5G ACCESS
TRANSPORT ARCHITECTURE

APPLICATION NOTE
SUMMARY

In this paper, a brief introduction of the 5G architecture is provided, but the focus is to address the transport architecture options for the 5G access network and how it has evolved from the previous 4G architecture. In particular, we identify the optical building blocks needed in each case.

OVERVIEW OF 5G TRANSPORT ARCHITECTURE

3GPP has specified several functional split options for 5G transport: fronthaul, midhaul, backhaul (as defined in [1]) as well as different combinations of functions, as illustrated in the following figure:

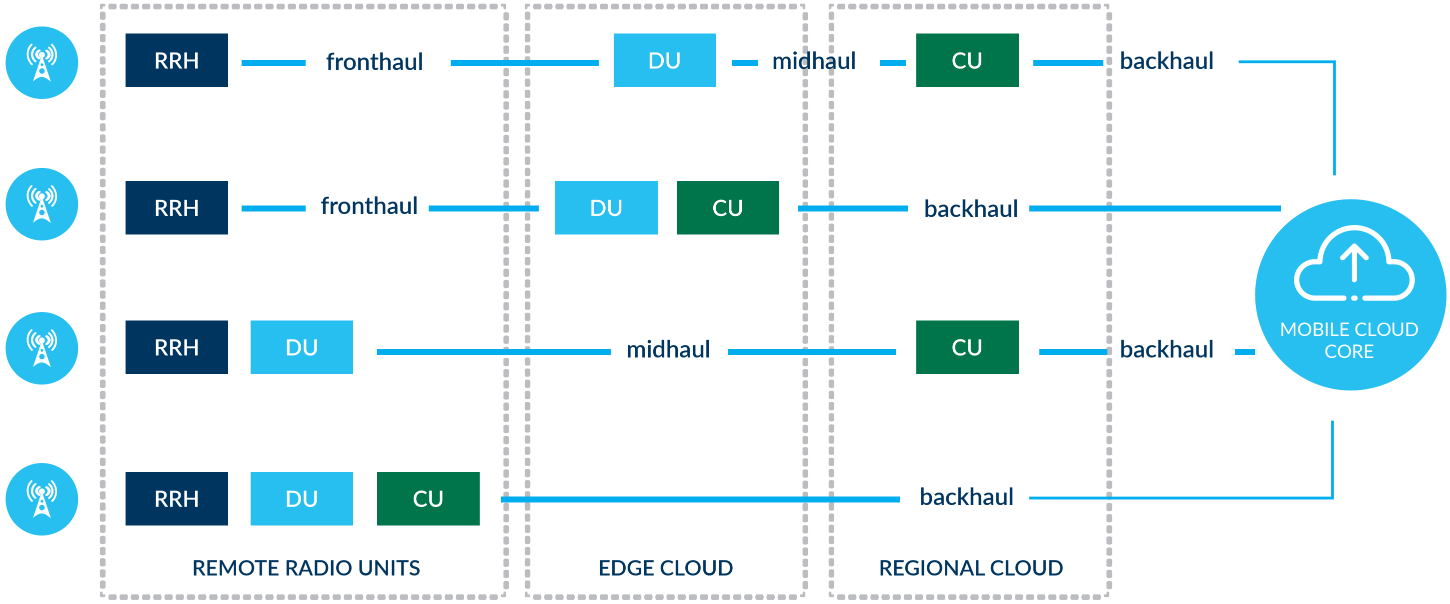

Figure 1 Different options for 5G transport

Typically, a single network can host different options at the same time depending on geography, amount of traffic, legacy network presence, etc. For this reason, the 5G transport network needs to be ready to transport any type of 5G traffic (fronthaul, midhaul, backhaul) at the same time. This presents important implications around bandwidth and latency requirements for the access network as described in [1].

5G ACCESS ARCHITECTURE

The 4G access network was primarily based on backhaul architecture (fronthaul was defined but not largely deployed), where the cell site gateway, typically a Layer 2/3 device, was connected directly to each base station and the traffic forwarded via fiber to the next level of L2/L3 aggregation

Topology was point-to-point or ring and the capacity was typically 1Gb/s with evolution to 10Gb/s.

Microwave connections were utilized to reach remote base stations not connected via fibers.

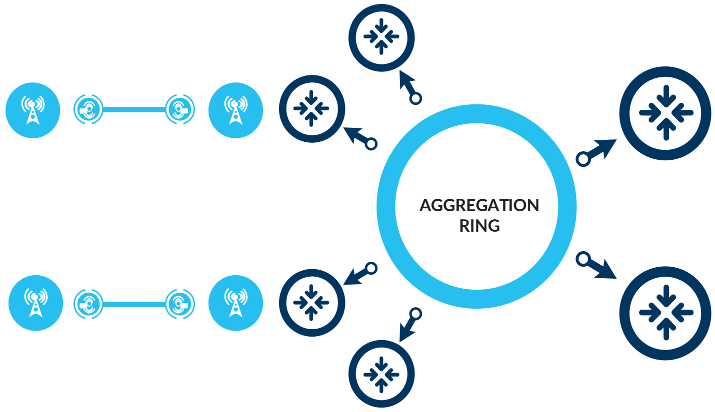

Figure 2 architecture of 4G access ring

The evolution from 4G to 5G architecture needs to consider the following elements:

- Increasing bandwidth from each RRH or CU/DU (typically 10Gb/s or 25Gb/s)
- Stringent latency requirements and requirements for the nodes to pass-through traffic at the lowest possible transport layer
- Coexistence with 4G architecture to allow sharing of a single infrastructure for the current and the previous network technology.

The consequence of this is that the access rings for 4G which were typically based on 'dark fiber' are migrating to WDM technology with two objectives: to increase the bandwidth and reduce the latency in the pass-through nodes:

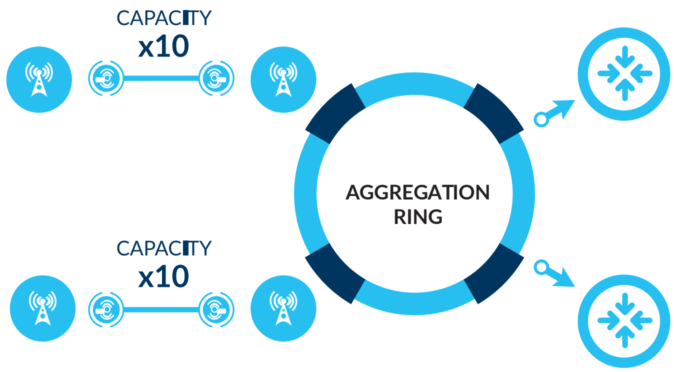

Figure 3 architecture of 5G access ring

In each access node, there can be still the Cell Site Gateway (with higher capacity and maybe with decentralized MEC functions), but logically this remote Cell Site Gateway will be connected (via dedicated wavelength) to the higher level L2/L3 node in the central office (or datacenter). This will minimize the accumulated latency in the network avoiding pass-through at the packet level:

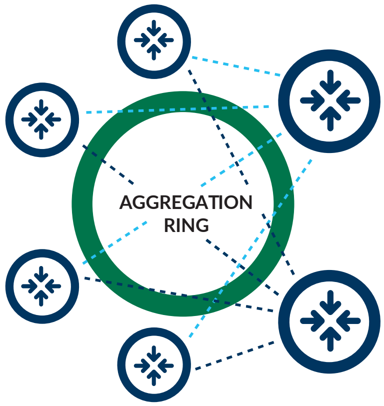

Figure 4 Logical connectivity between CSG and High level L2/L3 node

This architecture requires the following main WDM building blocks:

- Passive filters to add/drop the specific wavelengths in the access nodes and to terminate all the wavelengths in the hub node (ROADM architecture is a potential option but is currently too expensive for the target TCO of the 5G network)
- Amplification to exceed the pure passive network optical power budget
- Optical Transceivers (colored) hosted in all the network elements of the network both in the remote nodes and in the hub

In the case of fronthauling, it is possible to dedicate a transparent WDM wavelength from the Remote Radio Head (RRH) up to the hub node where centralized functions are located. This way, it will be possible for the same access architecture to support both backhaul/midhaul traffic and fronthaul and meet the bandwidth and latency requirements for each.

