Of note is that, for most existing service providers, these types of Ethernet capabilities are already considered transport, and therefore this transition does not cause too much operations organization disruption. This type of service looks much like provisioned circuits, so the training and concept of operating the system are familiar.

Traditional WAN services, such as routed Layer 3 MPLS/VPNs and Layer 2 VPNs (e.g., VPLS) are generally wholly in the domain of the data network engineering, planning, and operations groups. In the past, this separation has been a benefit, providing a clear boundary of responsibility that enabled each area to evolve and meet customer service needs.

The emerging "Available Today" (and in some cases, already deployed) has Optical Transport Network (OTN) capabilities that enables the same SONET and Ethernet-interface private line services integrated into DWDM transport as the previous generation. However, gone is the SONET-only multiplexor and the constraints of its associated set of rings[1].

[1] Current technologies do not require nor preclude the use of protection rings, but have the freedom of alternate approaches such as mesh restoration and protection.

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

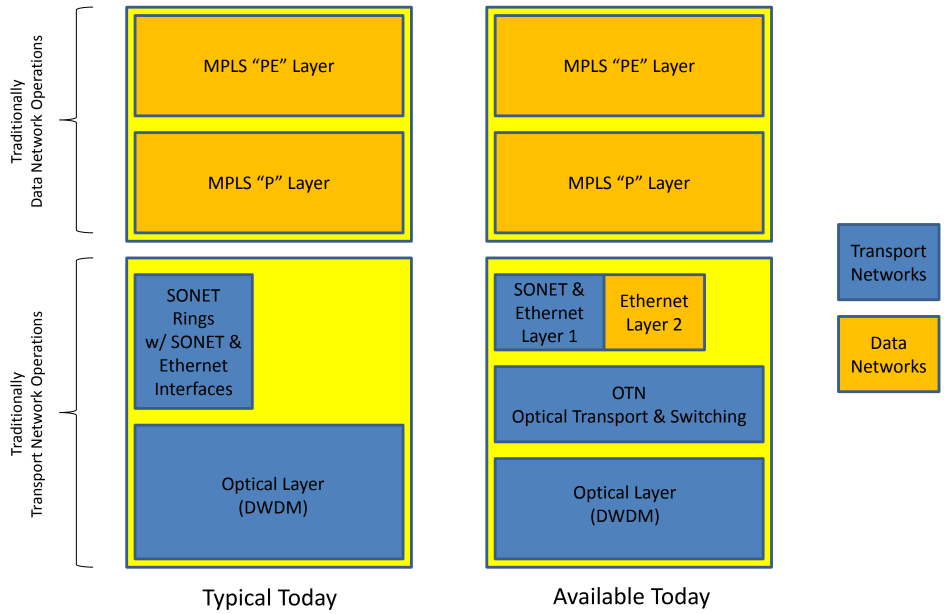

Figure 1, The Transport System's Convergence Step 1

The first major change in this transition is the emergence of OTN as the Layer 1 optical transport and switching technology. OTN enables significant flexibility in providing dedicated bandwidth between transport interfaces based on mesh and other protection mechanisms. This flexibility essentially removes the complexity of creating and managing SONET rings for service protection and replaces it with end-to-end point-and-click provisioning based on the number of Mbps required, the service interfaces (SONET or Ethernet), and resiliency (e.g., 1+1, 1+N, mesh protection, or unprotected). In addition, because of its mesh-protection capabilities, the OTN switching layer can incorporate any OTN path into the managed set of resources. This ability means that a provider can incorporate the same services on leased OTN bandwidth as on OTN bandwidth provided by its own optical transport infrastructure.

The second major change is that, in addition to these ONT-based TDM services, equipment vendors have also enabled a rich Ethernet Layer 2 services environment. These services enable the creation of Layer 2 WANs, as well as Layer 2 backhaul to other services, such as Layer 3 VPNs, in the network. It is precisely this capability that starts driving real convergence, both from an equipment perspective and operations perspective. As described in Section 4, the management systems provided by the traditional optical transport vendors generally expands on the point-and-click circuit provisioning with an analogous capability for Ethernet WAN services. This is the first area where the traditional responsibility of providing a WAN service (in this case Ethernet) may be taken away from the MPLS PE (i.e., which provides this via VPLS) and into the transport arena. Because of this result, there are organizational, planning, and operations issues that need to be addressed to take full advantage.

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

This first step of converging data services is also moving up the "stack".

