Flexible SDN Transport Networks With Optical Circuit Switching

Multi-Layer, Multi-Vendor, Multi-Domain
SDN Transport Optimization

SDN AT LIGHT SPEED™
INTRODUCTION

The economic benefits of converging network layers are powerful. Estimates suggest potential 35% to 50% savings in core router network CAPEX by allowing layer 3 to drive the optimization of optical transport networks. Converging network layers also offers up a new range of services and revenue opportunities, allowing end users and service providers to dynamically setup optimal paths based on traffic patterns, quality of service level commitments, and time of day effects.

Today however this level of optimization is constrained by the inability of the optical transport layer to flexibly respond to the requirements of the packet layer. While new technologies, such as CDC ROADMs offer the needed level of flexibility they are not deployed widely enough to support implementation of multi-layer optimization.

In this paper we offer a solution that solves these issues and supports network wide deployment of multi-layer optimization today. By deploying Optical Circuit Switches (OCS) at the edges of networks and between network and vendor domain boundaries, Service Providers and Data Center Operators can virtualize all of the disparate new and legacy resources in their optical transport networks, providing a pool of network resources that can be used and in some cases reconfigured on demand.

THE OPPORTUNITY AND CHALLENGES OF MULTI-LAYER NETWORK OPTIMIZATION

A fact that the networking industry has known for a long time is illustrated by the inverted triangle in Figure 1. - If you simply look at capital cost and operational cost on a per bit basis, it’s much less expensive to switch network traffic in the optical domain. It’s more costly to switch in the electrical domain, and routing, of course is the most expensive place to handle switching and forwarding of information. So, where possible it makes sense to switch at the optical layer.

![Figure 1 - Relative Switching Cost Per Bit](image)

But in order to be able to make choices about the most appropriate layer to switch in any given traffic scenario there are two primary prerequisites that must be in place. First there has to be control plane
visibility across the network layers, and second, all the network layers must be able to flexibly reconfigure topology and capacity to support traffic patterns in the most optimal way. In an ideal scenario for example, the control plane would allow the optical layer topology and capacity to be reconfigured in response to the demands of the layer 3 network.

This level of dynamic optimization also spawns the growth of new services. For example in the ideal scenario just mentioned, service providers could truly offer services on demand. A large data center, for example, might need a high capacity low latency link for a short period to facilitate a data migration or backup between data centers across the metro or wide area. That service could be provisioned essentially on demand for the needed time period and then shut down.

Multi-layer optimization hasn't seen much deployment to date however. Recent advances in Software Defined Networking (SDN) are enabling control plane visibility across the network layers, but the missing link is a truly ubiquitous flexible optical network layer that can respond to the control plane. Most of the metro and wide-area optical networks today consist of a mesh of fixed optical pipes. Even though conventional ROADMs allow some reconfiguration options, these capabilities are typically only used for network planning purposes, not for real time optimization.

New generation Colorless, Directionless (CD) and Colorless, Directionless, Contention-less (CDC) ROADMs offer a foundation for the needed flexibility, but there are so few deployments of these new technologies and the growth is so slow, that multi-layer optimization can only be realized in isolated network islands.

**MULTI-LAYER NETWORK CONCEPT**

Lets illustrate the challenge and the solution.

In the example in Figure 2 we show two metro networks or data centers connected over a wide area transport network. This is a representative model because the same principles apply generally to multi-domain networks whether they are connecting metros or data centers.

![Figure 2 - Multi-Layer Network Model](image-url)
The transport network layer is below and above that is a traditional IP network with metro and core IP/MPLS connected to another metro network.

In this example we want to setup a high-bandwidth, highly persistent data connection between hosts in the two metro areas for a large data migration.

Standard procedure in the way networks are built today would likely lead to a circuit that takes the sub-optimal path illustrated in red in Figure 3 - which is constantly bouncing up and down between the optical transport layer and the core routers.

Figure 3 - Sub-Optimal Network Path

In this case we see an end-end IP or Ethernet service over the IP/MPLS core that is chewing up a lot of capacity on several intermediate routers simply to move the package from the metro on the left to the metro on the right. There’s no fan out occurring. Nothing is happening in the core network other than IP packet transport. This is a good example of very inefficient use of network resources and it also potentially degrades performance because of the additional latency added by the intermediate router hops.

In a perfect world, it would make much more sense to express this connection through a pure optical-layer path without the intermediate hops.

With SDN, we now have the ability to start placing policies on traffic. In this particular example which is really a large bandwidth flow going from the left metro to the right metro, we would likely find that an express path (as shown in Figure 4) is much more cost and performance efficient. Transporting this traffic flow over the optical transport network and moving it directly without consuming ports up and down on the routed layer is a much better utilization of resources.
Figure 4 - Optimized Network Path

The technology to achieve this with a flexible optical layer has existed for several years with Colorless, Directionless (CD) and Colorless, Directionless, Contention-less (CDC) ROADMs but the multi-layer optimization vision hasn’t been realized yet. There are two main reasons for this. First was the lack of some kind of control orchestration to allow packet and routing engines to drive the optical topology, and SDN platforms are solving this problem today.