5G ACCESS VIA PON NETWORK

Operators that have heavily invested in PON infrastructure, now have a rich capillarity and the ability to connect RRH via fibers, and require a solution where PON and 5G access coexist on the same fiber.

PON architecture imposes some constraints on the access architecture:

- Usage of 'single fiber' (the usage of different wavelengths for Upstream and Downstream directions)
- Design of specific filters to accommodate wavelengths used for 5G access together with PON upstream and downstream signals
- Amplification needed for satisfying the power budget of a PON network
- Specific pluggable for RRH in order to interwork with PON network
- Another potential requirement is the coexistence between CWDM and DWDM over the same network.

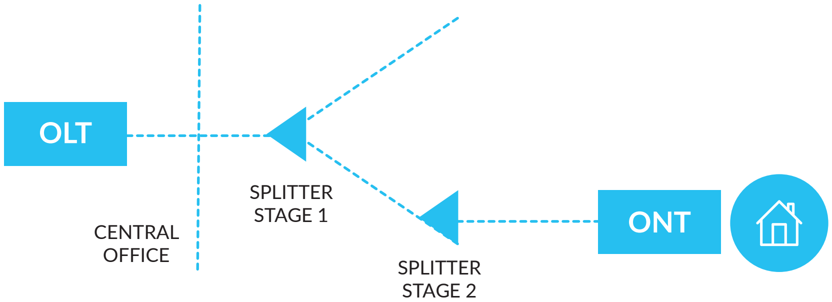

Figure 5 High level PON access architecture

A PON network can be then adapted for 5G by overlaying the PON network with a WDM network and introducing additional filters to add/drop the PON specific wavelengths from the others dedicated to 5G transport.

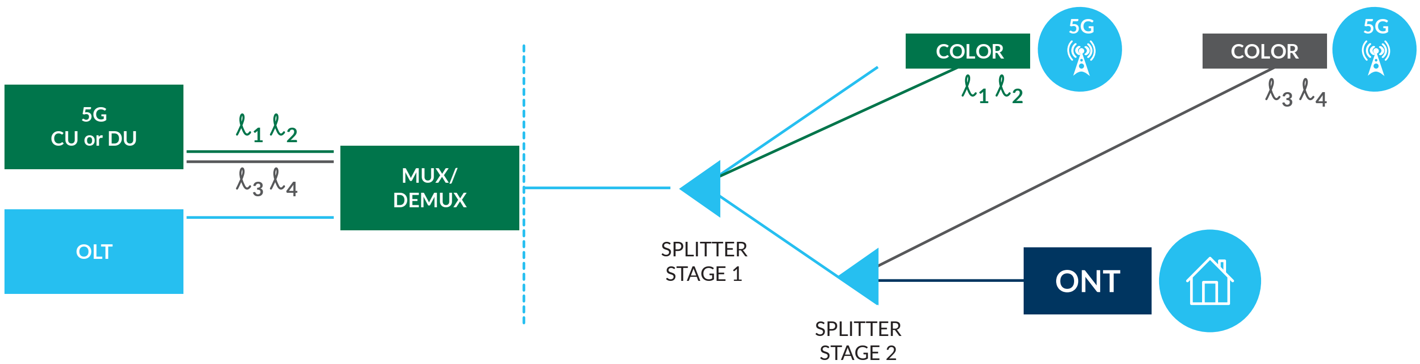

Figure 6 Overlay of 5G to PON network

Key elements of 5G access overlay with PON architecture:

- Passive filters with the capability to insert/extract specific PON wavelengths with WDM wavelengths
- Amplifiers to satisfy the optical power budget of the PON access network overlaid with the WDM network
- Colored WDM transceivers for 10G and 25G

ABOUT JABIL PHOTONICS

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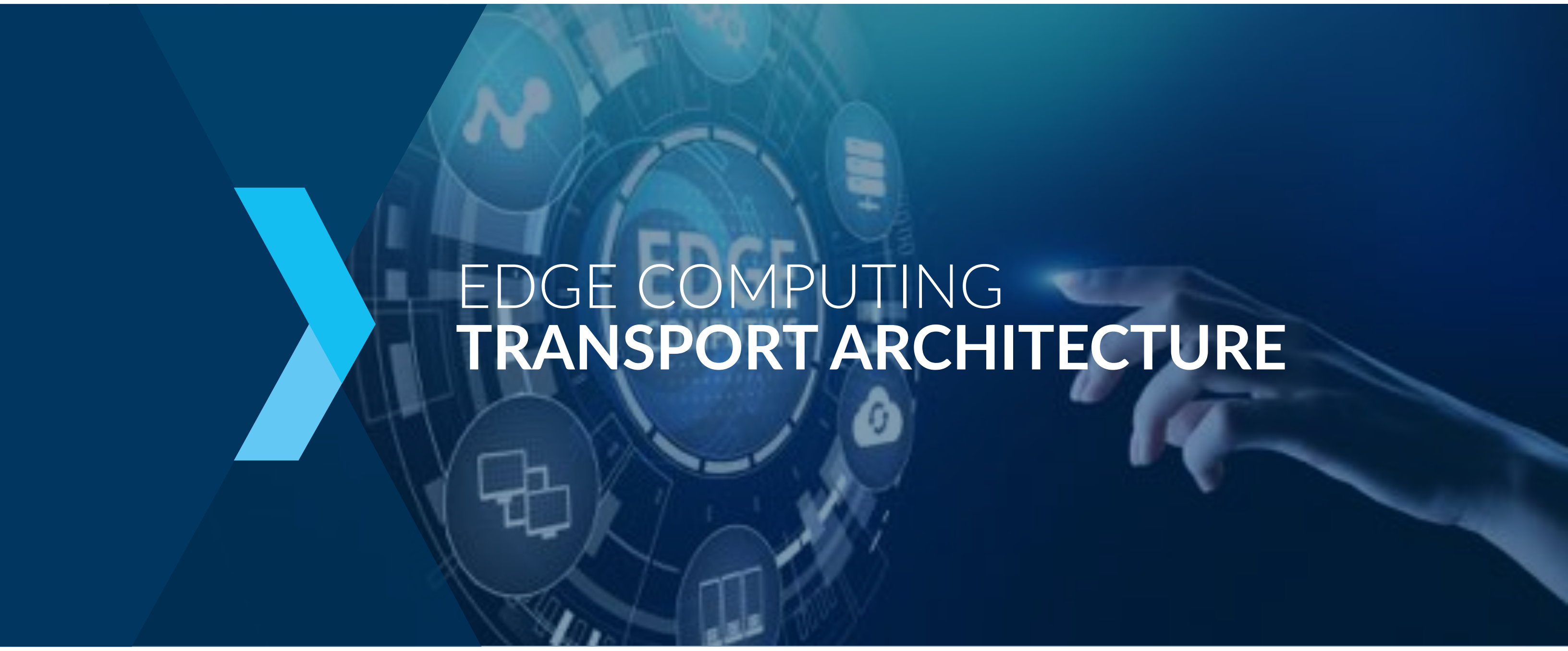
Jabil Photonics offers its expertise for the main optical building blocks for cable network evolution, in both subsystems and customized design, which can be integrated in products or utilized as stand-alone systems:

