Preparing the Metro Core Network for Disruptive Technologies Like DAA and 5G

A Technical Paper Prepared for SCTE•ISBE by

Fady Masoud, M. Eng.
Principal, Product and Technology Marketing
Infinera
555 Legget Drive, Suite 222, Tower B, Ottawa, ON, Canada K2K 2X3
fmasoud@infinera.com

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Introduction

The metro network is one of the most dynamic areas in the entire service delivery model, and it is expected to witness first the impact of emerging technologies such as the Internet of Things (IoT), 5G, and distributed access architectures (DAA), which will drive demand for capacity and a need for increased network agility.

It is estimated that 30 billion devices[1] will connect to the internet in 2020, while all-fiber access networks have surpassed xDSL connections, with nearly 60 million homes able to receive fiber to the home (FTTH) and 23.8 million homes connected in North America alone.[2] Moreover, the world is on the verge of the massive deployment of 5G mobility, which is poised to radically transform mobile connectivity and start a new era of high-performance mobile applications and machine-to-machine real-time communication. The number of commercial 5G network deployments is expected to grow to 55 globally in 2019, up from 13 in 2018.[3]

The deployment of 5G networks will dictate an unprecedented level of performance from the underlying optical transport networks, including ultra-low latency, network sliceability, and scalability. Some of these requirements, such as the dramatic reduction in latency, will require the implementation of multi-access edge computing (MEC) to process and push content closer to the end user, charting a new way of architecting and operating the network as a result. MEC is also fueling the conversion of existing access network sites into mini data centers, thus creating the need for access and core networks, along with MEC resources, to be managed as a single entity from core to edge. In 5G, the concept of network slicing is used to manage this core-to-edge flow of transport and MEC resources. Slices can be created to support the differing transport, storage, and compute resources required for each individual service type.

Overall, the deployment of data centers in metro areas has been increasing at a very fast pace. As a matter of fact, there are 3,600 data centers in the top 20 cities,[4] with London leading the pack with 429 data centers in its metropolitan boundaries. This paper describes the evolution needs of metro core networks and the innovative technologies that will enable network operators to gracefully embrace this journey.

Content

1. Evolving the Metro Core

Given its fit in the middle of the optical transport architecture (Figure 1), between access and regional/long-haul networks, the metro core network plays a key role in ensuring the successful deployment of the wireline optical infrastructure supporting 5G and DAA. Hence, its evolution must touch multiple fronts, such as:

1.1. Network Scalability:

In addition to demanding significantly more bandwidth when initially deployed, FTTH and emerging technologies like 5G will continue to increase the need for higher capacity, ensuring that a scalable metro core network becomes paramount.

1.2. Network Economics

Operational expenditure (OpEx) has a direct impact on bottom line (profitability). The order of magnitude and scale of connected devices enabled by 5G, as well as the bandwidth required for DAA, will certainly increase operating costs unless new, significantly lower network economics (power consumption, footprint, total cost of ownership, etc.) are achieved.

1.3. Network Automation

The proliferation of IoT and cloud applications, the push to MEC to cope with 5G requirements, and the constant expansion of data centers in the metro and closer to the edge are creating new pools of points of delivery (PODs) for services and applications. They also require a new level of practical network automation and programmability within and between the PODs in order to keep up with the constant and unpredictable demand for bandwidth, streamline operations, and eliminate sources of human error.

1.4. Network Evolution

While most of today's services are Ethernet-based, there is still a considerable amount of legacy services (e.g., SONET/SDH) delivered over platforms that require significantly larger footprint and higher power consumption. Preparing the network for emerging technologies must include a plan for a smooth migration toward next-generation services.

1.5. Network Agility

A key step toward preparing the metro core network for 5G and DAA is enhancing network agility and breaking away from current methods of optical capacity planning, engineering, and activation that require numerous truck rolls, extensive manual labor, and human interaction at multiple points in the network.

1.6. Network Security

As more content is being pushed to the cloud, cyber-attacks and data breaches are becoming frequent occurrences. The annual damage to the U.S. economy caused by cyber-attacks is estimated to be up to \$100 billion.[5] Network operators must protect data traffic carried over the network from intruders and hacking tools.

