Layer T and Layer C: Collapsing Communications Networks into Transport and Cloud Services

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Summary

Rapid network traffic growth is driving constant change in the infrastructure as operators strive to scale their networks to keep up with the growth. In addition to the capital expense of this infrastructure expansion, the network is becoming more complex, which has led operators to employ the IT tool of virtualization, in the form of network functions virtualization (NFV), to reduce network complexity. NFV is becoming a reality in the network as equipment designers have virtualized numerous network elements such as the firewall, evolved packet core (EPC) and provider edge (PE) router. As virtualization subsumes many functions that modify services and connections which were otherwise performed in physical network elements, vendors are freed to develop network elements that are focused on moving bits and/or packets (which cannot be virtualized), and not performing ancillary network functions. This segregation of network functions into virtual versus physical processes suggests a two-layer model, which can simplify network planning and result in a more effective and efficient network.

• The cloud services layer (Layer C) consists of the many functions of network that are virtualized into standard high volume servers, switches.
• The transport layer (Layer T) consists of the remaining functions of the network, which are focused on sending higher and higher traffic volumes across the network.

This Advisory Report analyzes the concept of a two-layer network world view, detailing requirements of, and implications for, the transport layer of the network.
Key Takeaways

- As the industry virtualizes whatever network functions it can, they naturally fall into two categories – those that can be virtualized to run on x86 servers (Layer C), and those that cannot (Layer T).
- It is only a matter of time before most, if not all, of the specialized network elements/appliances are replaced with - or supplemented by – virtual instances of themselves.
- As cloud services functions are transitioned out of network elements, network elements such as routers will support fewer (if any) value-add features.
- The removal of ancillary network functions from physical network elements frees network equipment designers to refocus the network elements on their original role, conducting the flow of the bits and/or packets through the physical network.
- Beyond supporting massive scalability, Layer T requires granularity, automatic network control and continued support of the transport sub-layers.

Perspective

Current Perspective

Overwhelming traffic growth and virtualization are the two primary factors that are disrupting the network. New broadband connections supporting an expanding base of mobile devices (receiving yet larger data flows) and distributed (cloud) services is driving traffic growth beyond 20% per year (Cisco VNI Global IP Traffic Forecast, June 2014). The traffic flows are also changing; “east-west flows” rather than “north-south flows” (Figure 1, below) are becoming predominant. This change is driven by the dominance of mobile broadband growth (57% per year, VNI Global Mobile Data Traffic Forecast, March 2015) and distributed processing/storage trends represented as data center interconnection (DCI) traffic (e.g., network traffic is 930x client access traffic, per a Facebook March 2013 OSA Executive Forum presentation).

![Diagram of East-West and North-South Traffic](Image)
The concept of NFV sprang from the complexity that was arising in the network from the use of countless specialized network elements and appliances, and from additional services the network operators wanted to offer which would only increase network complexity. In addition, virtualization allows operators to scale up and down the resources allocated to particular network functions quickly. The industry began leveraging standard IT technology to consolidate the functions of many network equipment types onto industry standard high volume x86 servers. Combinations of these functions, when linked with the connectivity provided by the network, constitute communications services.

**Network Decomposition and Reconsideration**

Virtualization implies that the control of services and networks can be accomplished outside the physical networks. Network functions that modify services (and their connections) are being consolidated into the servers of NFV, which now virtualizes network elements such as the firewall, EPC, broadband network gateway (BNG), customer premises equipment (CPE), network address translation (NAT), session border controller (SBC), provider edge (PE) router, and more. Virtualization is a reality; however long it takes, most, if not all, specialized network elements/appliances will be replaced with virtual instances of themselves. Note that when the conversion to NFV is completed, instantiation, movement and control of services will be accomplished in a single manner – virtually.

Meanwhile, physical network elements are having their roles aligned more with the original goal of transporting bits and/or packets. Network equipment vendors had been adding value-added features to their high-end products, ultimately resulting in routers equipped to support server blades. NFV fundamentally changes this direction, transitioning the transport/switching/routing network elements to a role of delivering traffic between points on the network. This change serves two goals in the network. The reduction in the number of network functions simplifies the network, and it frees network equipment designers to refocus the network elements on their original role, conducting the flow of traffic through a physical network that is made up of physical network links and physical network nodes. This clear purpose provides the best chance of meeting the transport network’s central challenge, which is supporting the extreme traffic growth (i.e., scaling the network).

