The Multi-Layer Transport Network Opportunity

An Infonetics Research Report
Written by Andrew Schmitt

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Traffic Growth ≠ Revenue Growth

The past decade was nothing short of a communications renaissance. You have experienced this transformation through greater reliance and use of smartphones, Netflix, Facebook, tablets—the list goes on. The latest estimates of data growth from the Cisco VNI forecast are 29% per year, with areas such as mobile traffic growing as fast as 78%. And not a day passes without a vendor or pundit pounding their fist and highlighting this growth. But some listeners foolishly make the mistake of equating this traffic growth with revenue growth.

The Challenge and Opportunity of Multi-layer Networks

Our research shows that between 2005 and 2012, worldwide service provider revenue grew at a compounded annual rate of 4.8%. It is not a coincidence that during the same period service provider capex grew at nearly the same rate—4.9%. Carriers learned the hard lessons of unfunded capex growth around 2000, and since then have indexed capex growth with associated revenue, not traffic growth. Regardless of whether data traffic growth is 29% or 78% per year, it is far outstripping both capex and revenue growth.

Accommodating this traffic growth within a constrained capex environment is a challenge, but this is not new; the industry has successfully solved this problem for decades by deploying new technologies, vendors, and solutions. Service providers periodically depart from the status quo to pursue the new approaches needed to deliver greater operational efficiency. The latest example is the ongoing transition to new equipment and vendors for 100G+ optical transport.

This challenge of data growth presents an opportunity; operators must select new architectures to differentiate their networks and services and gain competitive advantage. These new architectures must be designed for the needs of an all-packet age, but the most efficient approaches will blend technologies from the optical, circuit, and packet domains. Operators that build more efficient multi-layer networks that are flexible and responsive to changing customer requirements will emerge stronger as a result of this challenge.

Exploit Patterns in the Data

All traffic growth is packet based, so intuitively one would think routers are the only equipment needed. But widespread deployment of routers to accommodate this growth is not just expensive, it is unnecessary. Whether the traffic is inter-data center, multicast video, or superhighways of Internet traffic between major Internet POPs, there is a pattern in packet networks, one that should be exploited to reduce costs.

Just as there was once much voice circuit traffic between any two given cities, there is tremendous ongoing data traffic between each city’s data centers and enterprises. It might be periodic online backups or the ebb and flow of access to cloud storage, like moving large data sets for biological applications, or constant real-time syncing of cloud computing resources. But at a higher level, this traffic is omnipresent and relatively deterministic. Changing customer demands and traffic patterns are periodic and may be identified by operators or by software acting on their behalf.
One such periodic but deterministic connection pattern is elephant flows—large volumes of traffic flowing between data centers or from data centers to major Internet exchanges. The patterns and behavior of these elephant flows is not unlike the deterministic behavior of the old telephone network—lots of traffic to/from businesses during the day, lots of local traffic from residences during the day and long distance at night.

Paired with such elephant flows are mice flows, the smaller flows to/from individual users in residential, wireless, and enterprise environments. But operators know that most of these mice flows are destined for the Internet or Internet service providers like Google, Akamai, or Facebook, who may have a point of presence at the carrier; rather than use routers throughout the network, operators aggregate and backhaul these mice flows to this point. This knowledge of logical data flows eliminates the need to use more costly routers until traffic reaches the Internet gateway and peering points where layer 3 intelligence is needed to direct mice flows to the appropriate provider.

Once elephant flows are identified or mice flows are aggregated, it is fundamentally cheaper to bypass the additional hardware and software complexity of the IP layer and transport them with ROADMs and OTN circuit switching. Operators with knowledge and visibility of these flows can exploit this information to reduce network costs and keep pace with data traffic growth without stretching capex.

Transport Network Requirements

The fundamental requirement of what transport networks must do—move an ever-increasing amount of IP traffic from point A to point B—is well understood. Less clear is how, and there is no single solution that fits all networks. Aside from the most obvious requirement (low cost), there are four basic requirements generally desired by service providers:

- **Agile**: Networks need to be quickly reprovisioned as customers and services are added and deleted. Often the speed at which a new customer can be added is a key determinant for winning the business. Plus, the operational cost of a network that is more agile is inherently lower, as fewer touches are needed to meet business needs.

