A Software Defined Network Architecture for Transport Networks

The Importance of an Intelligent Transport Network as a Foundation for Transport SDN

Introduction

Software Defined Networking (SDN) has had a successful journey from experimental university networks to production deployments, simplifying networks at IP/Ethernet layers within the data center. It is now extending its benefits into the wide area network (WAN) at both the packet layer and the transport layer. SDN enables centralized and programmatic control of the underlying packet and transport layers to provide increased automation to reduce OpEx, optimize the network to reduce CapEx, and deliver new services to increase revenues and improve customer retention. With the proper architecture and implementation, SDN can also support service providers who want to transform to a DevOps model for rapid service creation and deployment for a better competitive posture in the marketplace.
When discussing SDN as a method to programmatically control the transport layer, we use the term Transport SDN. To benefit from Transport SDN, network providers need to have a transport layer that is fundamentally scalable and highly software controllable – this includes DWDM parameters along with converged packet, Optical Transport Networks (OTN), and Colorless Directionless Contentionless Reconfigurable Optical Add-Drop Multiplexer (CDC ROADM) switching functions. This paper reviews the necessary capabilities for SDN-enabled transport platforms and an open software approach to implement Transport SDN. Infinera believes that our SDN solution, which comprises the Infinera Intelligent Transport Network and the Infinera Open Transport Switch (OTS), provides the most scalable and software controllable transport layer foundation in the industry.

The Emergence of SDN

Several years ago a number of university research groups began to experiment with the idea of disabling the distributed control plane in campus Ethernet switches so that the flow of packets through these switches could be managed instead via centralized control. The idea was to be able to quickly simulate the setup of experimental “slices” of the campus production network and, once verified, to automatically configure all devices required to instantiate those slices. The SDN approach worked, allowing quick and reliable deployment of experimental slices on the production network, alleviating time consuming and error prone device-by-device configuration tasks that could take down production traffic. The next stop for SDN was inside the data center. The emergence of Virtual Machines (VMs) resulted in improved server efficiency but also increased complexity, with tens of VMs per hypervisor or server and thus a massive multiplication of network connections. VMs were connected to other VMs or users, and as VMs were spawned, retired, and moved from server to server, changing network configurations on each switch in the data path started to become unmanageable. Centralized SDN controllers have demonstrated value by analyzing the entire data center network as an abstracted and virtualized representation, simulating any network changes ahead of time and then automatically configuring multiple switches when the change was activated.

More recently, architects have been experimenting with SDN in the WAN. The aim was to extend the concepts of SDN for packet systems (used within the data center) into the WAN router layer and subsequently the optical transport layer, which includes simplified packet switching, OTN switching and Wavelength Division Multiplexing (WDM) transmission and switching technologies. The most well-known experiment to date in the WAN is the deployment of central SDN control on Google’s G-scale network, along with custom-built OpenFlow switches connecting its 12 data centers worldwide.

While this experiment focused only on the router and switching layer and used static optical connections, it served as a proof point of the value of SDN in the WAN. Google realized many benefits from this centralized network control, including:

- Faster and more deterministic convergence compared to a distributed control plane.
- Increased operational efficiency, with links running at 95% vs. 25%.
- Rapid innovation supported by simulating the network in software before production service deployment.
While Google’s G-scale network does not have the same amount of legacy equipment or constraints as a traditional service provider’s, this is still an impressive accomplishment. As mentioned, what Google did not do in this network experiment, however, was enable a dynamic SDN-controlled transport layer. All of this packet traffic was carried over optical links using a static muxponder approach.

**SDN-Enabled Transport Solutions**

In a constantly changing world in which customers have dynamic bandwidth needs, Transport SDN offers network providers the ability to respond in real-time using the power of virtualization and abstraction by leveraging centralized control and visibility of the underlying converged transport layer. It brings the ability to orchestrate, control and manage transport network resources in an open and programmatic way. Transport SDN serves as a middleware layer that allows users to write applications that sit on the northbound side and speak to the physical transport resource via southbound interfaces, which facilitates programmability of bandwidth services, and thus offers service providers a simplified programmable bandwidth service model.

The value of extending SDN to the transport layer includes:

- **Increased revenues**: programmatic control enables service providers to create and deploy services in a DevOps model faster than in traditional networks, resulting in new services, reduced service delivery times and increased revenues.
- **Customer retention**: enabling customer control of transport resources through a self-service portal or APIs exposed to the customer can help service providers create a more satisfying and sticky experience for their end-users.
- **OpEx reduction**: the automated nature of network control and service delivery helps replace the traditional manual processes and workflows, reduce operating costs and deploy bandwidth when and where it is needed.
- **CapEx reduction**: enables service providers to have both programmatic control and complete visibility of the transport layer to ensure maximum network efficiency and deploy bandwidth efficiently.
when and where it is needed. When combined with centralized SDN control of the router layer, transit traffic can be offloaded from the router layer to the Intelligent Transport Network to improve overall network efficiency.