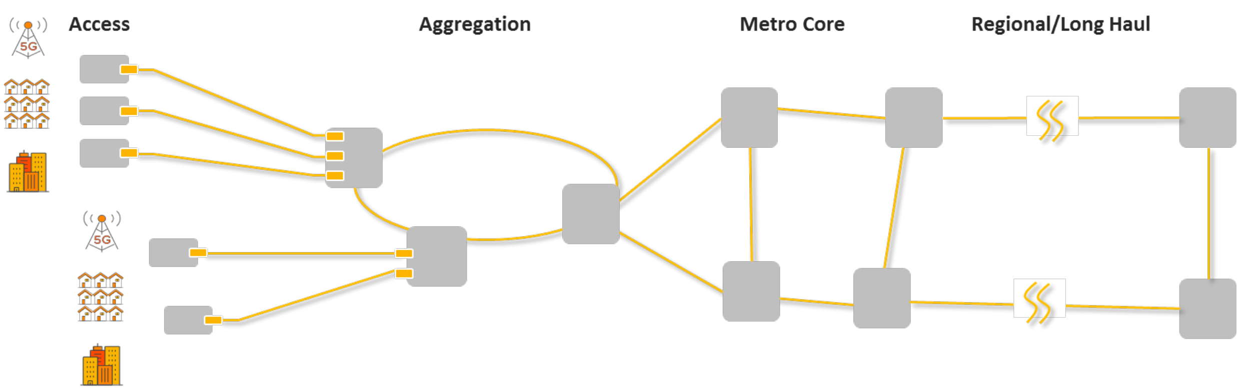

Figure 1 - Typical Optical Transport Network

2. Enabling Technologies for Metro Core Evolution

As discussed in the previous section, preparing the metro core network for 5G and DAA must touch multiple fronts. Below are some of the enabling technologies that play a crucial role in elevating network performance to the levels required by 5G and DAA:

2.1. Increase New Scalability Through Super-channels and Advanced Coherent Capabilities

DWDM technology disrupted the telecommunication industry by enabling multiple optical carriers to travel in parallel on a fiber, thus increasing capacity and maximizing fiber utilization. However, projected growth in traffic triggered by 5G and DAA is demanding a new level of scalability and spectral efficiency (the ability to pack more capacity on the fiber). A technology called super-channels solves the challenge of increasing network capacity quickly and without operational complexity. A super-channel includes several optical carriers combined to create a composite line-side signal of the desired capacity that is provisioned in one operational cycle (Figure 2). The use of super-channels increases spectrum efficiency and thus fiber capacity by reducing spectrum waste due to guard bands, up to 2 terabits per second when using the extended C-band. Once deployed, this service-ready terabit capacity allows seamless growth without the need for truck rolls, network re-engineering, or major disruption to current operating processes. Futhermore, the latest breakthroughs in optics and DSPs have led to the introduction of advanced coherent optical capabilities, such as Nyquist subcarriers, software-programmable modulation schemes, software-decision forward error correction (SD-FEC) gain sharing, pulse shaping, and so on, that maximize capacity over any given distance.

