X-Haul Architecture for 5G Transport

Key to building the best-in-class 5G transport infrastructure

Transformational impact of the 5G network architecture extends right from radio access to the optical metro and core segments. The transport infrastructure is the key to secure the best 5G experience. It is imperative to upgrade to a high-performance and highly reliable end-to-end optical fiber network that cost-effectively fulfils end-user demands. 5G use cases such as Ultra-reliable low latency communications (URLLC) and Enhanced mobile broadband (eMBB) require deterministic real-time latency (end-to-end delay) for services. Each use case presents distinct challenges for 5G transport performance. This paper discusses the nuances of how Tejas Networks is building cutting-edge 5G X-haul products and solutions that enables service providers to develop fast, secure and reliable communications services.

White Paper

Introduction

5G is a game-changer, bringing in a host of services which were only in the confines of imagination; whether it is smart grid, remote surgeries, autonomous cars, or factory automation. 5G will represent a significant advance over previous mobile technology generations due to an explosion in the number of network-enabled IoT devices, greater fiberization and densification of cell sites and a "cloudified" RAN architecture. The magnitude of these changes is such that it is likely to have a transformational impact on the 5G optical network architecture extending right from the Access to the Metro and Core segments. The emerging cloud architecture with its software-centric network paradigm also presents opportunities for telecom vendors and service providers to evolve innovative products and services that can contribute to the revenue growth.

Besides driving up the per-cell throughput by at least 10x when compared to 4G/LTE, 5G is also expected to lead to a massive 100x increase in the number of user devices through "Internet of Things (IoT)", a significant reduction in network latencies by a factor of 10x to support real-time tactile Internet applications and an ultra-reliable network for a seamless service experience. 5G is introducing several new features that increases the complexity of radio access networks (RAN). Together these changes will put greater demands on the transport network and have a disruptive impact on the optical network architecture to better accommodate these requirements.

5G Transport Design

5G operates at a higher frequency spectrum which results in increased number of base stations. Apart from the wireless upgrade to new radio technologies, new core infrastructure, the fiber optic wireline networks also needs to evolve to meet the stringent demands. The wireline transport network is the bridge between the services and subscribers which also needs to scale to meet the 5G constraints.

Mobile Backhaul evolving to Crosshaul (X-Haul): In 4G, mobile backhaul refers to the section of the telecom network that transports cellular traffic from base stations at cell towers to the nearest traffic switching center. While multiple backhaul options are available today - optical fiber, microwave or copper, with the arrival of pre-5G/5G mobile operators are fast gravitating towards optical fiber as the physical medium of choice. 5G is introducing new radio access architectures such as C-RAN (centralized RAN) using new protocols such as CPRI/eCPRI to connect multiple remote radio heads (RU) at street level to a centralized cloud-resident baseband unit (DU/CU) at the macro base station. Midhaul is the link between the DU and the CU controllers that feeds the next link. While optical fiber is the popular choice for this "fronthaul" network (link between RU and DU), 5G also imposes additional demands in terms of latency, jitter, scalability and connection bandwidth. These requirements are met through a "crosshaul" architecture that integrates fronthaul, midhaul and backhaul in a single transport network to achieve overall reduction in capex and opex.

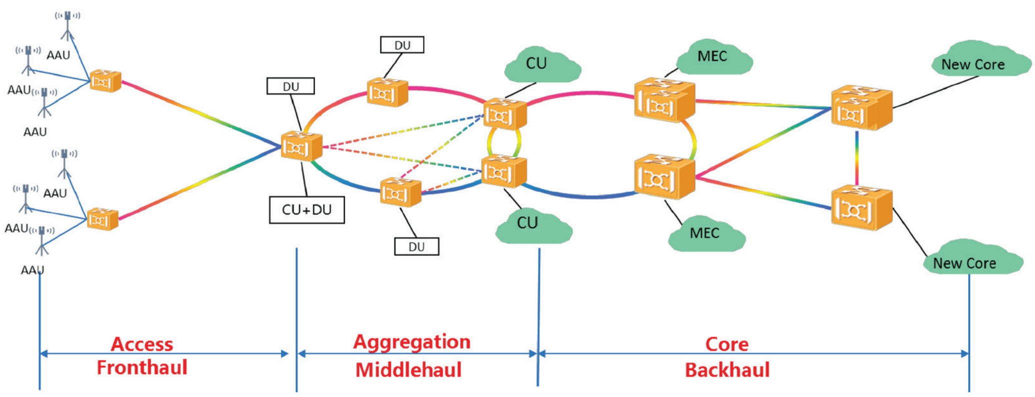


Figure 1: 5G X-haul (Image credit: https://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-HOME-2018-PDF-E.pdf)