Figure 7 Jabil Photonics Portfolio

References

[1] ITU-T G.Sup67 - Application of optical transport network recommendations to 5G transport



EDGE COMPUTING
TRANSPORT ARCHITECTURE

APPLICATION NOTE
SUMMARY

Edge computing will be driven by 5G and serve as a key technology and architecture. Edge computing is geared to be the basis of all the applications requiring processing with extremely low latency. As a result, a centralized process will not be possible and the distribution of the intelligence in the network will be the only solution to satisfy this requirement.

Initially, edge computing was defined for mobile technology, but it has now grown into a more general concept. At the beginning, the acronym MEC defined by ETSI [1] stood for Mobile Edge Computing; now it stands for Multi-Access Edge Computing.

In this paper, we analyze the impact of edge computing on transport technology along with the basic technologies required to support this architecture.

EDGE COMPUTING TRANSPORT ARCHITECTURE

Edge computing and virtualization are two concepts that are related, and the capability to move applications from a centralized datacenter to the periphery of the network is allowed by virtualization concepts. Project impacts of this include:

- On the plane level – connectivity will be flexible to allow increases/decreases of data path bandwidth (e.g., MPLS LSP) to transport information from the edge to the core and vice versa
- On the orchestration level – the NRV management needs to drive the transport to create the connectivity required to move information (e.g., MPLS LSP)

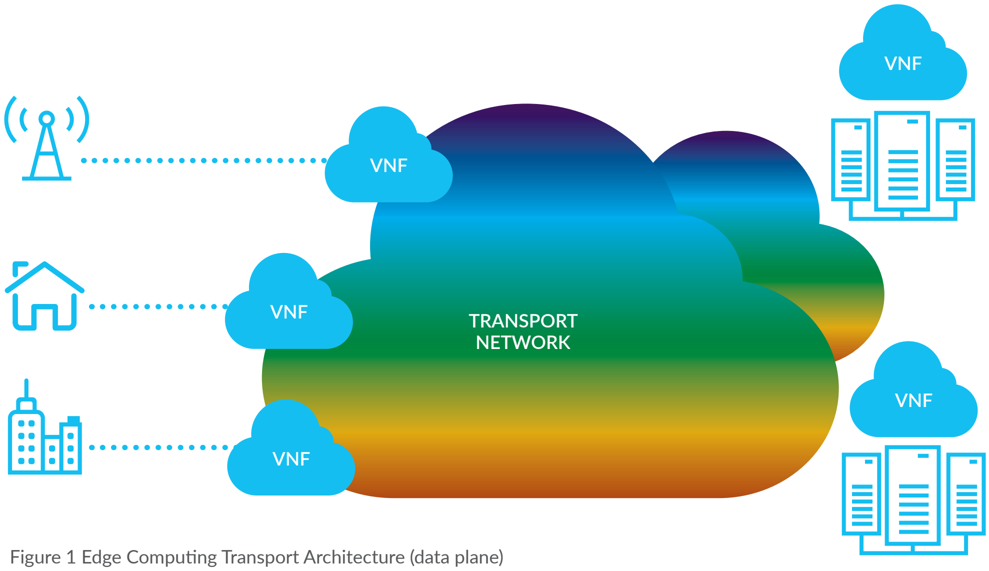


Figure 1 Edge Computing Transport Architecture (data plane)

Network architecture can be quite simple: In principle, all the network functions can be implemented via software (developing specific Virtual Network Functions) on blade servers (x86 based), with the transport network providing the communication (via P2P connection) between each remote server and a pair of datacenters (for redundancy purposes).

In this way, the need for specialized hardware and complex network architectures is eliminated. The connectivity is simpler, and the same hardware can support different functions by implementing a different software.

Key characteristics of transport networks associated to edge computing and cloud architecture include:

- Bandwidth – VNF will be allocated where needed (either centralizing or distributing in the periphery of the network) but this does require bandwidth
- Flexibility – the allocation of bandwidth is not permanent but should allow for fast re configuration

To fully optimize the usage of resources in the network, these characteristics should be applicable not only to the L2/L3 service layer but also to the L0/L1 transport layer.

Localization of computation resources can differ depending on the network context. From an extreme case of association of a computation resource to each access point (for example: to each 5G access point) up to a rural case, where the first Central Office is the ideal position for a mini-datacenter.