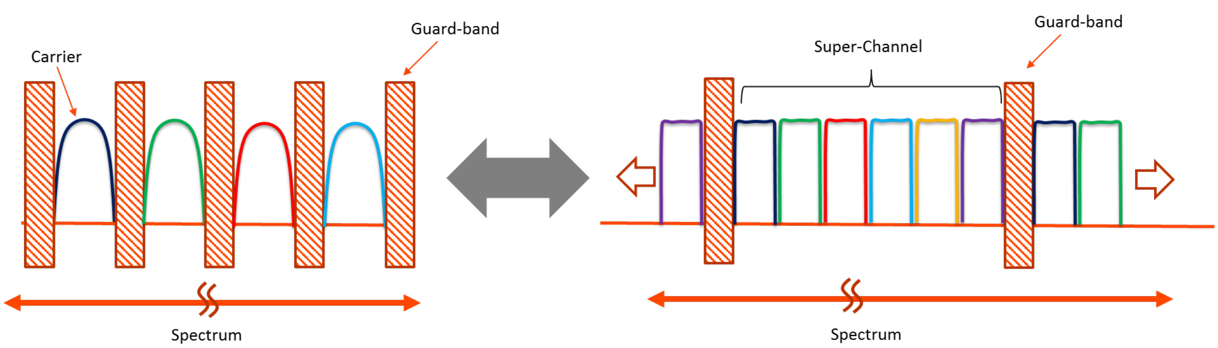

Figure 2 - Increasing fiber capacity with super-channels

2.2. Redefine Economics with Compact Modular Platforms

A new breed of optical platforms, called compact modular, has been created to set a new benchmark in scalability, low power consumption, and compact footprint. Compact modular platforms are the outcome of "disaggregating" the optical layer with design and specifications tailored to the needs of the next era of hyperconnectivity. While the first generation started around data center interconnect (DCI) applications, current and future generations are equipped with the required features and capabilities to be deployed by all optical network operators, not just internet content providers, and in a wide scope of applications beyond DCI, including metro, regional and long-haul networks. Compact modular platforms redefine network economics (Figure 3) with

- Significantly lower power consumption, a compact footprint, add-as-you-grow architecture through a sled design that allows network operators to eliminate the up-front cost of buying all the hardware on day one

- High level of flexibility with the ability to use client/line (100 Gigabit Ethernet [GbE], multi-service, 100G-600G, etc.) and photonic (ROADM, OTDR, amps) sleds to build different configurations with low power and a compact footprint,

- Ease of deployment and turn-up so traffic can be up and running literally in minutes

- Future-proofing investment by setting a clear path for higher capacity and advanced features without forklifting, as new technologies are faster to develop and much easier to implement in a sled in compact modular platforms vs. monolithic systems.