Hyperscale Metro and Core Networks: High-capacity optical communications is a key technology advance that is driving network transformation in the Metro and Core networks. Thanks to advances in this area, a single optical fiber strand is now capable of carrying tens of terabits of traffic today through modern techniques such as dense lightwave multiplexing (DWDM), optical amplification, reconfigurable optical add-drop multiplexing (ROADM) and coherent optical processing. 5G will capitalize on recent advances in coherent DWDM technology to build hyperscale metro and core networks that transmits 100G/200G+ bit rates per wavelength over thousands of kilometres at the lowest cost per bit. Coherent DWDM achieves these gains primarily through the use of superior modulation formats that make use of amplitude, phase and polarization of light waves and better compensation for chromatic dispersion and polarization mode dispersion (CD, PMD) through sophisticated digital signal processors. Advanced network functions such as multi-degree ROADM, universal terabit-scale OTN/PTN cross-connects (DXC) and generalized MPLS protocols (GMPLS) for efficient automated switching at the wavelength layer enable the system to optimally pack service traffic over fewer wavelengths and engineer a highly cost-effective solution in high-bandwidth DWDM networks.

Open and Virtualized Networks: 5G is driving a major transformation to a software-defined network (SDN) paradigm that makes these networks more programmable to allow a more agile deployment of new applications and faster instantiation of services. With SDN, telecom operators envision re-architecting their networks such that new services can be turned up automatically "on-demand" as opposed to taking months of tedious, manual processes. Network Function Virtualization (NFV) virtualizes proprietary network appliances for specialized functions such as firewalls, routers, switches, intrusion detection, NAT and DNS such that they run in software often implemented in cloud service frameworks. The benefits of NFV include reduced investments in dedicated hardware and associated operational costs in terms of space rentals, power and cooling. In addition, NFV enables telecom service providers to rapidly launch innovative network services with the flexibility to scale as per varying business demands.

RAN Deployment Scenarios

Various hybrid deployment scenarios of backhaul, midhaul (called mid-haul by ITU-T and Fronthaul by 3GPP) and fronthaul are required for dense deployment of network infrastructure. Some of the deployment scenarios are:

- Independent RRU, CU and DU locations - In this scenario, there are fronthaul, midhaul and backhaul networks. The distance between an RRU and DU is in the range of 0-20 kilometers while the distance between the DU and CU is tens of kilometers.
- Co-located CU and DU - In this scenario, the CU and DU are located together, consequently there is no midhaul.
- RRU and DU integration - In this scenario, an RRU and DU are deployed close to each other, maybe hundreds of meters, for example in the same building. In order to reduce cost, an RRU is connected to a DU just through straight fibre and no transport equipment is needed. In this case, there are midhaul and backhaul networks.
- RRU, DU and CU integration - This network structure may be used for small cell and hot-spot scenarios. There is only backhaul in this case.

The recent commercial deployments of 5G is the Non-Standalone (NSA) version that is built over the existing 4G/LTE infrastructure. The requirement from the transport networks in this case is only to provide higher bandwidths for enhanced mobile broadband (eMBB) applications such as UHD video and real-time gaming. This was achieved through increase in the mobile backhaul capacity (MBH) of the network.

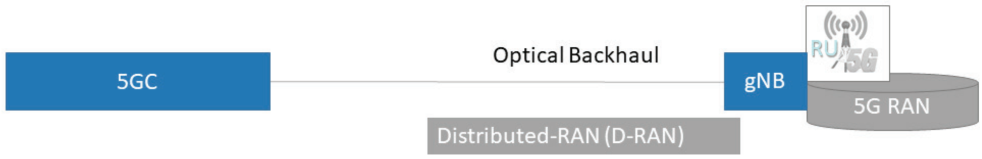


Figure 2: Distributed RAN Architecture (Phase-1)

As we move to 5G NR Phase 2 (3GPP Rel16), there are arduous performance demands on the transport network with increased speed, latency, number of connected devices and synchronization requirements. Situations with high bandwidth required hotspots such as office clusters, apartments, event locales and commuting hubs require centralized baseband deployments. The new applications necessitates re-architecture of the mobile backhaul transport to support either centralized-RAN (C-RAN) or virtualized-RAN (V-RAN) architecture comprising of converged crosshaul solutions (fronthaul, midhaul and backhaul) to meet the lower latency and synchronization requirements.

