White Paper

Architecting the New Metro Network for the Cloud Era

Prepared by

Sterling Perrin
Senior Analyst, Heavy Reading
www.heavyreading.com

on behalf of

www.infinera.com

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Disruption in Metro Networks

The evolution of cloud, video scale and the explosion of mobile and the Internet of Things (IoT) are not only driving tremendous traffic growth in telecom networks, but are also forcing fundamental changes in how networks are built and how network services are delivered.

Cloud/data center applications and video applications (of all types) are tremendous traffic growth and volume drivers. A December 2013 Bell Labs traffic growth study predicted that cloud/data center traffic would increase more than 440 percent from 2012 to 2017, and that video traffic would increase 720 percent over the same forecast period.

Cloud/data center and video applications are also causing a shift in traffic from backbone networks to metro. Although backbone traffic will continue to grow significantly (as the current 100G long-haul transport boom attests), the metro will grow more rapidly. Cloud/data center applications and now video (due to the proliferation of content delivery networks) reside close to the customer and so the majority of traffic remains within the metros.

The advent of cloud-based applications have also really changed the game for operators well beyond the requirement for increasing capacity. The cloud model is based on sharing storage and computing resources that have been virtualized across distances. In order for these resources to be shared efficiently, however, the communications network must be both dynamic and flexible – a dramatic change from the static-pipes communications model of the enterprise networking past.

In the age of cloud applications, the old way of building networks and delivering services breaks down because the characteristics of the static and proprietary telecom networks don’t match the requirements of cloud services delivery. After struggling with this challenge for several years, operators have come to the realization that the best way to adapt their networks to the requirements of the cloud is to adopt the very same technologies that have made cloud possible.

Thus, we have seen the emergence of carrier software-defined networking (SDN), network function virtualization (NFV), software-based network automation and open source software initiatives for telecom network equipment – much of this being driven by the network operators themselves.

The trends in traffic and applications discussed above are global. The breadth of membership in the ETSI NFV ISG – AT&T, BT, China Mobile, Verizon, Telefónica, NTT, Telstra and 31 other leading service providers around the world – underscores the common challenges facing network operators in every geography.
The Emergence of Layer T & Layer C

A new concept that is emerging to describe the network transformation taking place is the division of the telecom network into two layers: the cloud services layer ("Layer C") and the intelligent transport layer ("Layer T"). This section defines Layer C and Layer T and discusses their relevance to telecom networks.

Defining Layer C

Network functions virtualization (NFV) takes functions that previously resided on purpose-built hardware and recreates them as software functions that reside on x86-based hardware. As stated, the ETSI NFV ISG is driving standardization efforts around NFV globally, including the creation of 38 proofs of concept (PoCs) to date. Functions that can be virtualized abound. AT&T, for example, has identified 200 functions in its network that have the potential for virtualization.

Just a few commonly-cited examples of virtualized functions are: Evolved Packet Core (EPC), deep packet inspection (DPI), firewalls, load balancers, wide-area network (WAN) accelerators, mobile network nodes (HLR/HSS, MME, SGSN, GGSN/PDN-GW, RNC, Node B, eNodeB), session boarder controllers (SBCs), IP Multimedia Subsystem (IMS), content delivery networks (CDNs), customer premises equipment (CPE) functions, and even some fundamental routing functions, such as broadband remote access server (B-RAS) and provider edge (PE) routing.

Getting back to the Layer C and Layer T terminology, all of these functions that can be virtualized to run on x86 hardware are part of the cloud services layer: Layer C.

Defining Layer T

Ultimately, all network functions that can effectively be virtualized to run on general purpose hardware will do so. Those network functions that are left reside in Layer T, and Layer T’s job is to provide the most efficient and lowest cost transport for the Layer C applications.

Optical communications operates in the analog domain (photons) and cannot be created as software code; thus, wavelength-division multiplexing (WDM) transport and optical switching will be the foundation of Layer T. But Layer T also consists of more than optics. Some digital and packet processing functions (bits encoded in electrons) will also remain in Layer T with the following characteristics:

- Performance requirements will dictate the choice of silicon for Layer 2/3 processing. Today’s routers and switches use a combination of specialized ASICs, merchant chips and x86-based designs. Heavy packet functions such as high-capacity peering and virtual private networks (VPNs) rely on ASICs, while other functions are being increasingly ported onto merchant silicon. Intel x86-based designs are used for network control and low-capacity processing.
- Operators have benefitted in terms of capex and opex savings from integrating transport functions in the same element under the same management systems. In metro networks, Heavy Reading has defined this category of equipment as packet-optical transport systems (P-OTS), and the market has grown globally from almost $0 in 2007 to $2.0 billion in 2014.
Moving forward in metro networks, we see an intelligent transport layer based on highly scalable optics with the right amount of packet switching for sub-wavelength traffic grooming and aggregation. We see the key requirements as follows:

- Scalable dense WDM (DWDM) optics, including coherent detection and N x 100 Gbit/s per wavelength data rates. Photonic integration is increasingly becoming required at high data rates (i.e., 100G and beyond), delivering form factor reductions and density improvements that lower total cost of ownership (TCO) beyond what is achievable using discrete components. Where Infinera once stood alone as the photonic integration evangelist, we now see some level of photonic integration widely used by major optical components suppliers such as Finisar, JDSU, Oclaro, NeoPhotonics and more. Infinera continues to differentiate based on its PIC innovations and remains the only company commercially producing a 10+ channel PIC today.