As the network is segregated into two functions - services and control, versus the physical network – both network operators and network systems vendors are taking a new look at the network to maximize the efficiencies offered by functional segregation. While this approach may seem “clean slate”, providers are nonetheless attracted by its benefits and have begun migrating their current infrastructure in this direction.

**A Two-Layer Network**

The segregation of network roles suggests a new model for the network in which the functions naturally fall into two layers – a cloud services (virtualized functions) layer and a transport layer. The cloud services layer (or Layer C) is the collection of all virtualized functions that define and control services. The processes that are being virtualized are not only virtual network functions (VNFs), but also the policy and service definition functions that are currently conducted in the operations/business support systems (OSS/BSS). Operators are attempting to virtualize as many functions as possible into Layer C to simplify the network (and the scaling of the network). In addition, they are transforming rapidly to a DevOps model of development to deliver XaaS quickly in order to grow revenues and become more competitive.
However, not all network functions can be virtualized and implemented on x86 servers. The physical transport network cannot be virtualized; photons, for example, are not created in software. Thus, a transport layer (Layer T) is the set of functions that cannot be virtualized. For a descriptive definition (rather than defining transport by what it is not), Layer T can be thought of as the set of processes required to transfer data from the ingress point to the egress point of the network, that is, all of the transport functions, including data forwarding and transport-specific control. These functions include the lower layers of the Open Systems Interconnection (OSI) model – optical transport (DWDM), Layer 1 digital (but called “Physical” in the model - SONET/SDH and OTN), Layer 2 data link (Ethernet and MPLS data plane), and Layer 3 network (IP). These lowest layers of the OSI stack can be considered sub-layers of Layer T.

Requirements of the Transport Layer

In order to meet the twin goals of scalability for, and simplification of, the network, Layer T will need to provide highly scalable capacity, flexible granularity for its connections and offer real-time programmable control.

**Scalability:** The transport layer will need to scale to meet the onslaught of traffic. Foundational to scaling Layer T is the optical network, in which fiber capacity needs to be continually increased, while space, power, and cost need to be minimized. Methods for increasing fiber capacity include employing the most efficient modulation format for each span and using a flexible wavelength grid and tight wavelength spacing. Because this optimization of optical spans implies that various spans will support different capacities, the capacity along each span should be managed as pool of bandwidth (rather than a number of optical channels with a fixed capacity) to simplify provisioning on the span.

Optical system designers address the physical platform requirements (minimized space, power, and cost) with miniaturization and integration of electronics and photonics, including higher capacity digital signal processors (DSPs), silicon photonics, and photonic integrated circuits.

**Granularity:** Network operators employ granularity in the network (subdividing the physical capacity of network links into multiple “channels” that can be independently directed) to match the capacity of each network connection to the required capacity of the service it carries. Granularity increases utilization of network capacity and reduces the number of physical connections across the network, increasing both network efficiency and simplicity. It is achieved through the use of the Layer T sub-layers, which are also used to meet the specific transmission requirements of various service connections. Designers provide granularity in the optical layer by employing optics and ROADMs that allow independent routing of wavelengths within a super-channel. They provide digital and packet granularity with switches.

**Transport Control:** The network has traditionally been controlled by the network management systems provided by the network systems employed in an operator’s network, which are integrated into the operator’s OSS/BSS. However, the OSS/BSS is integrated with elements of both Layer C and Layer T, while the network management systems of the vendors do not interwork, and they are inflexible. Layer T will need to short-cut this OSS/BSS roadblock by employing service provider software-defined networking (SP-SDN) to provide real-time control of the Layer T, multi-vendor/multi-layer orchestration and control, multiple operator and administrative domain orchestration and a standard applications programming interface (API) to Layer C to abstract network connections to Layer C and to pass policy and provisioning directions to Layer T. The Layer T SDN controller(s) need to direct all elements of Layer T.
Transport Sub-layers: The notion that Layer T introduces a single method of transporting data would be a gross over-simplification. As previously noted, transport sub-layers improve network utilization and simplicity. The network carries traffic in various digital formats to meet service needs. The physical media is the foundation for all transport and the fundamental source of its capacity. For high-capacity transport in core, regional, metro and, increasingly, aggregation/access networks, the physical media is generally fiber optics, and wavelengths are the physical signals on the media. As noted earlier, this physical layer of the network cannot be virtualized. Closely associated with the physical sub-layer is the digital layer of the network, which is generally the simplest and most reliable and cost-effective method of sharing the physical (wavelength) capacity. This close association between the physical and digital layers of the network implies that digital (generally OTN) switches should be integrated into the optical networking equipment at the end of each optical span.