The other problem, which is significant, is that CD and CDC technology is not ubiquitously deployed in transport networks and without this, layer convergence doesn’t work. Service providers have substantial investments in legacy network equipment with limited or no re-configurability and these will remain in service for many years.

Similar problems exist with separate islands or domains of equipment from different vendors that don’t interoperate. For example it’s not possible for an edge router to dynamically select an optical path from a network element that it isn’t physically connected to. So if the router is connected to a network from Vendor X but the optimum path is on a network that uses Vendor Y, it can’t physically access that capacity.

Without having the flexibility to bring these legacy systems into the fold, and to allow access to network resources from different vendor islands, multi-layer convergence can only partially be realized and this will delay and limit it’s benefits.

Lets illustrate this dilemma and the solution by going back to our earlier example where we created an express optical layer path between the two metro areas or data centers.

The question arises – what if the express network path available between the two end-points is on a legacy network path or a separate vendor island that the edge routers are not connected to as shown in Figure 5? The routers simply have no physical means to reach the available express path. This is one of the big reasons that multi-layer convergence is problematic in real service provider networks.
There is a solution - Optical circuit switching solves this challenge by providing flexible optical layer on-off ramps between different equipment and network domains.

In this example, as shown in Figure 6, adding Optical Circuit Switches (OCS) at the edges of metro and wide area networks allows the multi-layer control plane to access and select resources from any domain or vendor, including a legacy network.

This allows Service Providers and Data Center Operators to virtualize and control all of the disparate resources in their optical transport networks.

The optical network capacity becomes a pool of resources – It doesn’t matter which vendor’s equipment is in use, or whether it’s a new CDC system or a legacy system. The OCS at the network edge allows any client side resource to be connected to any network resource and supports network-wide SDN control of the optical layer.

**Figure 5 - Available Express Path on Legacy Network Not Accessible**

**Figure 6 - Optical Circuit Switching Provides Flexible On-Off Ramps**
SDN management of the network is achieved with or without OpenFlow and REST APIs on all of the transport systems in the network. The optical layer is reconfigured through a co-ordination of switching elements on the CD and CDC ROADMS and the OCS nodes.

With everything under SDN control as shown in Figure 7, we’ve essentially taken the entire transport network including all vendor and geographical domains and virtualized it as a giant optical switch. Any router port can request an optical connection to any other router port in the network. The optical transport network can make the connections on demand. Importantly, it works across CD, CDC, and legacy network solutions.

![Figure 7 - Transport Network as a Giant Optical Circuit Switch](image)

The result is real-time flexibility that the packet layer can take advantage of. It is also now also possible to use holistic analytics to look for network congestion points and reroute traffic to routes with more available capacity.

This means that the substantial operational and economic benefits of multi-layer optimization can be fully realized TODAY, independent of network and vendor domain boundaries and also across legacy networks.

**ENHANCED CLIENT-SIDE NETWORK PROTECTION WITH OPTICAL CIRCUIT SWITCHING**

Multi-layer optimization is a powerful reason to deploy optical circuit switching in optical transport networks, but not the only reason.

Another challenge with ROADM solutions, including the newer CD and CDC variants is that they offer limited redundancy options. Specifically they offer little protection against failures on the client-side of network nodes. When a client transceiver fails (on a core router for example), the corresponding transport capacity (wavelength) sits idle, and this represents huge wasted investment and loss of capacity.
Equivalent loss of bandwidth occurs if a ROADM Transponder fails or if there is a client-side fiber failure. These three failure modes are shown in Figure 8.

![Figure 8 - Optical Transport Client-Side Failure Modes](image)

Also, while CDC functionality can be used to protect against fiber cuts and many ROADM node failures, it only works on paths that are part of that vendor’s domain. It specifically can’t protect between a CDC network and a legacy network.

Deploying Optical Circuit Switches at the network edge (as shown in Figure 9) adds the ability to protect against client-side failures. In the event of a Router card failure the OCS can switch alternate router ports to the WAN Transponder. Similarly, if a Transponder card fails the OCS can switch the router port to a standby Transponder, offering either 1:1 or 1:N protection modes. Client side fiber failures are protected by the same protection mechanisms.
Protecting the client-side network in this way ensures that WAN network capacity is always fully utilized and the Client equipment has access to the full provisioned bandwidth.

**OTHER POWERFUL BENEFITS OF OPTICAL CIRCUIT SWITCHING IN OPTICAL TRANSPORT NETWORKS**

Multi-layer optimization and client-side network protection are primary benefits of deploying optical circuit switching in SDN Transport Networks. OCS also enables other benefits that will be fully realized over time. These include:

**New Services**

**Integrated NFV**: Optical transport systems are integrating low cost electronics that allow some NFV capability to be supported directly on the transport network. For example, Firewalls, caching, etc. could be done on transponders instead of deep inside the service provider’s own data center.