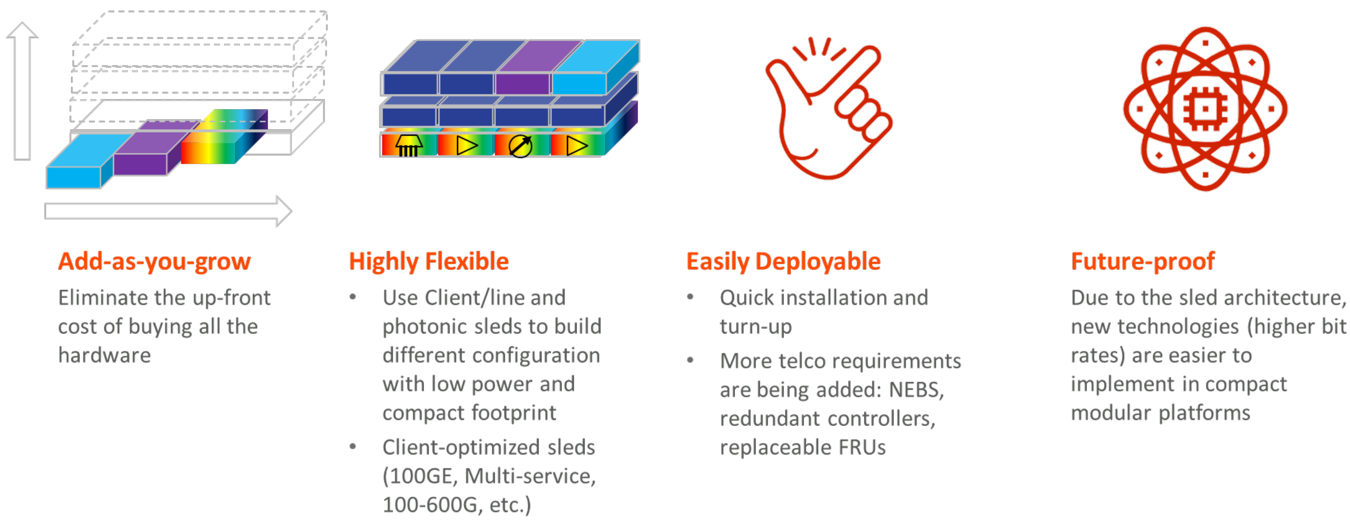

Figure 3 - New network economics with compact modular

2.3. Evolve Legacy Services to the Next Generation

Throughout many years of service evolution, from time-division multiplexing to packet and from sub-10G to 100G+, service providers have slowly built up parallel and service-specific networks in an effort to meet service requirements and market windows. This has led to complex architectures, costly operations, and limited flexibility and scalability due to the numerous network interconnects that make the metro core network ill-suited for 5G and DAA. A new breed of packet-optical platforms supporting "universal switching" have proven to simplify network architecture and ease the evolution of legacy services by replacing many service-specific platforms and collapsing multiple networks into one flexible and highly scalable multi-service infrastructure. Deploying a universal switching platform allows service providers to smoothly and gracefully migrate legacy services to packet-optical services at their business and operational paces (Figure 4).