5.2 Nearly Now

The "Nearly Available Today" enables network operators to start down an additional path. Shown in Figure 2, this new convergence is the incorporation of the traditional MPLS "P" function. This incorporation is moving the function normally provided by a large router providing MPLS-only (e.g., handles Labeled Switched Paths only and does not "route") capabilities into the same hardware environment that provides OTN and DWDM transport. Optical transport system vendors are banking on merging these capabilities to significantly reduce total hardware costs and improve overall system efficiency:

- Eliminate the back-to-back optics costs that are incurred by connecting separate pieces of equipment together (e.g., between the "P" MPLS router and DWDM optical transport)
- Universal switching matrix (i.e., combining TDM and Packet switching) eliminating redundant hardware
- Simplify the operations environment with fewer connections and easier capacity upgrades

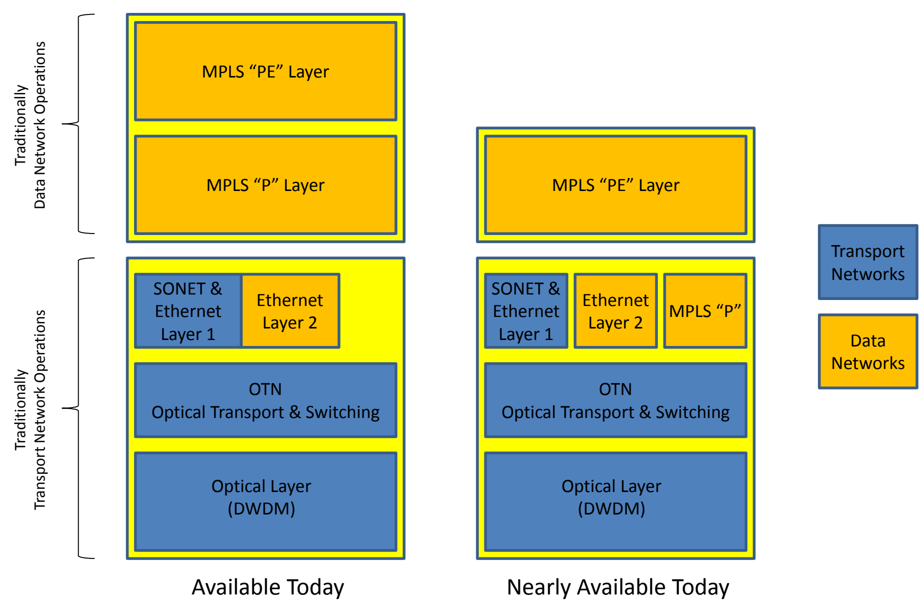

Figure 2, The Next Evolution Step - Sooner than Later

As shown in Figure 2, this approach places within the transport network domain devices that have traditionally been acquired, engineered, and operated by an IP data network organization. To take advantage of this convergence, the traditionally "stovepiped" engineering and support organizations must change. For example, the IP engineering organization has to directly participate in the specification, testing, and eventual deployment of such an integrated network component. This requirement complicates the selection of systems as the normally separate

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

buying decisions now have dependencies in technology and service provider organizations. As an aside, a real question for equipment vendors is whether this integrated approach creates a set of overly complicated organizational issues for service providers. In general, engineers (and operations staff) love to hug their hardware. If they are no longer in control, their natural reaction will be to resist the change, in spite of the what may be best for the service provider at large.

In parallel with changes in engineering, there are needed changes in operations. In general, the operation of MPLS devices is managed by a "Data" Network Operations Center (NOC), and the transport equipment by a "Transport" NOC. For many service providers, these may not even be located in the same building. In general, the data network looks at the optical service as an independent resource provided by an internal service provider. Data network robustness, such as optical path failures, is addressed at the MPLS-layer. The Transport NOC provides circuit resources and performs maintenance as needed, generally not directly in regard with the users of their service, including the MPLS network.

There should be a benefit for the closer engineering and operations of these layers:

- Engineering. Reduced disconnects between transport and data planning. New architectures that reduce service complexity and increase performance and flexibility
- Operations. Consolidated operations, improving provisioning, service reporting, and service management.

5.3 Potential for Radical Changes

There are significant opportunities for architecture changes based on the capabilities offered in these new transport platforms. Not only are they incorporating switching and MPLS LSR functions, but they offer OTN switching and protection of a wide range of bandwidth. For example, with optical line rates going to 100Gbps and 200Gbps, and even 400Gbps and 1Tbps (or more) so-called super-channels in sight, is there a need for an MPLS P function? That is:

- Do we ditch for efficiency and cost another hardware layer of expensive (in cost and power) packet switching whose essentially sole purpose is reliable bandwidth between two major service provider locations?
- For many VPN-type services, do we even need to have MPLS technology to support bandwidth management and service protection?