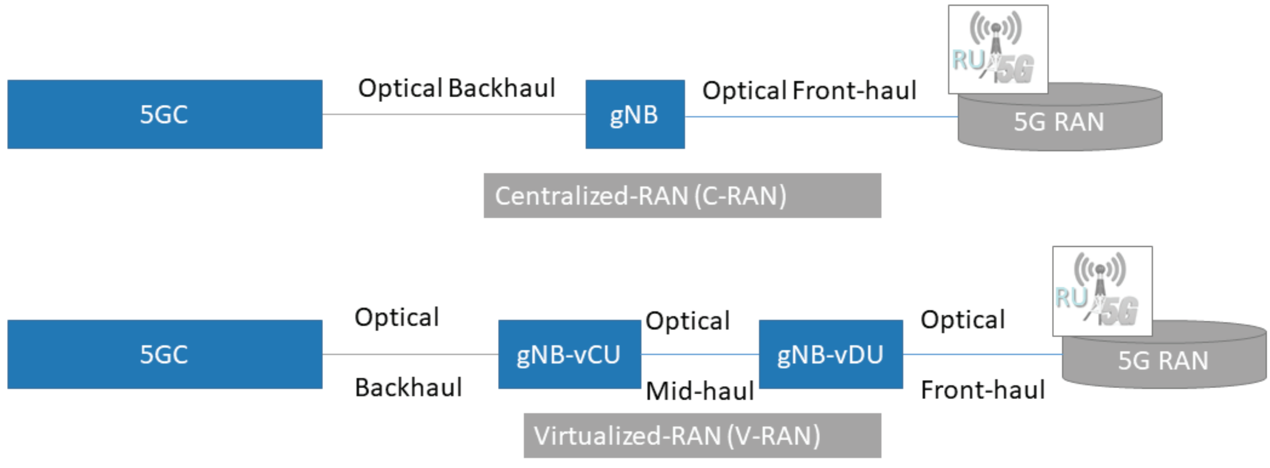


Figure 3: RAN Architecture (Phase-2)

5G Fronthaul Requirements

Fronthaul transport requirements of achieving gigabit speeds with 1-millisecond latency raises the bar for all aspects of 5G infrastructure. The key requirements for fronthaul are enumerated below:

1. Traffic Prioritization Stringent Latency and Timing Requirements

Network latency depends on the speed of the network, available bandwidth and the size of the transmitted data. The market for M2M is expected to grow exponentially in coming years. Low latency is one of the necessary conditions for enhanced indoor and outdoor broadband, enterprise collaboration, augmented and virtual reality.