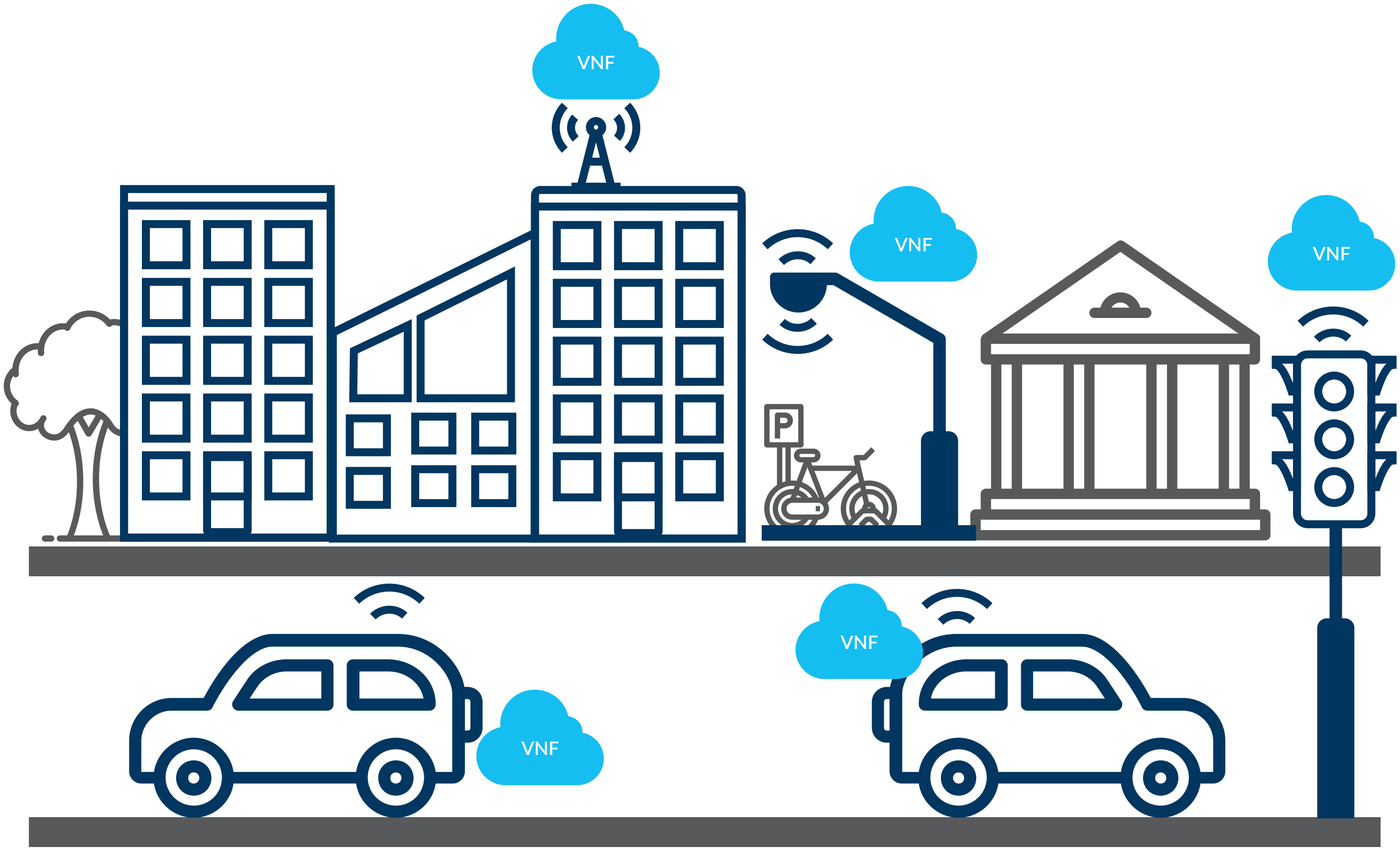


Figure 2 VNF localization for smart city application.

In any case, one of the most important and critical points in this architecture is the Network Orchestration.

NETWORK ORCHESTRATION

Network Orchestration is the process of managing both the cloud resources (VNF) and the transport resources from a single multi-purpose platform. One of the architectures defined for NFV Orchestration is the ETSI MANO [2] that has been developed in the ETSI context as an open project.

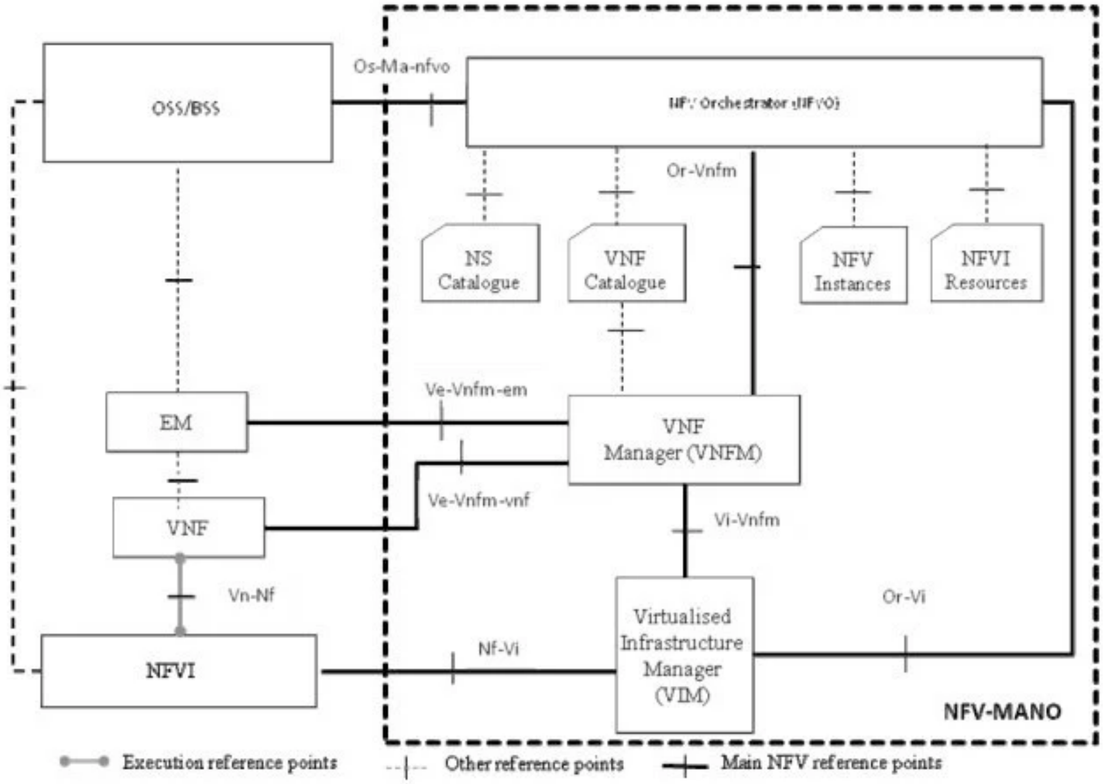


Figure 3 ETSI MANO Architecture

> Interfaces have been defined to automatically drive the transport resources (typically managed by the SDN Controller) from the NFV Orchestrator.

KEY TECHNOLOGIES

Transport networks optimized for edge computing requires:

- WDM technology to increase bandwidth and minimize latency
- ROADM (WSS based) function to enable reconfigurability transport resources according to the requested connectivity and bandwidth
- Coherent technology to provide high-capacity network connectivity