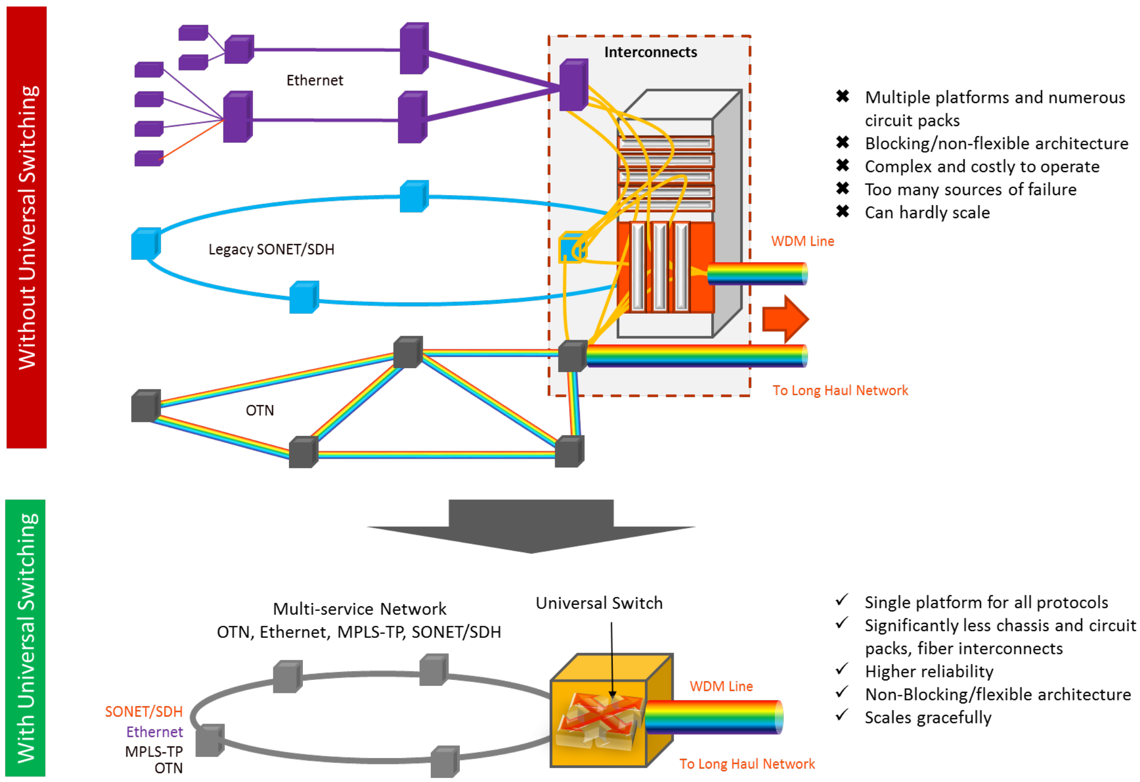

Figure 4 - Evolving the network with universal switching

2.4. Automate Network Operations:

Building practical automation throughout the network is central to preparing for 5G and DAA, as content is being processed/pushed closer to end-users with MEC, and traffic profiles and trends are becoming difficult to predict. Moreover, human error is often behind major network outages, especially in POD environments where multiple platfoms (servers, routers, Layer 1/2 transport, etc.) are interconnected, hence the need to automate recurring tasks within and between the PODs for better efficiency and reliability. Network operators can use the latest developments in multi-layer, multi-domain, and multi-vendor orchestrators; SDN controllers; and virtual POD controllers. They can also take advantage of the implementation of open interfaces such as REST application programming interfaces, NETCONF/YANG, and others to simplify network management and automate recurring tasks. These multi-layer, multi-vendor, and multi-domain orchestrators and SDN and POD controllers elevate network automation to a whole new level by adding intelligence and "rule-based" capabilities for planning and traffic restoration. For example, a path computation engine (PCE) can be enhanced by adding context-oriented "rules" to automatically restore traffic while meeting certain requirements (e.g., maintain minimum latency, avoid congested links, etc.). Other automation capabilities include real-time monitoring of network parameters and optimization of networking assets like optical spectrum. Practical automation is also a stepping stone toward cognitive networking that is multi-layer, self-aware, self-organizing, and self-optimizing, and can take predictive and/or prescriptive action based on what it has gleaned from its collected data and experience.

2.5. Enhance Network Agility with Software-defined Capacity

A key step to preparing the metro core for 5G and DAA starts with allowing intelligent software tools to dynamically add, modify, move, and retire optical capacity based on the real-time requirements of upper-layer applications. With current and conventional methods, activating a new service or adding extra network capacity is a long, complex, and labor-intensive process that can take many weeks and requires numerous truck rolls. Breakthroughs in software and practical automation led to the creation of software-defined capacity (SDC), which provides instant software activation of additional capacity, creating a pool of bandwidth that can be dynamically allocated based on traffic demand from 5G and DAA, as depicted in Figure 5. SDC is a true game-changer from both business and operational perspectives. It enables a perfect match between the timing of capital expenditure (CapEx) and service revenue, thus accelerating time to revenue from months to minutes. SDC also reduces OpEx by streamlining operations and eliminating truck rolls. Moreover, SDC is a key enabler of automation throughout the network and across all operational levels, which is a vital element in building the foundation for cognitive networking, in which real-time network analytics, microservice-based engines, and machine-learning algorithms can dynamically increase or decrease network capacity on specific routes based on past trends, spontaneous changes in traffic demand, or an anticipated spike in capacity.

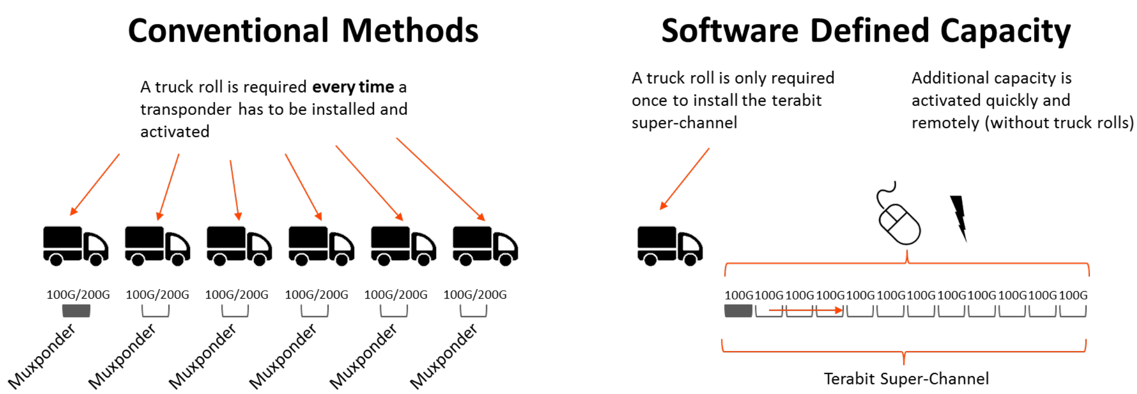

Figure 5 - Software-defined capacity vs. conventional methods of adding bandwidth