- **Flexible**: Uncertainty reigns in the networking world as traffic growth is compounded by the addition of new services and customers. Predicting the future is ultimately a losing game, and having a network that can adapt is vital.

- **Simple**: Transport networks are a mix of OSI layers 0 through 3; as more vendors and control planes are added to the mix, simplicity suffers. The number of hardware and software systems used to operate the network should be minimized.

- **Resilient**: Networks break, and they need to fix themselves with a minimum of disruption to affected services and adjacent traffic, and with a minimum of redundant transport capacity added to the network.

Individual service providers place different values on each of these characteristics, so there is a range of transport architectures to meet their needs in various parts of their networks.
The Failed Promise of IP over DWDM

One technological approach put forth a decade ago, IP over DWDM, was positioned as the solution of the future. The premise was simple—since all traffic growth is data, why not just put WDM interfaces on routers and eliminate standalone optical equipment entirely? This should create a network that is agile, simple, and resilient at minimal cost.

But this approach of layer elimination never gained widespread deployment - even among customers with networks well adapted to the approach. Some feel that the transition to 100G presents another opportunity to roll out this architecture, but the lack of adoption of IPoDWDM at 10G is in essence an existence proof that this approach doesn’t work. Let’s look at why:

1. Routers have typically performed poorly at integrating the optical layer, particularly management of optical layer components such as ROADMs and amplifiers. This impacts operations, limiting network visibility and control. Also, private line services such as storage and video, and permanent optical circuits where customers demand the carrier not touch or inspect traffic simply can’t be supported at all. Though data may be all of the growth, many customers still do not trust the statistical uncertainty of having data processed at the IP layer. Carriers themselves may desire the strict separation of internal networks that circuit switching provides. Bottom line, IPoDWDM lacked the flexibility operators wanted.

2. Routers are expensive machines because of the complexity of the task they perform. They perform fine-grained inspection, manipulation, and management of tens of thousands (or more) of individual flows. As demonstrated by mice and elephant flows, this complexity is overkill for many parts of the network. It is better to deploy this high value tool at points in the network where large amounts of uncorrelated traffic exist. Most of the traffic growth in carrier networks today doesn’t meet these criteria.

3. Operators seek to maximize capacity utilization of router line cards because of their relatively high cost. Though the latest generation router line cards will support 4 or 5 ports of 100GbE short reach interfaces, using coherent optics limits interface density to 2 ports. Therefore, if operators choose to deploy IPoDWDM router line card, they do so at the cost of router capacity.

4. There are many vendors of optical equipment, but service providers are often forced to choose between two or three router vendors. When the optical interfaces are absorbed by the router equipment, the carrier has essentially handed over control of transport to the same vendor, limiting the ability to have a flexible equipment supply chain.

5. As demonstrated at 10G, the promised cost savings of eliminating the optical layer never materialized. Part of the problem is that routers typically have gross margins of 65%, much higher than equipment in the optical layer (approximately 30–45%). Router vendors were wary of collapsing pricing as a result of integrating lower margin optical functions. Service providers concluded it does not make sense to add more functionality to the highest margin equipment.
The New Transport Layer: OTN Switching

Thus, most service providers concluded that IPoDWDM and the elimination of a fully featured circuit-based optical transport layer is not a feasible data network solution. Though this network architecture is simple and flexible for some operators with a single IP network, it lacks the needed features for most large operators with diverse networks—and is prohibitively costly in most configurations.

Instead most operators are looking toward multi-layer integration, as it provides significant benefits from economic and technical standpoints. Even Cisco, an early proponent of IPoDWDM, is now a supporter of OTN switching in its optical equipment.

Service providers recognize that a standalone optical layer fundamentally provides a lower-cost method for transporting data. A standalone optical layer with OTN switching also provides key circuit-based functionality for separating the traffic of multiple internal or external customers that cannot be replicated at the IP layer.