JABIL photonics

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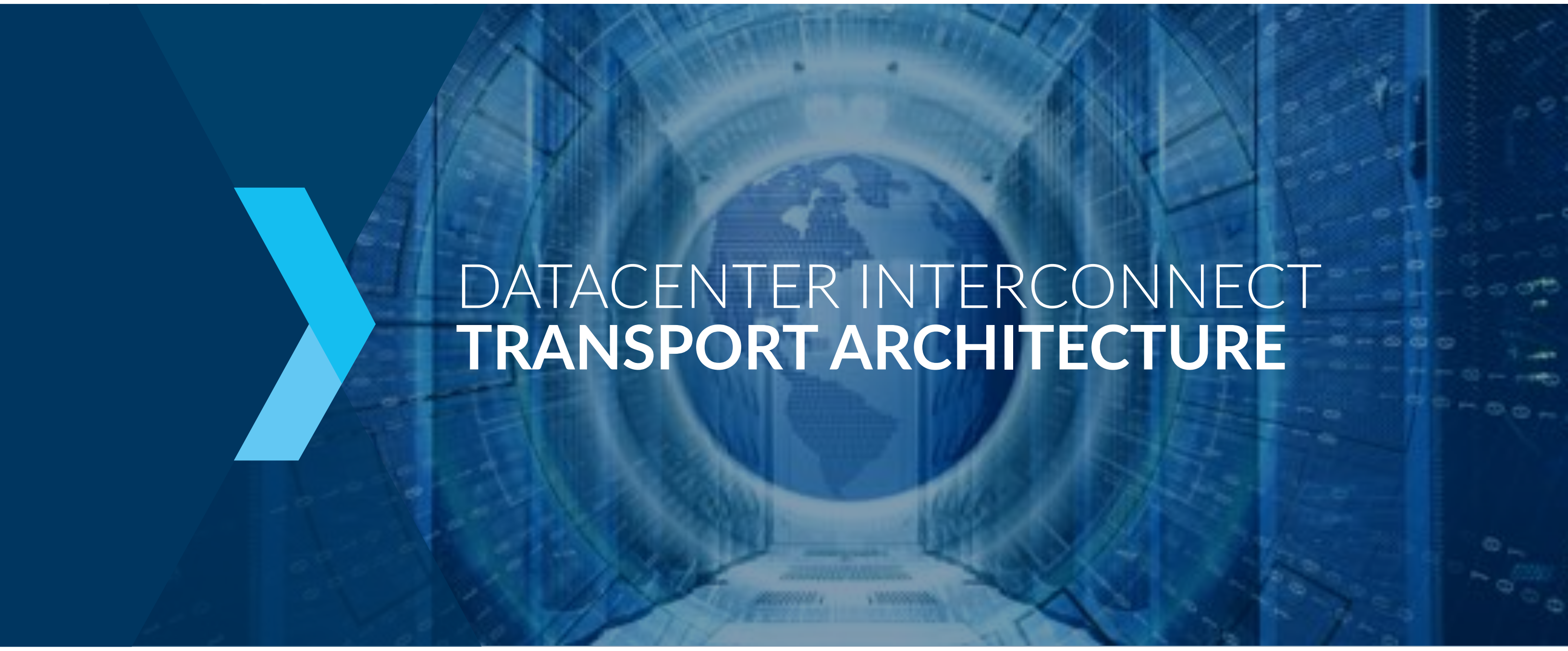
Figure 7 Jabil Photonics Portfolio

References

[1] ETSI – Multi-access Edge Computing architecture

[2] ETSI GS NFV-MAN



DATACENTER INTERCONNECT TRANSPORT ARCHITECTURE

APPLICATION NOTE SUMMARY

In the past few years, 'datacenter interconnect' has been one of the largest growing trends for the optical market, pushed by the deployment of new datacenters by major cloud operators. According to optical market analysts, this segment has grown in the double digits.

The introduction of 400ZR modules to the market, in particular with QSFP-DD form factor, is going to change datacenter interconnect architecture in the metro/metro-regional space. In this paper, we will discuss the current architecture and the evolution towards 400ZR interfaces along with some related key technologies.

DATACENTER INTERCONNECT TRANSPORT SOLUTION

One of the applications of coherent interfaces in the optical market is the interconnection between metro regional datacenters through dedicated point-to-point WDM links with higher rate coherent WDM interfaces. This has pushed optical system vendors to introduce specific products dedicated to the transport of this traffic, with reduced form factor (typically one rack unit), very high capacity and in datacenter practice (600 mm rack compliant, DC powered for example).

Figure 1 Datacenter interconnect optical solution (disaggregated solution)

In this architecture, datacenters provide high speed optical 'grey' interfaces (for example: 100GbE, 400GbE and, in the future, 800Gb/s). The task of the 'disaggregated transponder' is to mux the client signals over a single 'colored' wavelength at the highest possible rate to maximize the spectral efficiency via coherent optical interfaces.

Each single coherent signal is then transferred to a WDM system that provides the MUX/DEMUX and amplification functions. This last building block is also called 'Open Line System' in the disaggregated architecture.

Typically, the network architecture is simple point-to-point and the majority of the applications are now in metro/regional areas with the distance between the two datacenters usually below 100Km.

Activity has also been run in open consortium (e.g. Telecom Infra Project) to define white boxes for 'disaggregated transponders.' The latest example is the Phoenix platform. [1]

400ZR SOLUTION

OIF has developed an implementation agreement for a coherent interface to satisfy the requirements of datacenter interconnection in the metro/metro-regional space, with a distance of 120Km or less (minimum 80Km) and 400Gb/s rate. The 400ZR specification is now available [2].

The DWDM link will be amplified, point-to-point and noise limited.

The main scope of the implementation agreement was to open the market to different players, including transceiver vendors and system vendors, achieving the most optimized architecture for the requested limited distance, with clear target of reducing the price per Gb/s respect to the current coherent interfaces (that have been designed to cover higher distances).

Different form factors are allowed by OIF's implementation agreement (QSFP-DD, OSFP, COBO, CFP2, CFP8), but with port densities equivalent to grey client optics that are to be inserted directly into client systems currently hosting 400Gb/s client pluggables.

Figure 3 Impact of 400ZR in Datacenter Interconnect architecture

This implies that the 400ZR optical coherent interfaces hosted in datacenter switches will be connected directly to MUX/DEMUX inputs of the Open Line System, without the need for an intermediate disaggregated transponder.

IMPACTS ON OPEN LINE SYSTEMS

Coherent 400ZR optical interfaces bring plugged directly inside client nodes (e.g. switches inside datacenter) will affect the architecture of the Open Line System and its evolution in the 400ZR era. The first scenario is simple and is applicable when a very limited number of 400ZR channels (e.g. 8) must be aggregated over a fiber.

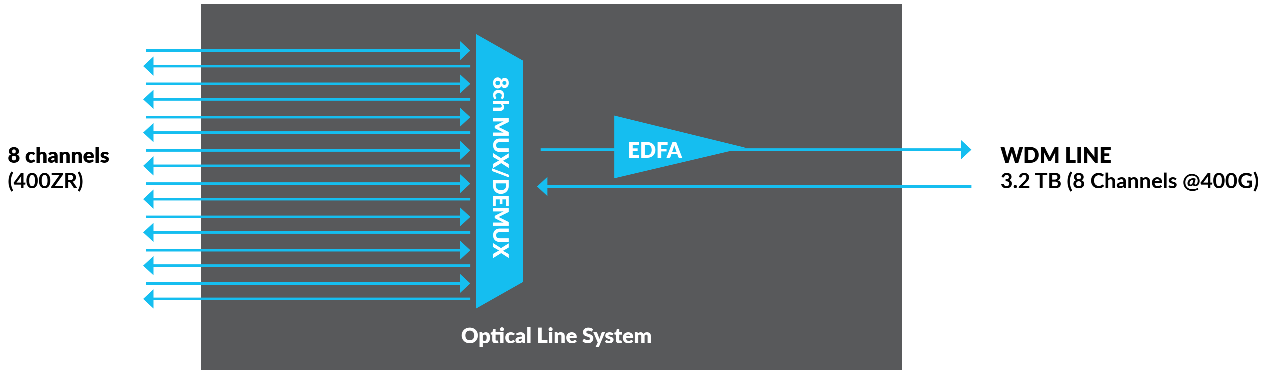


Figure 4 Open Line System architecture for 8 channel link.

When such a simple architecture is requested, it is possible to aggregate all line system functionalities (MUX/DEMUX and Amplifier) in a pluggable that could be also inserted directly in the datacenter switch (like a 400ZR module). In this case, no other functions are needed (for example, OSC is not necessary). This architecture has been recently announced by some system vendors [3] in OSFP form factor.