- Sub-wavelength packet grooming and aggregation – in some cases achieved through the use of optical transport network (OTN) switching

- Software programmability and automation through the use of SDN

Figure 1 illustrates the telecommunications network migration from the traditional, many-layered model to the new model consisting of Layer C cloud services, functions and applications, and Layer T intelligent transport for Layer C.

Figure 1: Migration From Traditional Networking to Cloud & Intelligent Transport

Source: Infinera, 2015
Metro Transport Market Segmentation

Heavy Reading defines two major sub-segments for metro transport, each with its own characteristics and requirements and products to meet those requirements.

Data Center Interconnect

Metro data center interconnect (DCI) was initially driven by the Webscale providers (Google, Yahoo, Facebook, Amazon, Microsoft), but, as traditional telecom operators have moved into data center businesses, they have also become buyers of DCI equipment.

Regardless of whether the service provider is a Webscale provider or a telecom operator, the main requirement in DCI is the same: to interconnect data centers within a provider’s network or to connect a user’s data center to a data center residing within the provider’s network. There are differences in applications across different providers but, at a high level, the main characteristics are same:

- Hyper-scale (100G interfaces are a must)
- Lowest power consumption and smallest footprint for the application
- Operational simplicity
- Open application programming interfaces (APIs) for direct and customized programmability by the provider
- Matching features exactly to the DCI application, with no more and no less

As a result of these specific requirements from service providers, we have seen a proliferation of purpose-built DCI equipment emerge in the past 18 months, including Infinera’s CloudXpress, Ciena’s Waveserver and Fujitsu’s 1Finity T100, for example. These products are all built around high-speed optics and omit the packet-switching fabrics that add cost and size, and that DCI applications do not require.

Metro Aggregation

Where DCI equipment serves a single application (connecting data centers to each other), metro aggregation equipment serves many, including:

- Mobile backhaul for 2G, 3G and 4G services
- Residential broadband backhaul, including xDSL and FTTx-based services
- Carrier Ethernet services for business customers
- Transport for video services, including both broadcast programming and unicast/on-demand services
- Delivery of time-division multiplexing (TDM)-based private line services for business customers

Metro P-OTS equipment emerged in the mid-2000s to address the diverse service requirements of metro aggregation, and today P-OTS equipment is the workhorse of the telecom metro network. Key requirements for P-OTS equipment are:

- High-capacity packet switching/aggregation
- Legacy services transport and aggregation (i.e., private line/TDM)
- Superior operations, administration and management (OAM)/management
- Carrier-class reliability (5 nines or 6 nines)
- Lowest overall cost for lowest cost per bit

Figure 2 shows Heavy Reading’s forecast for metro P-OTS and Carrier Ethernet Transport (CET) equipment combined. As demand for TDM has declined, demand has risen sharply for products that combine optics, packets and TDM (i.e., P-OTS) or focus on packets exclusively (i.e., CET). The combined P-OTS and CET metro market totaled $3.3 billion in 2014, and we forecast that this next-generation segment will reach $5.4 billion in revenue by 2019, increasing at a 10.1 percent CAGR over the five-year period.

![Figure 2: Global Metro P-OTS & Carrier Ethernet Transport Revenue, 2013-2019](image-url)

Source: Heavy Reading, 2015
Metro Aggregation Architecture Evolution

The metro aggregation network has undergone several transitions over the past decade. The most significant was the migration from multiservice provisioning platforms (MSPPs) to metro P-OTS that began in 2007-2008.

During the metro P-OTS era, however, there have also been smaller transitions that occurred through each generation of equipment. We are now at the beginning of a new transition, which Heavy Reading believes will be as significant as the migration from MSPP to P-OTS nearly a decade ago.

This section details the architecture requirements of the new generation.

Legacy Aggregation Architecture Shortcomings

Current metro aggregation architectures have the following shortcomings:

- **Lack of hardware modularity**: A key benefit of P-OTS equipment is the integration of multiple functions within the same chassis/system. Legacy systems lack flexibility and modularity in their hardware often resulting in rigid solutions and compromised performance. The lack of modularity results in additional hardware interfacing with the switch fabric or restrictions in usage of shelves and slots. These systems also occupy valuable rack space and waste power.

- **Heavy emphasis on Sonet/SDH capabilities**: P-OTS-based networks were conceived as a bridge connecting the Sonet/SDH networks of the past to the Ethernet/IP networks of the future, and they have been tremendously successful in this mission. Over time, however, the TDM requirement has become less and less important for operators. Today, operators need optical and packet-layer innovations, but current-generation equipment is focused too heavily on the TDM capabilities and features at the expense of packet and optical features that are needed.