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

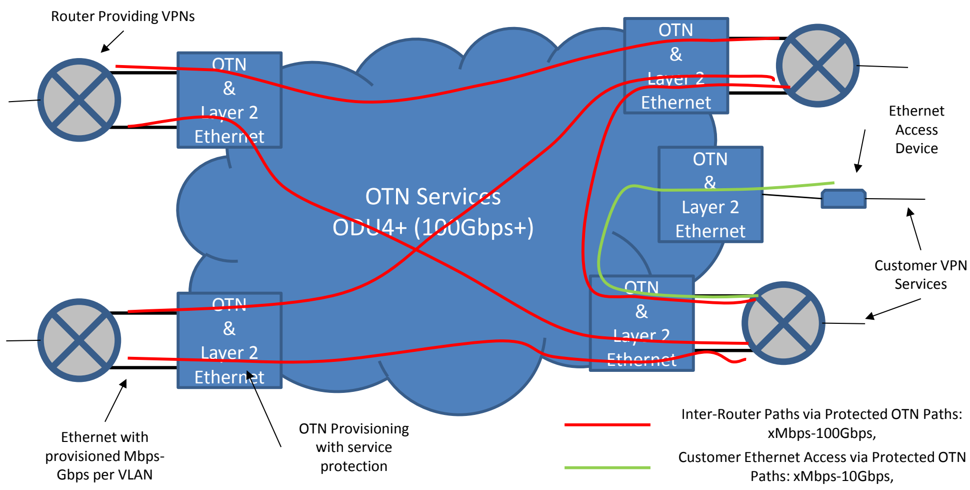

Figure 3, Potential VPN Services Architecture

Figure 3 shows just one of several potential architectures that takes advantage of OTN capabilities. In this case:

- Routers with VPN capabilities (essentially PE routers) are configured with standard Interior Routing protocols. This is what is left of the IP services Core.
- Protected OTN bandwidth is configured between the VPN Routers providing the required connectivity and performance. This can range from as little a 1Mbps to 100Gbps.
- Protected Layer 2 Ethernet WAN service is used to provide cost effective access at remote IP locations, and can be dual-homed to improve service resiliency.

From an IP network perspective, you could make the observation that this approach is a throwback to the "circa 2000 architecture" of the past. At that time, before widespread use of MPLS techniques such as Fast Re-Route, routers were connected via protected SONET circuits. However, OTN, unlike SONET, provides for a real mesh of protected bandwidth controlled either via provisioning point-and-click, or via signaling such as GMPLS.

The discussion here is not meant to be a direct recommendation, only that the recent common wisdom of network architecture needs to be questioned in light of new capabilities and the need for more cost effective solutions.

6 Organizational Consequences of Convergence

In this new environment, the transport and data network worlds collide. Indicated previously, there are significant engineering operations inter-dependencies that need to be reconciled:

- Which engineering team is primary on the equipment?

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

- How do you get the data network engineering team to give up the independent selection of their core routers?
- What network management system monitors the equipment?
- How do you coordinate maintenance activities?
- Are there training gaps and skill gaps that need to be filled?
- Do you collapse the Data and Transport NOCs?

Even in light of these issues, the convergence train has left the station and its next stop is yet another consolidation of equipment which promises to improve scalability, reduce cost, and increase power efficiency.

It is critical that service provider leadership examine these issues. Strong consideration should be given to the creation of Network Services Architect and Engineer positions. These positions would be specifically tasked with exploring these options, and helping to foster a convergence oriented view in the engineering and operations staff.

In addition, changes in the definition of typical existing engineering groups may follow something like the example in Table 1.

Table 1, Example Organizational Changes

Functional Area	Traditional Definitions	Converged Environment Definition
Transport	• Optical Infrastructure • DWDM Transport • SONET and Ethernet Private Lines	• Optical Infrastructure • DWDM Transport • OTN-based Services ○ SONET-interfaces and Ethernet Private Lines • Ethernet WAN (Layer 2 VPNs) • MPLS P functions
IP Core	• P and PE Engineering • Core Routing (MPLS VPNs, VPLS, etc.) • Network Peering	• PE Engineering • Core Routing (MPLS VPNs, VPLS, etc.) • Network Peering
Edge	• Customer Edge (CE) routing • Customer LAN	• Customer Edge LAN to WAN • Customer Edge (CE) routing, if required • Customer LAN

The respective staffs of the Engineering and Operations organizations are going to have to get used to these changes, and learn to understand how to share their network hardware engineering and operations responsibilities.

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770

7 It's About Service Delivery

The concepts in this paper are not academic; the issue is the ability to leverage rapidly changing, new technologies, and evolving planning and engineering and operations approaches, to improve service delivery. The old stovepipes that defined solutions based on an organizational construct need to make way toward a more integrated approach that understands the need for cost effective technical solutions that meet needs that vary from providing Mbps of access to corporate intranets to the very high-packet delivery requirements in the tens of Gbps that are needed to tie together corporate datacenters.

14900 Conference Center Drive
Suite 280
Chantilly, VA 20151
703-955-7770