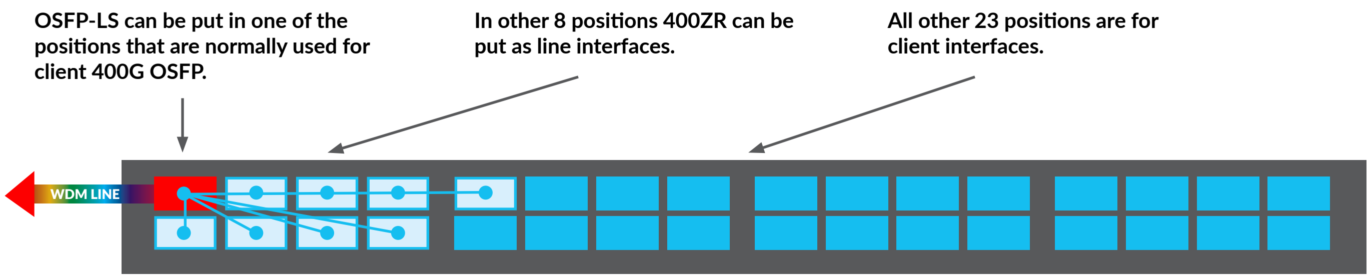


Figure 5 Example of pluggable Open Line System in a shelf.

This architecture is limited by the physical space available in a single pluggable 'drawer' and cannot grow beyond an eight-channel point-to-point system.

An alternate architecture, able to support up to 40 channels (with 100GHz grid) is for the service provider application. One of the main impacts of this architecture is that each single channel will be considered as an 'alien lambda' from the open line system perspective, with likely few possibilities to manage optical parameters directly in the client system. In a disaggregated architecture where the coherent interfaces are hosted by an optical device, like a disaggregated transponder, which is capable of managing all of the optical parameters, an Ethernet switch would not be able to heavily manage the optical 400ZR coherent parameters.

This opens the window for development of new products or sub-systems dedicated to monitoring of incoming wavelengths, with the capacity to measure incoming optical power, verifying the SLA and balancing the channels (for example via battery of VOA functions).

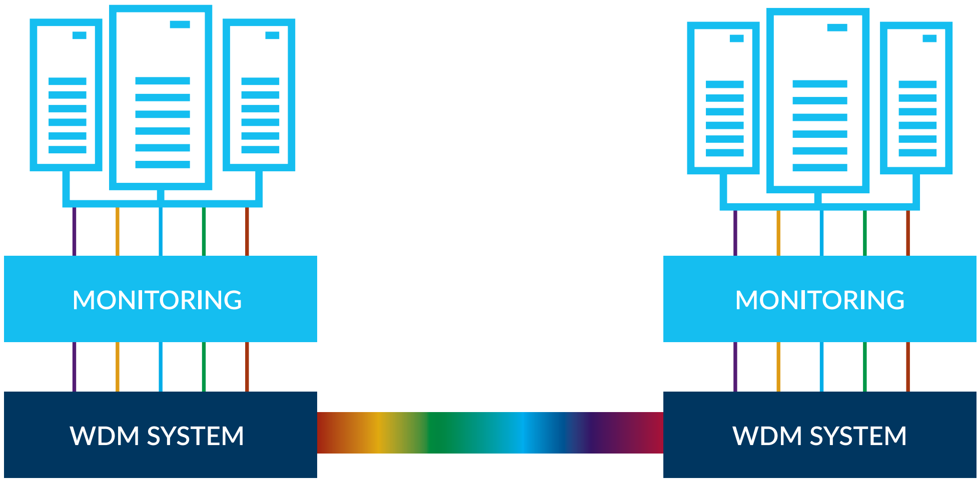


Figure 6 Open Line System architecture in 400ZR era with Monitoring

KEY TECHNOLOGIES

Open Line Systems in the 400ZR era require the following main WDM building blocks:

- Passive filters to add/drop the specific wavelengths in the access nodes and to terminate all the wavelengths in the hub node. ROADM architecture is also an option but is likely less applicable to pure datacenter interconnect scenarios. FlexGrid will play important role in maximizing the fiber usage (400ZR is compatible with 75GHz grid).
- Amplification is needed to exceed the pure passive network optical power budget. Mini amplification or pluggable amplifiers could play important roles for simple scenarios.
- Monitoring systems based on filters, monitoring and attenuators could be new required systems in the new datacenter interconnect architecture for 400ZR.

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Figure 7 Jabil Photonics Portfolio

References

[1] Telecom Infra Project - Phoenix Technical Specification

[2] OIF Implementation Agreement 400ZR OIF-400ZR-01.0

[3] Arista Networks Open Line System for 400G

CABLE ACCESS TRANSPORT ARCHITECTURE

APPLICATION NOTE

In this paper, a brief introduction on the evolution of cable access network scenarios is provided with focus on transport architecture.

CableLabs has recently announced the release of DOCSIS 4.0 specification with the target to provide 10G access capabilities via cable access.

Main characteristics of DOCSIS 4.0:

- Downstream capacity: 10Gb/s
- Upstream capacity: 6Gb/s

Compared to DOCSIS v.3.1, the bandwidth is almost doubled. This has implications for the 'backhauling' architecture that needs to provide the required bandwidth.

Hereafter some network scenarios as defined by CableLabs with focus on optical transport capabilities needed.

REMOTE PHY ARCHITECTURE AND ITS EVOLUTION

Remote PHY Architecture is described in [1].

Main components of a Remote PHY Architecture:

- CCAP (Converged Cable Access Platform) Core
- RPD (Remote PHY Device)

The RPD component has a network interface on one side and an RF interface on the other. The RPD provides Layer 1 PHY conversion, Layer 2 MAC conversion, and Layer 3 pseudowire support. The RPD RF output may be RF combined with other overlay services such as analog or digital video services.

The CCAP Core contains everything a traditional CMTS does, except for functions performed in the RPD. The CCAP Core contains the downstream MAC, the upstream MAC, and all the initialization and operational DOCSIS related software.

The reference network scenario is the following:

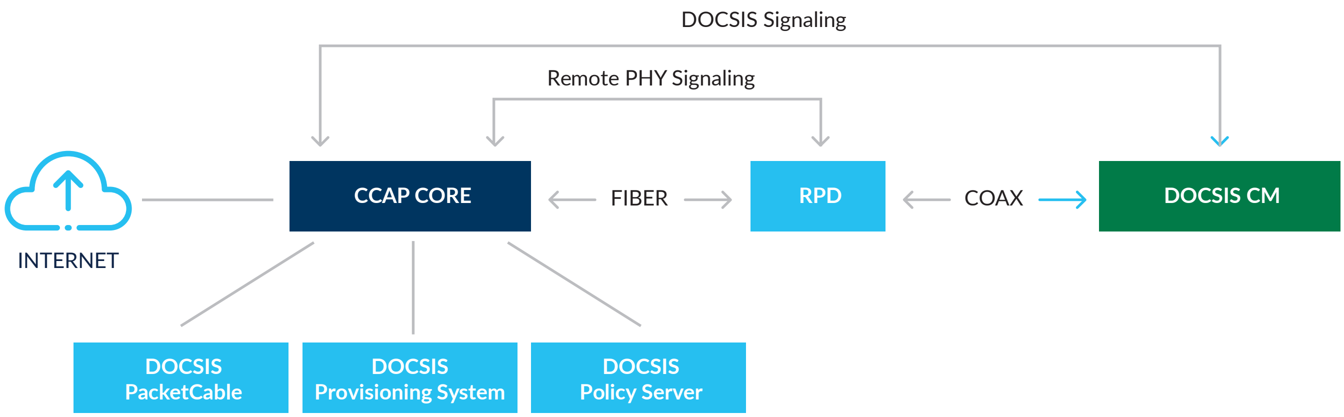

Figure 1 Remote PHY architecture (CableLabs)