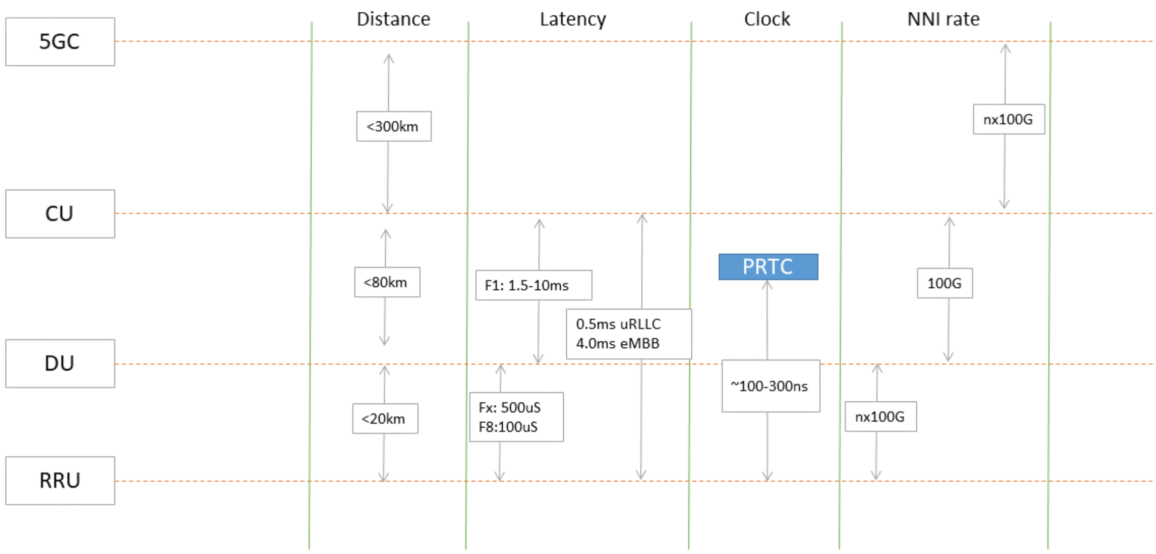


Figure 4: Latency requirements across the 5G network

2. Traffic Prioritization

Latency requirements depend on traffic priority, and ranges from 100μs to 100ms. Highest priority traffic such as synchronization and IQ samples require:

- Either all frame sizes to be less than 2000 bytes (Profile A)
- Or pre-emption of low priority frames by high priority ones (Profile B)

3. Synchronization

5G supports new services, technologies, and network architecture. It is essential to manage multiple timing sources across the network. A key consideration for 5G transport networks is to achieve time synchronization for both the backhaul and fronthaul transport network. This is made more challenging by the fact that GPS may not be easily accessible in outdoor small cell and indoor deployments.

5G RAN Architecture

In the 5G CRAN architecture, the BBU functionality is split into two functional units; a centralized unit (CU) and a distributed unit (DU). The radio unit (RU) handles the digital beam forming functionality and the parts of the PHY layer. The key elements are the PDCP, RLC/RRC, MAC and PHY. The DU runs the RLC, MAC, and parts of the PHY layer and its operation is controlled by the CU. The centralized unit (CU) runs the RRC and PDCP layers.

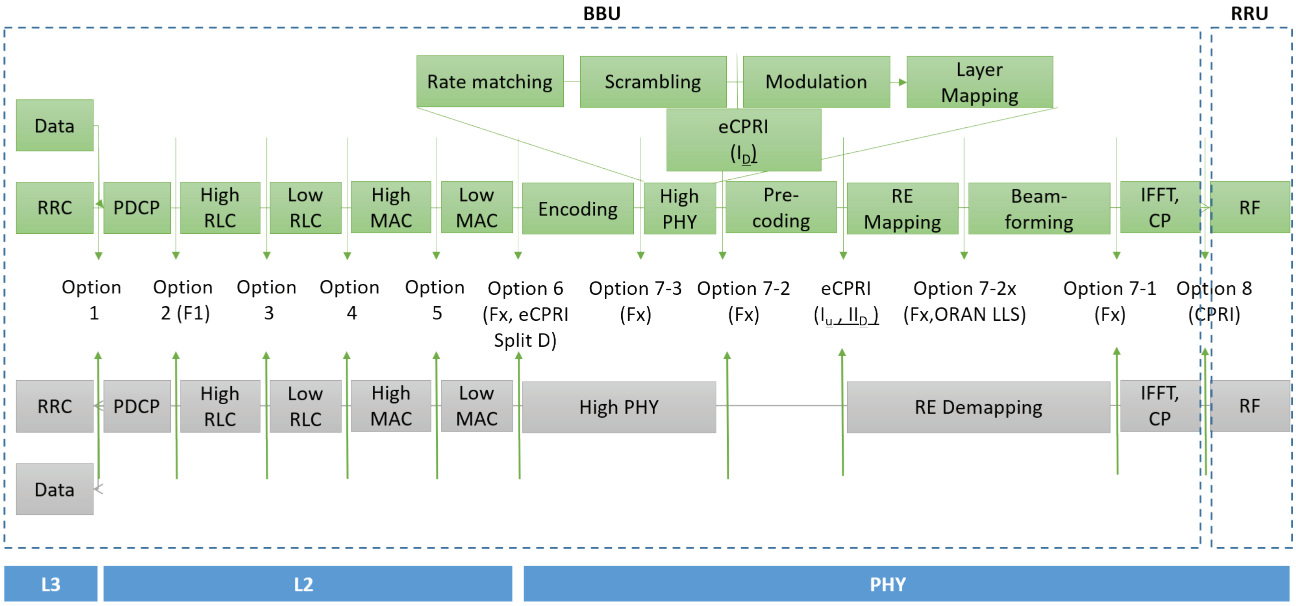


Figure 5: CU-DU and DU-RU split options

Solving the bandwidth problem of 4G requires redistribution of functions between BBU and RRH. The split between DU and RU will be different depending on the specific use-case and implementation. Service providers will need to look at a solution that can support not just 5G but also 4G which is most prevalent; not to mention support for 2G and 3G as well.