OTN switching is the fundamental technology at the heart of the next generation transport layer, bringing forward many of the features of legacy circuit based optical networks but incorporating the functionality required for packet transport. OTN switching technology was discussed at length in a previous Infonetics white paper, *Integrated OTN Switching Virtualized Optical Networks*, showing it fundamentally improves transport networks in the following areas:

- **Capacity**: OTN switching makes networks more efficient by virtualizing capacity, ensuring that WDM links are fully utilized and that no stranded bandwidth remains.
- **Service velocity**: Virtualization of computing resources allows new services to be quickly added in the data center. OTN switching virtualizes the transport network allowing end-to-end service changes to be processed easily.
- **Provisioning**: Customers may request different latency, protection, and restoration policies. Integrated OTN switching allows a mesh based approach to provisioning, allowing multiple clients sharing the same virtual transport network to take paths that meet each customer’s specific requirements.
- **Restoration**: The meshed nature of OTN switching gives the control plane more options to restore a customers original provisioning requirements if there is a link failure in the network.

These four characteristics provide the underpinnings for a data-aware transport layer that is flexible enough to accommodate changing operator requirements; paired with the IP layer, this separate layer can be referred to as IP over OTN (IPoOTN).

IPoOTN uses the end to end granularity of OTN switching coupled with knowledge of traffic flows to reduce the waste of router capacity on transit traffic, creating a more efficient routing architecture and slowing the need for more routing capacity as traffic grows.
Comparing IPoOTN and IPoWDM

IP over DWDM (IPoDWDM) connects routers directly to the optical transmission layer. The routers provide all multiplexing and bandwidth management; traffic between the source router and the destination router may traverse intermediate routers. This transit traffic in the intermediate routers requires additional routing capacity in the network incurring additional expense.

IP over OTN (IPoOTN) connects routers using short-reach Ethernet interfaces to an OTN/WDM transport layer. Provides multiplexing, bandwidth management and transport using WDM interfaces integrated in the OTN switch platform. These interfaces are denser and cheaper than equivalent interfaces in routing equipment. Traffic between the source router and the destination router can bypass intermediate routers by using the converged OTN/WDM switch. Transit traffic traversing intermediate routers is reduced, lowering required routing resources and overall network expense.
Service providers are again adjusting how they plan to build networks to keep pace with the requirement of transporting more traffic in a capex constrained environment. They recognize the value of retaining a separate transport layer with OTN switching that underpins the IP layer. Let's look at the key features and benefits of this network.

**Integrated WDM and OTN switching**

For our May 2013 *OTN, MPLS, and Control Plane Strategies: Global Service Provider Survey*, we interviewed 21 service providers that have deployed OTN transmission or switching equipment or equipment with G.709 interfaces, or that plan to do so by the end of 2014. 89% of respondents planned to use integrated WDM and OTN switching in their systems.

OTN switching is a very desirable feature but the incremental costs of introducing it to the network must be minimal. Some WDM transport systems are designed from the ground up to support OTN switching today; the nature of their designs allows these systems to offer the benefits of virtualized optical networking at minimal incremental cost to standalone WDM systems.

The value of mesh networks increases as the amount of connectivity increases; but for this to be true in an optical network the cost of these connections must be minimized. It is important for WDM hardware, particularly 100G coherent interfaces, to be vertically integrated and provide the highest density and lowest cost possible; not all optical transport suppliers have this capability. Vendors that can provide lower cost optical connectivity will, dollar for dollar, build better mesh networks.
Mesh Planning and Restoration Capabilities

Most existing networks are not meshed and don’t have the features to deliver IPoOTN functionality. In the core, 58% of service providers in our May OTN survey currently use point to point or ring based network planning, and a similar number use these same techniques for protection and restoration.

Almost all these service providers plan to migrate their transport topology to either partial or full mesh approaches within the next 3 years. The economic benefits of this approach, particularly the reduction in the amount of redundant protection bandwidth, are the main reason for this dramatic shift. But deploying mesh networks also allows service providers to price and provide different levels of latency and protection to customers who have different needs. Protection that was once handled at more costly higher layers can be implemented in the lower-cost transport layer.

Carriers are evaluating and installing solutions today that need mesh topology and restoration features. This requires a large OTN crossconnects paired with planning and control plane software capable of providing rapid route planning and restoration.
Multi-Layer Planning and Control

Optical transport equipment is only half of the solution for IPoOTN architectures; it must interface with the IP layer to identify and route flows efficiently. This requires incorporating software defined networking (SDN) technology that allows external application visibility and control of network assets. These applications (whether automated orchestration software or a human) must be able to plan and control the optical and IP layers simultaneously. This is only possible if the equipment vendors have designed and delivered the appropriate interfaces.