Packet switching is important to Layer T because it increases the control, flexibility and utilization of the transport of data traffic. Packet switches address three protocol layers, each of which provide important features for data traffic:

- Frame (Ethernet/MPLS) – Provides virtual connections for packets, offering flexible utilization of the digital capacity. It employs the least costly switching components, and is the original data plane layer for SDN.
- Packet (IP) – Generally the layer associated with routing, and the layer that simply delivers packets to their destination. The formal name for this layer is “Network Layer”, and it is considered “the network” by the higher layers.

Implications of the Two-Layer Model on Transport

One of the strengths of the two-layer network model is that it matches today’s trends in network evolution. However, the emergence of a network that is segregated into cloud and transport layers also implies some changes in the way networks are designed and operated.

New Transport Hardware Roles: As cloud services functions are transitioned out of network elements, the roles of several network elements will change.

- Network appliances such as network firewalls are likely to become extinct.
- Value-add functions that are virtualized (likely most) will be removed from routers.
- Large layer 2 switches are likely to be employed to support massive capacity within major cloud service (NFV) server locations.
- Because reading packet addresses (layer 3) is not significantly different from reading VLAN or MPLS addresses (layer 2), routers and Ethernet/MPLS switches are likely to merge into one platform type.

Hardware Differentiation:

Even as the two-layer model brings about changes in network elements, it will also imply features (some old, some new) that will differentiate tomorrow’s Layer T platforms.

- Controllability – The key to the simple and efficient delivery of services over a transport platform will be its interworking with the network operator’s SP-SDN controller.
• Capacity – The evolution to the Layer T model will free designers to refocus on equipping these platforms, and the fibers they support, with scalable capacity, which is key to the support of the cloud services layer. Massively scalable photonics is the fundamental building block for the transport layer.

• Flexibility – As the number of network elements is reduced, transport platforms will need the flexibility to support a variety of network requirements. New client connections (e.g., 400GbE) will emerge, various transmission parameters will affect new modulation techniques, multiple sub-layers will need support (and switching), and fast protection must be provided.

• Cost-Effectiveness – Space, power and the transport platforms, themselves are costs for the network operators who need to run profitable businesses. Thus, while providing the high scalability to meet the demands of escalating traffic, transport platforms will need to minimize space, power and equipment costs. Equipment designers are likely to continue to employ silicon photonics and/or photonic integration to control these costs.

Conclusions
The challenges posed by the never-ending increase of network traffic, and the potential benefits provided by virtualization, have resulted in operators employing virtualization, in the form of NFV, to support traffic growth and reduce complexity. This virtualization of certain network functions results in a segregation of network functions into virtual and physical, suggesting a two-layer network model. A cloud services layer - Layer C – virtualizes network functions that can be virtualized. Network transport, which cannot be virtualized, forms the other layer – Layer T. The primary role of Layer T is to scale to support traffic growth, and the capacity supplied by optical transport systems is the foundation for scalability. However, this scalability must also be accompanied by flexible granularity and network control.

Recommended Actions

Vendor Actions

• Transport vendors should develop open, lightweight software for their systems to facilitate control of their networks by third-party SDN controllers. Most network operators are likely to prefer a single (pair, for redundancy) SDN controller to control a Layer T domain, whereas most (at least for the time being) will employ network elements from multiple vendors in a domain. Each vendor’s optical transport system could be controlled by its own transport controller, which would in turn be controlled by a parent controller, but operators are likely to prefer a simpler one-controller domain.