Evolving the capacity over the access COAX cable via DOCSIS 4.0, requires the network between CCAP Core and RPD to evolve accordingly. Introduction of WDM technology allows to cope with existing and future requirements in terms of bandwidth. In this way:

- CCAP CORE sends traffic to all RPD multiplexing different wavelengths over the same physical fiber infrastructure.
- Each RPD filters its own wavelength (and uses the same for transmission).

Wavelengths can be initially 10Gb/s evolving to 100Gb/s in future.

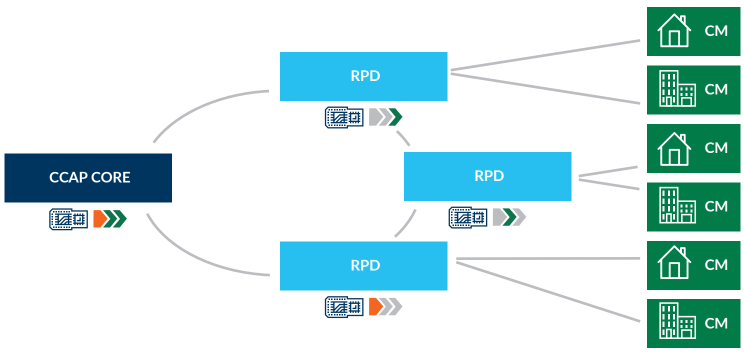

Figure 2 Remote PHY evolution with WDM Access

10G ACCESS AND EVOLUTION

A convergent single network able to host different kinds of services has been defined by CableLabs as a combination of technologies that will deliver symmetric multi-gigabit Internet speeds with the promise to be 10 times faster than today's networks and 100 times faster than what most consumers currently experience, with lower latencies, enhanced security and greater reliability [2].

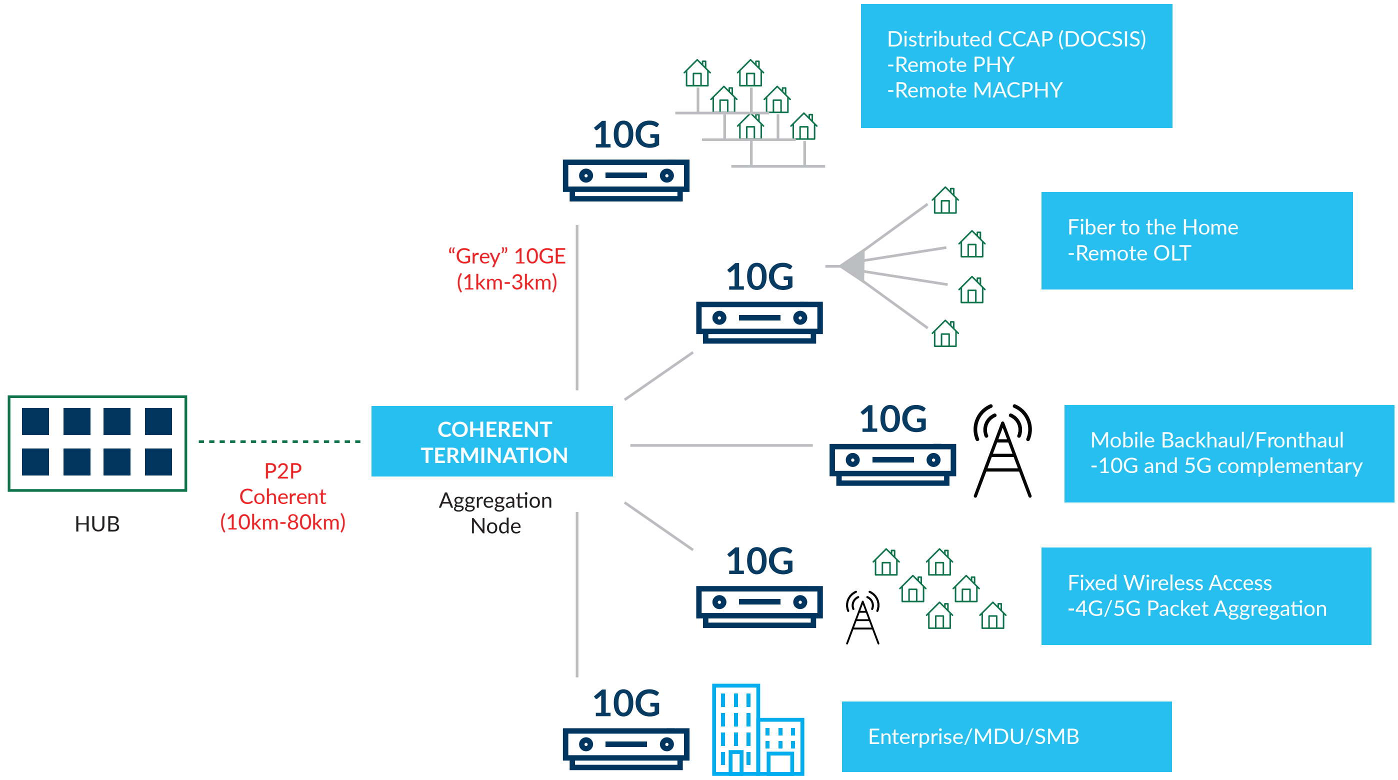

Figure 3 10G CableLabs architecture (from CableLabs website)

Technologies enabling 10G architecture:

- DOCSIS 4.0
- Coherent Optics
- 10G/25G/50G PON

In this architecture, the Aggregation Node is located in the connection between the metro and access network. Utilizing coherent termination, this architecture is set to evolve with the introduction of WDM in the connection between the HUB and the Aggregation Node (instead of the P2P link).

This allows the HUB to distribute many wavelengths (one for each Aggregation Node) that are dropped/inserted by aggregation nodes that then delivers 10Gb/s point-to-point to each 10G access node.