For our July 2013 SDN and NFV Strategies: Global Service Provider Survey, we interviewed 21 service providers that have evaluated SDN projects or plan to do so. Network provisioning is among respondents’ strongest reasons to evaluate SDNs.

![Exhibit 4: SDN Evaluation Drivers](chart)

The means for accomplishing this are still under study, and different service providers will choose different paths, but the optical layer needs a vendor commitment to a feature roadmap that will allow northbound external communication with a third party. Organizations such as the ONF’s Optical Transport Working Group are good examples of work in progress.
“As silicon integration progresses, we expect the incremental cost of adding MPLS transport functions to OTN systems to drop. Once this takes place, we believe the transport OTN and MPLS features will merge into a single hardware system.”

**Intelligent Use of ROADM**

A network that requires ROADMs for mesh connectivity introduces a new level of complexity due to optical planning, compromising fast and flexible provisioning and restoration. But ROADMs play a key role for some routes, and just as OTN switching is an effective tool for eliminating transit traffic on routers, ROADMs can help eliminate transit traffic for OTN switches.

Certain network paths will benefit from bypassing OTN switching capacity. The optical span, particularly in the metro, may be short enough to not require regeneration, and it contains multiple wavelengths that can express through.

**Blueprint to integrated MPLS**

MPLS is an attractive technology that provides a more cost-effective approach for data transport than IP routing in many networks. It is not however, a replacement for the optical layer. The industry learned during its evaluation of IPoDWDM that there is a need for a separate optical layer.

But a new generation of core transport systems is arriving that brings limited MPLS and Ethernet circuit switching intelligence to the optical layer. The objective of these systems is not to duplicate the functions of the routing layer, but to provide enough function to perform some MPLS switching. Multi-layer planning software and SDN control will leverage the flow and circuit intelligence contained in routers to perform these functions in the lower-cost optical layer.

Though some MPLS implementations are less expensive than full blown core routers, these systems sell today at a premium to pure OTN switching. These standalone MPLS solutions are difficult to justify—less powerful than a router but lacking the needed optical circuit functions.

But as silicon integration progresses, we expect the incremental cost of adding MPLS transport functions to OTN systems to drop. Once this takes place (in 2014–2015), we believe the transport OTN and MPLS features will merge into a single hardware system, completing a transition to a 2-layer network from what is today multi-layer (one layer for transport, another for IP services).
Vendors offering OTN switching today must have hardware and software architectures that can incorporate MPLS transport functions in the future without a forklift upgrade. This requires traffic-agnostic switching fabrics and aggressive pursuit of open multi-layer networking via SDN.

Summary

Service providers survived the challenge of bandwidth growth in the face of constrained capex over the last decade, and they will continue to do so. The key ingredient for success is the continued willingness of these companies to adopt new vendors, equipment, and network architectures that keep dropping the cost per bit per kilometer in their networks while adding the features and services customers demand. Technologies like metro ROADM in the 2000s and coherent WDM today are good examples; IPoDWDM is not.

The next step is a move to widespread multi-layer networking built on an intelligent optical transport mesh. At first this requires an OTN switching architecture with integrated WDM and multi-layer planning and control software, referred here as IPoOTN. We expect this to evolve to one that requires OTN and MPLS switching in the same equipment, ultimately unifying the transport layer in a single hardware element capable of OSI layers 0-2. This layer would serve the transport needs of more expensive and scarce routers performing high value packet processing and delivering the required service intelligence at the edge of the network.
White Paper Author

Andrew Schmitt
Principal Analyst, Optical
andrew@infonetics.com
+1 408.583.3393

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To learn about custom research opportunities with Infonetics Research, please contact:

North America (West), Asia Pacific
Larry Howard, Vice President, larry@infonetics.com, +1 408.583.3335

North America (East), Texas, Midwest, Latin America
Scott Coyne, Senior Account Director, scott@infonetics.com, +1 408.583.3395

Europe, Middle East, Africa, India, Singapore
George Stojsavljevic, Senior Account Director, george@infonetics.com, +44 755.488.1623

Japan, South Korea, China, Taiwan
http://www.infonetics.com/contact.asp