• Transport vendors should focus on delivering optical platforms that meet the scaling requirements posed by rapidly growing traffic. The platforms must scale not only fiber capacity, but must also scale cost-effective switching and port capacity while minimizing space and power consumption. Vendors need to employ the latest technologies to meet these challenges, integrating electronics and photonics in the form of DSPs, silicon photonics and photonic integrated circuits. Because network control functions will be provided at higher layers, and often by third-party controllers, much of the operator focus will be on network efficiency (along with flexibility and control).
• Transport vendors need to ensure that their platforms are not just scalable, but also granular, flexible and controllable. Transport platforms at the edge of the network may be specialized (e.g., simple, high-density and low-power for DCI), but most platforms will require optical and digital switching to provide granularity and flexibility. The ability to independently direct wavelengths in a super-channel provides granularity and flexibility in the optical layer. Digital switching inherently provides flexibility and granularity on top of the optical layer. These vendors need to facilitate SDN control to provide the fundamental flexibility and control for these platforms.

• Transport vendors should also add packet switching to their platforms to further increase the granularity and flexibility of their solutions, as well as offer operators platforms that will provide the complete set of Layer T functions, further simplifying their networks. The added layer 2/3 functionality would be particularly appealing at sites that require a modest amount of packet switching; the requirement for an operator to deploy a separate packet switch at such sites would be a “needless complication.”

• Router vendors should continue developing versions of their platforms that focus on high-speed packet reading and high-capacity switching. In addition, they should develop virtualized routers (vRouters) to prepare to participate in the Layer C marketplace as well as to leverage the expertise in vRouters to develop superior control of their Layer T switching platforms. The leveraging of high-speed ASICs used in present-day routers and network control expertise should provide router vendors an advantage in high-capacity Layer T switches.

• Those carrier Ethernet switch vendors that have not already done so should add IP packet reading to their switch's features. As value-add features are stripped from routers, there will be little reason not to consolidate routing and layer 2 switching. Routers generally require less modification because they are already providing layer 2 switching in the form of MPLS, but Ethernet switches are generally more cost-effective at simple packet switching because their designers have already cost-optimized them. In addition, switch vendors need to maximize economies of scale to compete with transport vendors that integrate packet switching into their solutions.

**User Actions**

• Operators that are planning to deploy, or are deploying, NFV in their networks should evaluate the effect of the ultimate virtualization of all possible network functions in their networks, particularly as it affects their transport and routing infrastructure. This evaluation is likely to guide the operators in their transport planning, particularly in regards to optimizing the transport functions (Layer T) for providing the physical foundation for the virtualized functions and services (Layer C).

• Operators that are creating a Layer C need to develop an architecture for SP-SDN that will control their Layer T. Whereas service routers use to control the network based on service requirements, this control will be transitioned to Layer C. Operators will need to employ SDN to pass network policy and control to the Layer T and provide network abstraction for Layer C.

• Operators of IP networks need to conduct trials of vRouters to gain experience in segregating service control from packet switching. Virtualization is already beginning to take place; the major router vendors have already introduced their first vRouters, and vendors are delivering the first virtualized version of a specialty router, the EPC. The value of virtualization of the router’s service functions is likely to become compelling; operators would be well-served by preparing to take advantage of its benefits.
• Network operators should focus on scalability when evaluating optical transport solutions to ensure that the solutions will support major capacity increases cost-effectively while minimizing space and power requirements. Network traffic growth is accelerating; supporting this traffic with legacy systems may be theoretically possible, but the economics of that support is likely untenable. These operators need to investigate transport solutions from vendors that are taking advantage of all technologies possible to scale their solutions.

• Network operators should begin to look for consolidation of transport network functions (wavelength, digital and packet switching) into fewer network elements to simplify the attainment of network granularity and flexibility. Numerous optical platforms already combine wavelength with digital (OTN) switching. However, operators will need packet (layer 2 and/or layer 3) switching at NFV server locations, which are being distributed throughout the network. A separate packet switch would provide the function, but an integrated packet-optical platform would likely provide it more cost-effectively in many locations.

• Network operators need to insist on open SP-SDN solutions to control their Layer T networks. Each network domain will probably contain network elements from two or more vendors for an extended period of time. The goal is for the domain’s SDN controller to seamlessly control all of those elements as a single Layer T network. Network element selection should focus on simple standard APIs to the network, while SDN controller selection should require the same level of control and optimization for all network elements.