Options	Option 6	Option 7.3	Option 7.2	Option 7.1	Option 8
Data Rates	X Mbps	3*X Mbps	3*X *(2*16)*P/8 Mbps	6 * X* P*nTxRU Mbps	6 * X* P*nTxRU *nTx Mbps

Assumptions:

“X” Mbps MAC to PHY Data rate 1/3 Coding Rate

256 QAM Modulation Order (16 bits per I and Q)
P = Number of Antenna Ports nTxRU = Number of RF chains
nTX = Number of transmission Antennas

NR perspective:

Option 7.2=> 3300*(2*16)*8 (layers)*13 (OFDM)/0.5 ms ~ 20 Gbps
Option 8 => 61440 Msps*32*64/0.5 ms ~ 250 Gbps

As an example, option 7 split architecture sets up DU to handle the PDCP, RLC, MAC and higher PHY functions, whereas the RU handles the lower PHY and Radio functions. The lower level interface that connects RU and DU should be eCPRI to provide low latency as demanded by 5G. The current 5G eCPRI Radios use this split option.

Option 7 allows operators to take advantage of sharing or pooling gains while maintaining the lowest processing utilizations on both the DU and RU – leading to a very cost-effective solution with a low TCO.

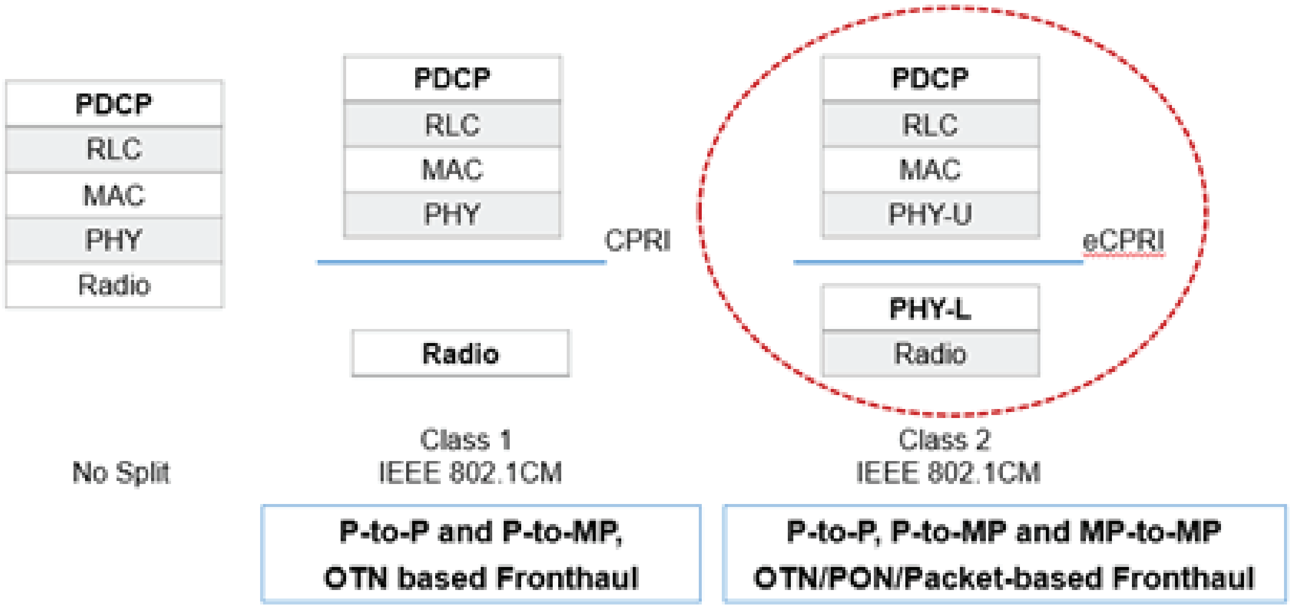


Figure 6: Option 7.2 - eCPRI

Fixed wireless applications delivering high bandwidth services to users in fixed locations are conducive to option 2, which places real-time functions within the radio head and creates an RU/DU functional element. Since high level coordination of multiple radio elements is not necessary, placing more functionality at the RU location can reduce the bandwidth and latency burden placed on the fronthaul, thereby allowing the CU to be positioned dozens of kilometers from the radio head.