In order to extend SDN to the transport layer, the platforms and solutions that are used to build this layer must be inherently scalable, agile and software controllable. They must be able to support virtualization and abstraction of their physical resources, such as optical wavelengths, into pools of resources that can fundamentally be controlled by software. In our approach to SDN, Infinera enables the realization of a programmable optical network using Bandwidth Virtualization through the convergence of several key and innovative technologies that span optical components, system design and network architecture. In addition, features such as packet-aware transport, OTN switching, CDC ROADM switching, Instant Bandwidth and FlexCoherent are all highly software controllable and are designed to provide a solid foundation for SDN programmability.

Infinera leverages Photonic Integrated Circuits (PICs) to support super-channels that create large pools of software controllable Dense Wave Division Multiplexing (DWDM) bandwidth which, when combined with a large non-blocking OTN switch (5 Tb/s up to 12 Tb/s) and an intelligent software control plane, support Bandwidth Virtualization. It allows point-and-click provisioning of “client-side” services into super-channel pools of 100G optical “line-side” capacity. The OTN switch slices up the optical resources into granular 1 Gb/s chunks, and the software control plane represents each unit of capacity as “available” or “in use” between any two neighboring nodes, hiding the complexity of the actual underlying wavelengths.

In contrast, many other DWDM solutions today are highly static in nature, based on transponder and muxponder approaches. Muxponders offer a client-side service port (e.g. 1x100GbE or 10x10GbE connected to a router or a switch port) that is in turn hardwired to a line-side wavelength (e.g. 100G waves) inside a line card module (Figure 3). This hardwired approach
results in many manual operations and engineering processes to deploy new services, including a need to track each service that is mapped into specific wavelengths between every pair of nodes as well as significant wavelength-by-wavelength engineering. Cascading from this are requirements for truck rolls, manual patching and many additional operational costs.

This hardwired muxponder approach also results in a challenge with a diverse set of client side bit rates and line side bit rates. The DWDM line side has moved to 100G in the long haul market and 500 Gb/s and terabit super-channels, and will move to 100G in the metro market. Client services on the other hand are across the spectrum from 1G up to 100G. This can create an impedance mismatch between the lower rate client-side 1 - 100 Gb/s services and the line-side 100 Gb/s and beyond optical capacity that can result in tremendous inefficiencies with a muxponder-based approach. ROADM can help with network automation; however, they can only redirect photons and therefore switch entire wavelengths in 100 Gb/s or greater increments. They do not have the electrical switching capability required to access sub-lambda transport services at 1 Gb/s granularity and therefore cannot solve the impedance mismatch.

Infinera’s Bandwidth Virtualization leverages software-controllable OTN switching and is designed to solve the general problem of the impedance mismatch between client services and line-side transport and also to offer a high degree of programmability. In addition to Bandwidth Virtualization, four key functions that are or will be exposed to an SDN controller are Instant Bandwidth, FlexCoherent modulation, CDC super-channel ROADM and packet switching. Instant Bandwidth combines Infinera’s PIC-based 500 Gb/s super-channels with Digital Network Administrator (DNA) enhancements that allow network operators to instantly software-activate 100 Gb/s increments of line side bandwidth with the intent that they can quickly support additional revenue-generating services. An SDN controller or application can determine when this bandwidth is needed and could be pre-authorized or prompt a network operations specialist when an additional 100G of capacity is required to support a new revenue-generating service. Furthermore, Infinera’s FlexCoherent Processor supports software controllable modulation.
selection that could be exposed to SDN control, such as Binary Phase-Shift Keying (BPSK), extended BPSK (eBPSK), 3 Quadrature Amplitude Modification (3QAM), Quadrature Phase-Shift Keying (QPSK), 8QAM and 16 QAM, with the intent that customers can optimize for reach and fiber capacity. Programmatic control of CDC ROADM functions could be implemented to automate optical express paths in cases where the 100G, 500G or 1.2T optical super-channels are filled sufficiently that bypassing the digital switching function and staying completely at the optical layer with all-optical switching may be warranted. Finally, Infinera has introduced the packet switching module (PXM) with 10 GbE and 100 GbE interfaces, which is designed to allow more efficient use of transport resources by mapping Virtual Local Area Network (VLAN) and MPLS packet flows to flexible rate Optical Data Unit (ODUflex) containers and supporting packet switching. Exposing this functionality to the SDN control layer provides a full Packet Optical Transport System (POTS) multi-layer solution that can switch at any layer: the Optical ROADM layer, OTN layer, or the Ethernet and MPLS layer.