- **Proprietary and closed network management system (NMS)/element management system (EMS)**: While many long-haul networks migrated to Generalized Multiprotocol Label Switching (GMPLS) control planes more than a decade ago, metro networks never made this transition. Current metro networks are static and EMS/NMS-based, while cloud applications require metro networks that are flexible and readily adaptable to adjust to changes in traffic and application demands. There is an unprecedented mismatch between how metro transport networks are managed today, and what operators need to meet their customers’ demands.

New Aggregation Architecture Requirements

A new generation of metro aggregation equipment is now emerging to address the shortcomings of the previous generations and adapt metro networks for the cloud era.

**Rise of 100G & Nx100G in Metro**

100G has already become the default line rate for long-haul DWDM networks globally, and we are now in the early stages of a migration to 100G in metro networks (primarily in the metro core). Webscale providers have driven initial demand in 100G (and even 200G) for DCI applications, but cloud, video, fixed broadband, Carrier
Ethernet and mobile broadband are driving the need for 100G line rates in metro aggregation networks as well.

One key difference between DCI and metro aggregation is that while DCI networks may only need 100G or higher line rates, metro aggregation networks will require a mix of line rates, spanning from 10G to 100G, 200G, Nx100G super channel, due to the wide diversity of applications supported.

The metro 100G migration has already begun and will occur at the expense of 40G line rates (which we expect to decline at 42 percent compounded annually through 2019). Heavy Reading also believes that Nx100G line rates (or super channels) will become a significant contributor to metro networks both in DCI applications and in dense metros. Heavy Reading forecasts that 100G and higher line side ports will increase at a 56 percent CAGR from 2014-2019 – a higher growth rate even than the 100G+ long-haul segment.

**Mix of WDM & Packet Switching**

State-of-the-art optics combined with the right amount packet switching is essential to the next generation of metro aggregation equipment. As discussed earlier in this paper, high-capacity packet switching and aggregation will remain a key part of Layer T, even as several packet functions move to Layer C (via NFV). Some operators will require OTN switching in the metro core as the bridge between legacy TDM services and new Ethernet/IP services in the post Sonet/SDH era. Other operators will skip the OTN step altogether and move straight from Sonet/SDH to packet switching, preferring to handle legacy TDM traffic via circuit emulation over the packet network.

A high degree of hardware modularity will be required moving forward, as operators will look to best match their capacity and features purchased to current requirements with the ability to quickly add capacity and features as their requirements change.

**Devaluation of Routers in the Aggregation Network**

Routers have made their way into aggregation networks to perform more packet aggregation functions and deliver Ethernet, MPLS, multi-cast, and subscriber management services. This results in a multilayer aggregation network of routers delivering services connected to each other via simple transport equipment. With the advent of Layer C, many of these services functions will be converted to software running on x86 hardware. Basic packet services such as multi-cast, Ethernet and MPLS will be subsumed by Layer T in the form of next generation P-OTS, backhauling these services to centralized routers. This collapse of multiple layers will dramatically simplify the scaling and operation of the metro aggregation network. (See Figure 3 for an AT&T example.)

**Open APIs & SDN**

The endgame for all metro transport networks – whether DCI or metro aggregation – is control plane and data plane separation via open, standards-based SDN. We are seeing metro DCI equipment moving quickest in this direction, as Webscale providers have driven the trend, and the application doesn’t require backward integration with legacy networks and services.

However, network operators globally are clearly focused on migrating away from legacy EMS/NMS management and driving open APIs and SDN control into their metro aggregation networks. In the Layer C and Layer T model (Figure 1), SDN becomes the glue that ties together the cloud services and the intelligent transport that supports those services.
Figure 3. from a presentation by AT&T, illustrates a long-term network evolution in which the central office ultimately transforms into a data center in which all network functions that can be virtualized run as software applications on x86 hardware, with SDN controlling the metro and core packet-optical networks.

Where metro DCI is straightforward, metro aggregation is highly complex as network operators have many different services to operate and multiple generations of network equipment. New networks have limited value if they are silos separated from the vast legacy networks.

Operators, suppliers and standards bodies must work together to solve these legacy challenges in order universal adoption of SDN in metro networks to become a reality. In the meantime, operators will increasingly look for roadmaps to SDN control and open APIs in metro aggregation networks, even though their plans do not call for SDN operation in year 1.
Conclusions

Metro networks are entering a period of profound change and disruption driven not only by the continued growth in metro IP traffic but, even more significantly, by the changing demands and requirements for network services driven by the cloud. The gap between the flexible and on-demand requirements of cloud applications and the static nature of today's metro networks is unprecedented, and is leading network operators globally to radically re-think how networks are built and operated. In short, Layer C is the business driver for metro transport evolution.

While NFV will ultimately drive the virtualization of hundreds of network functions, not all functions will be virtualized. The job of the next-generation metro transport network will be to combine state-of-the-art optics innovations with the right mix of packet switching in order to support the cloud layer. Heavy Reading believes that the key building blocks for next-generation metro aggregation are as follows:

- Scalable optics, including use of coherent electronics, some level of photonic integration and best-in-class packet switching (including OTN)
- High degree of hardware modularity
- End-to-end integrated network with photonic-driven packet-optical transport
- Open, programmable interfaces for rapid, operator-driven software innovation
- Open SDN control