In this scenario, OCS is needed to move services onto network resources with the required capabilities in real time.

**Low Latency Circuits**: Service providers are facing increasing pressure to deliver shortest path point-to-point circuits across the MAN/WAN to meet low latency requirements and new NID/transponder
technology is emerging to allow service providers to offer latency based SLAs. In this scenario, the OCS is needed to switch services to low latency paths on demand.

2. Realize Full Benefit of Holistic Telemetry and Network Analytics Tools

New application layer tools are available which look at network metrics such as service distance/latency, power, and bandwidth congestion points. In such cases, real-time network optimization requires an optical switch

3. Seamlessly Roll Customers To The Latest Generation Transport Systems

New transport systems are continuously being installed which offer lower cost per bit in the transport network. 400G, 1T, and SDO are just a few examples of new technology that will reduce the cost of delivering bandwidth.

In this use case, OCS can be used to roll existing services from transponders to muxponders to reduce transport cost and relieve network congestion. This can all be done on demand and without physical intervention by field engineers.

CONCLUSION

Service Providers and Data Center Operators are aware of the need to add flexibility to the transport network so that circuit end points and traffic paths are optimized to meet bandwidth demand and eliminate expensive intermediate layer 2/3 hops.

Such Multi-layer optimization can only happen however if flexibility is ubiquitous across the MAN/WAN cloud. This is not the case in today’s networks, which consist of separate vendor and geographical domains, in addition to completely fixed legacy networks.

Adding optical circuit switching under SDN control at the edges of the network and between network domain boundaries provides the real time flexibility needed to support multi-layer network optimization, and it does so without being constrained by network and vendor domains.

Optical circuit switching also brings with it important benefits in protection of client-side failure modes and new service opportunities such as integrated NFV and Low Latency Circuit Paths.
ABOUT CALIENT TECHNOLOGIES

CALIENT Technologies is the global leader in pure photonic Optical Circuit Switching with systems that enable dynamic optical layer optimization in next generation data centers and software defined networks.

CALIENT’s 3D MEMS switches allow data center operators to dramatically improve utilization rates of expensive compute resources, which typically account for 75 to 90% of investment.

Data center operators and metro service providers also deploy CALIENT switches to offload large highly persistent data flows from packet networks to optical circuit switched networks within and between data centers, delivering light speed express path connectivity between compute resources with virtually no latency.

The company designs and manufactures its systems using the state of art MEMS fabrication equipment at its corporate headquarters in Santa Barbara California.

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CALIENT’S S320 OPTICAL CIRCUIT SWITCH

The explosion of video, mobile data, and server virtualization is driving the demand for flexible, scalable, high-bandwidth networks. CALIENT’s S320 Optical Circuit Switch is a reliable and cost-effective solution for these networks because the technology is transparent to data speed, and is protocol agnostic, thus it offers very high bandwidth and configuration flexibility as networks grow in speed from 10Gbps to 40Gbps and 100Gbps.

Based on field proven 3D Optical MEMS technology that CALIENT has deployed in more than 300,000 optical connections globally, the new S320 Optical Circuit Switch delivers a sweet-spot of high reliability, small form factor, low power consumption & cost, and ease of use that allows the benefits of true all-optical switching to be realized for the first time in a wide range of service provider and datacenter applications.

Applications
The S320 provides the scalable and protocol independent automated fiber interconnect and management infrastructure for a wide range of Datacenter, Service Provider, and Government applications including:

- Flexible, scalable on-demand resource optimization in enterprise and cloud computing datacenters
- Rapid disaster-recovery from multiple network failure scenarios in any optical network
- High port count colorless, directionless and contention-less (CDC) ROADMs in fiber-optic service provider networks
- Physical fiber network virtualization in metro SDN Service Provider networks
- Fiber To The Home (FTTH/FTTP) network automation – automated service activation & testing
- Sharing of high-value testing resources in lab automation & Cyber-range applications

Features & Benefits
- Small Size: 320 Ports (Tx/Rx pairs) in 7RU Chassis
- Low Power Operation: 45 Watts maximum
- Low Cost: Supports deployment in datacenter, service provider, and government networks
- Ultra-low Latency: All-optical connectivity adds no latency.
- Scalable: Supports all data rates to 100 Gbps and beyond
- Reliable: Based on proven 3D MEMS design deployed in over 400,000 fiber terminations globally
- Simple to use and integrate: GUI-driven, EMS-ready, supports TL1, SNMP, CORBA, OpenFlow
- Low loss: < 3.5dB maximum insertion loss
- Built-in power monitoring: Every in/out fiber is monitored providing powerful network diagnostic capabilities.