Open Transport Switch Software

Once a fundamentally scalable and software controllable transport layer is in place, the next step is to create a modern set of application programming interfaces so that third parties, including customers, can integrate it with an SDN controller, an orchestration solution or an application written for transport control. Virtualization and abstraction of the physical transport resources are key notions that will make the transport network easier to program and enable network operators to realize the true potential of Transport SDN in multi-layer networks.

![Open Transport Switch software architecture](image-url)
Infinera’s Open Transport Switch (OTS) software is a key building block in a network operator’s SDN-enabled architecture. OTS is a lightweight Web 2.0-enabled software platform that enables a very high degree of virtualization and abstraction of the physical resources of the underlying Intelligent Transport Network. The abstraction is intended to eliminate a rigid relationship between bandwidth services and physical network components to reduce the number of programmatic commands from hundreds to tens, simplifying the programming model. Infinera’s OTS has a very open and modular software design that is intended to allow it to easily integrate with any application, SDN controller or orchestration layer through standard and secure Representations State Transfer (REST) APIs. OTS software was designed with an Information Technology mindset from the ground up and has a very lightweight design. This enables Infinera to innovate new features more easily as opposed to other solutions that have started with an existing telco product and built APIs on top of heavyweight element and network management systems. Infinera believes that the lightweight design and open and modular approach of OTS software and the ability to rapidly innovate new features paves the way for service providers to leverage a DevOps model of software for new service creation.

**Hybrid Control Mode**

Transport SDN brings the ability to respond to dynamic bandwidth needs in real-time using the power of abstraction, resulting in reduced service delivery times and improved use of network resources. When service providers wish to migrate to an SDN model, they want to do so without disturbing revenues from their existing production services. Using Hybrid Control mode, OTS can be deployed in a network to introduce and manage SDN enabled transport services alongside existing production services, which are managed by Infinera’s network management software, DNA. This is intended to allow network operators to migrate to an SDN model without disturbing their existing services.

**Multi-layer Optimization**

One of the longer term use cases of WAN SDN is to combine SDN control and visibility of Network Functions Virtualization (NFV), the routed network and the transport network. Today these networks are typically planned, provisioned and managed separately, without knowledge of each other. Achieving a state where SDN has a centralized view of the topologies of all layers allows optimization across layers, reducing L4 – L7, router and transport costs both from a CapEx and OpEx perspective.
Conclusion

Software Defined Networking has come a long way. It started experimentally in university networks and is now being commercially deployed in real-world WANs. Transport SDN, which enables abstraction, virtualization and programmatic control of the underlying transport network, will help speed new service delivery while maximizing the efficiency of bandwidth utilization within a WAN. A successful Transport SDN implementation requires the underlying transport networks to be scalable and fundamentally software controllable to support programmability.

Infinera’s Intelligent Transport Network is designed to be scalable and highly software controllable. It leverages the PIC to incorporate distinctive capabilities such as Bandwidth Virtualization, Instant Bandwidth, Infinera FlexCoherent and all-optical CDC ROADMs to offer a robust foundation for Transport SDN programmability.

Infinera’s OTS software enables a high degree of virtualization and abstraction of the underlying converged transport layer, resulting in automation and programmability of bandwidth services. Its ease of integration, open and modular architecture and lightweight software design are intended to pave the way for service providers to transform to a DevOps model.

Network operators need to have a truly programmable, open and flexible transport layer to realize the benefits of Transport SDN. Infinera believes that our SDN solution, a combination of the Intelligent Transport Network and OTS software, delivers the following key benefits to the network operators:

- **The ability to scale networks quickly** by facilitating programmable deployment of optical bandwidth and IP resources to quickly support application-driven bandwidth demands.
- **Efficient resource utilization** by selecting the most optimal path through the multi-layer network and minimizing transit traffic through the router layer, thereby eliminating overprovisioning of the network.
- **Lower CapEx and OpEx** through automating operations across the network layers, eliminating device-by-device configuration at the router layer, and coordinating resource provisioning functions along with the intelligent transport layer.
- **Speed to revenue** by enabling a single screen or an API to provision, monitor, and optimize multi-layer services.