2.6. Protect Critical Data While on the Optical Network

According to a study on cybercrime[6], an average organization suffered 130 cyber security breaches in 2017, up 27 percent from the previous year, with the average cost of these breaches now at $11.7 million USD. Securing mission-critical data is more important than ever in a world where security threats are constantly on the rise. While data encryption can be performed at different layers, Layer 1 (OTN payload) and Layer 2 (MACsec) encryption provide significant advantages over upper-layer encryption like Internet Protocol Security (IPsec) encryption at Layer 3. These advantages consist of higher throughput at relatively low cost, minimized latency, and the ability to support non-IP traffic. Adding encryption requires no network re-engineering and is quite easy, as it's often already supported on compact modular platforms as well as some metro core universal switching platforms as depicted in Figure 6.

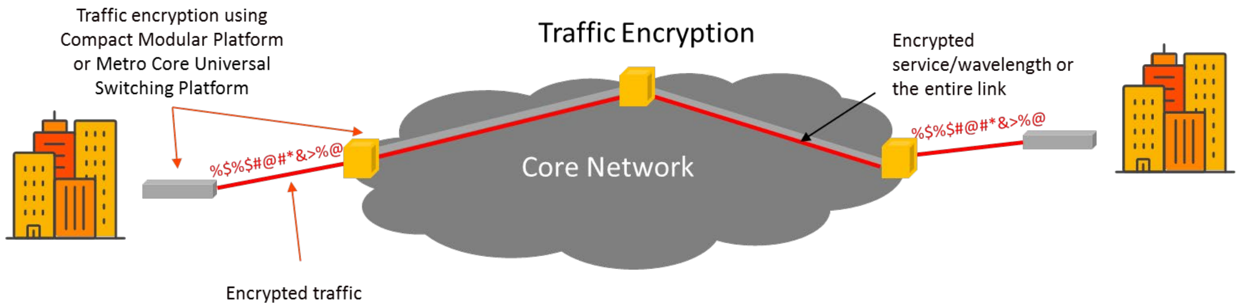

Figure 6 - Traffic encryption

Conclusion

Disruptive technologies like 5G and DAA and their need to process/push content closer to end users through MEC will impact how metro core networks are built, operated, and evolved, with a new set of requirements for higher capacity, better optical performance, and a new level of automation. The latest innovations in software and hardware are evolving metro core networks to gracefully embrace this new era of machine-to-machine and human-to-machine connectivity.

Abbreviations

5G	Fifth generation of mobile networks
API	Application programming interface
CapEx	Capital expenditure
DAA	Distributed access architectures
DCI	Data center interconnect
DSL	Digital subscriber line
DSP	Digital signal processor
DWDM	Dense wavelength-division multiplexing
FTTH	Fiber to the home
GbE	Gigabit Ethernet
gRPC	Generic Remote Procedure Call
ICP	Internet content provider
IoT	Internet of Things
IPsec	Internet Protocol Security
MPLS-TP	Multiprotocol Label Switching–Transport Profile
NETCONF	Network Configuration Protocol
OC	Optical carrier
OpEx	Operational expenditure
OTDR	Optical time-domain reflectometer
OTN	Optical Transport Network
MACsec	Media Access Control Security
MEC	Multi-access edge compute
PCE	Path computation engine
POD	Points of delivery
QAM	Quadrature amplitude modulation (8QAM, 16QAM, 64QAM)
QPSK	Quadrature phase-shift keying

REST	Representational State Transfer
ROADM	Reconfigurable optical add-drop multiplexer
SDC	Software-defined capacity
SD-FEC	Soft-decision forward error correction
SDH	Synchronous Digital Hierarchy
SDN	Software-defined networking
SE	Spectral efficiency
SLA	Service-level agreement
SONET	Synchronous Optical Networking
TCO	Total cost of ownership
YANG	Yet Another Next Generation

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