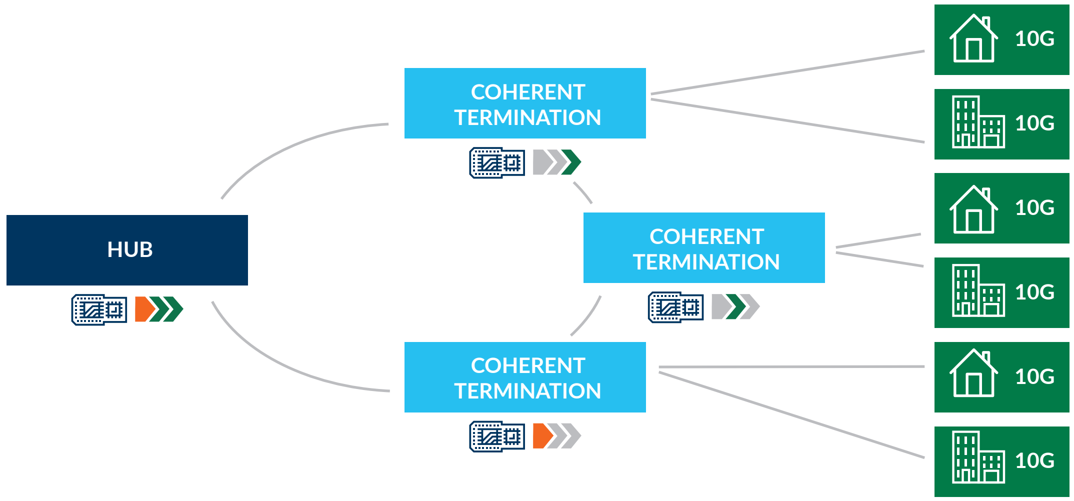

Figure 4 10G access evolution

OPTICAL COMMUNICATION MODULE LINK EXTENDER

A Technical Paper prepared for SCTE/ISBE introduces the DWDM Access for Remote PHY Networks Integrated Optical Communications Module (OCML) [3].

OCML (Optical Communications Module Link Extender) is a concept for cost effectively transporting a mix of DWDM 10GbE, GPON and 10GEPON wavelengths over the same fiber to a typical Hybrid Fiber Coax node serving area.

This is possible because the wavelengths used for GPON, 10GPON and for traditional C-band WDM do not overlap:

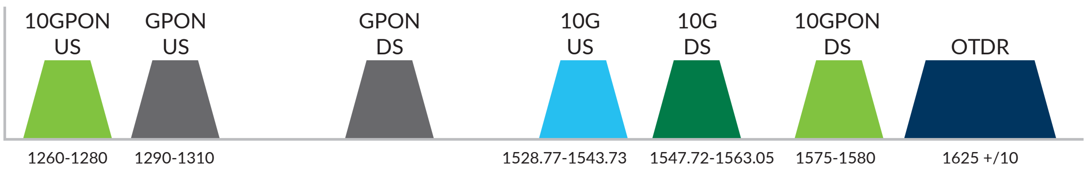

Figure 5 Wavelengths used for OCML services

Some key requirements for OCML include:

- 5 to 60 Km fiber rings
- 10G DWDM - transport up to 20 X 10G bi-directional wavelengths
- GPON/10EGPON transport over 20Km

The OCML has been defined with the vision that it could support future requirements for 100GEPON and 100G Coherent.

Two components are introduced:

- Headend node: located in the central office, it is the node that performs the multiplexing of different signals and services over the same fiber.
- Outside plant: it is the remote node mostly passive that separates the traffic coming from the headend node into the services towards the access (PON, P2P)

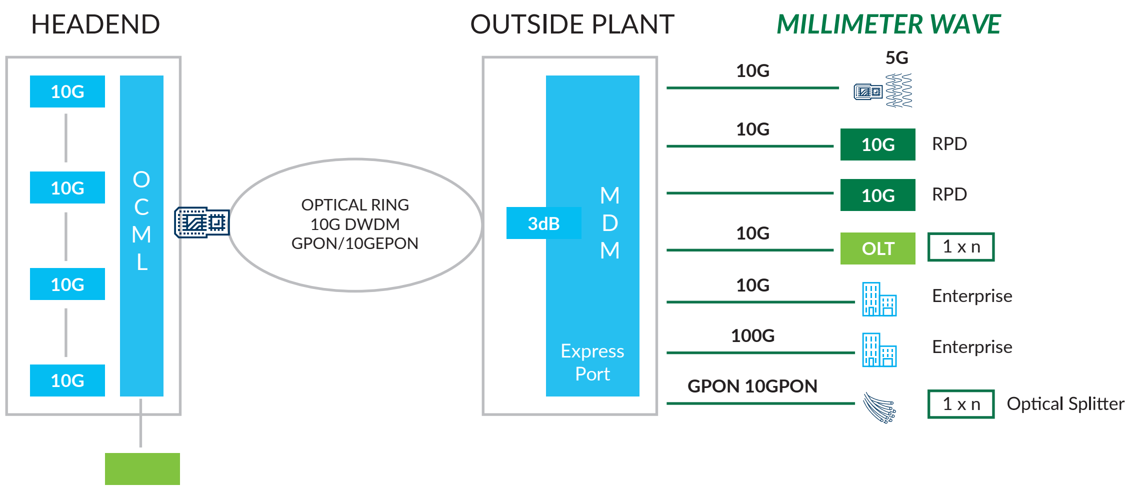

Figure 6 OCML network architecture [3]

The main building blocks of OCML terminal are the following:

- Passive filter with the capability to mix wavelengths used for PON access with traditional C-band wavelengths
- Optical Booster and Pre-amplifier to satisfy the requirements defined for OCML
- Couplers/splitters and optical switch to provide optical protection

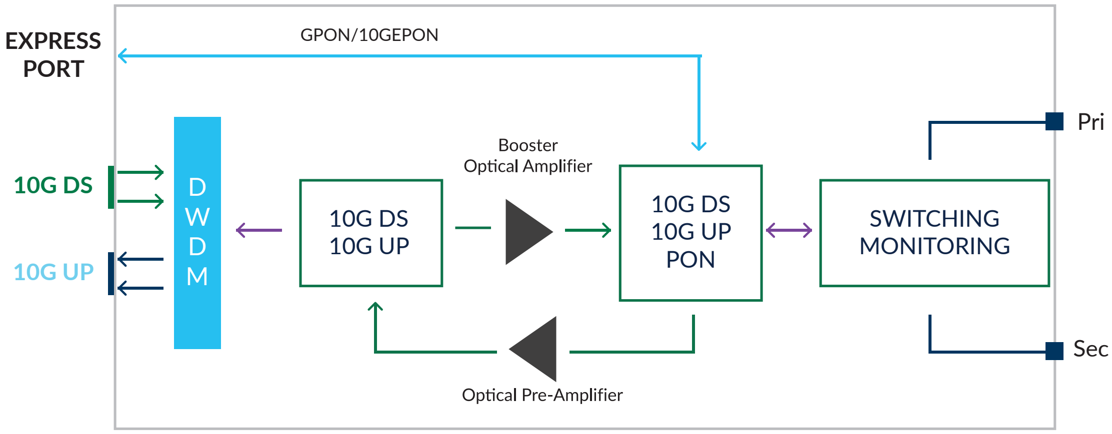

Figure 7 OCML Building blocks [3]

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Figure 8 Jabil Photonics Portfolio

References

[1] Data-Over-Cable Service Interface Specifications DCA - MHAv2 - Remote PHY Specification - CM-SP-R-PHY-I14-200323

[2] CableLabs - 10G: The Next Great Leap in Broadband

[3] DWDM Access for Remote PHY Networks Integrated Optical Communications Module (OCML) - A Technical Paper prepared for SCTE/ISBE.