Conversely, for the eMBB use case, options 6 and 7 pair only physical layer radio functions with the RU with the additional layers remaining in the CU/DU. This is more conducive to the coordination of multiple radios in mobile applications and reduces the fronthaul bitrate support. These options also introduce more stringent latency requirements that limit the geographic separation between RU and DU.

5G Xhaul Transport Technologies:

At the crux of the 5G story is its ability to support time-sensitive applications that require processing of massive amounts of data with minimal delay.

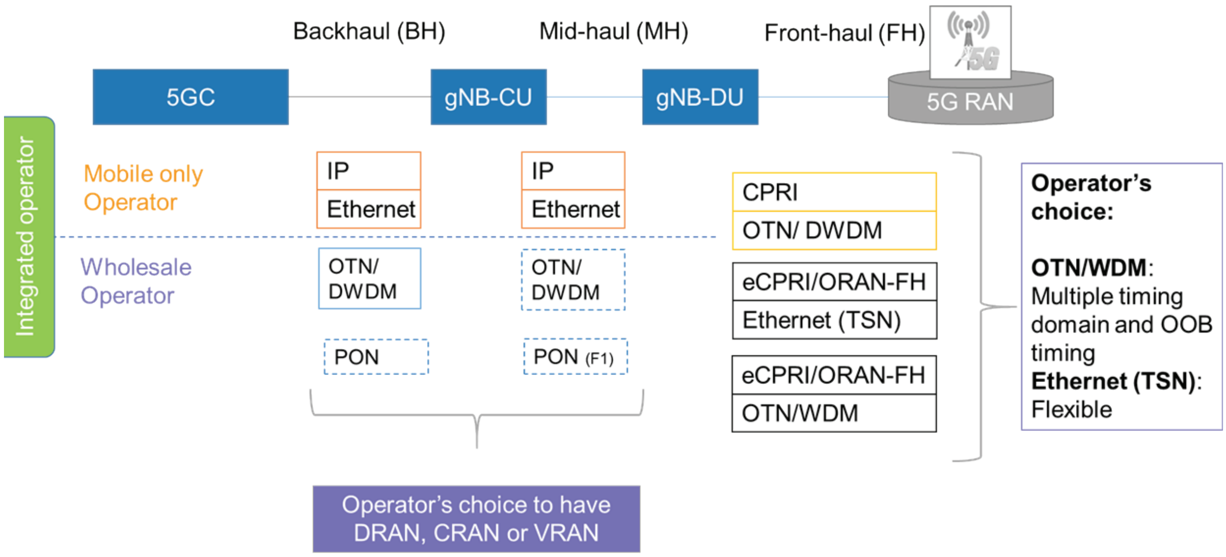


Figure 7: 5G Xhaul Technologies for CRAN / VRAN

XGS-PON/ NGPON2

GPON (Gigabit Passive Optical Network) is a widely deployed technology used to manage and share traffic over a fiber from the service hub to homes and enterprises. Thus, reuse of the existing infrastructure is a key motivator for xPON technologies to be used to build mobile Xhaul networks. Though PON technology originated in the 90's and has continued to evolve with differing wavelengths and speeds. The underlying concept of all fiber optic PON networks remains the unpowered or passive state of the fiber and its splitting or combining components.

XGS-PON is a 10-Gigabit-capable symmetric passive optical network that provides symmetric 10G transmission. Simultaneous upstream and downstream transmission over the same fiber is made possible through wavelength division multiplexing (WDM). This technology allows one XGS-PON wavelength or color of light transmission for upstream and another for downstream. NG-PON2 is the platform that most service providers will eventually adopt, with XGS-PON as a short-term solution where the bandwidth requirement does not exceed 10G. NG-PON2 (Next-Generation Passive Optical Network) developed by the International Telecommunications Union (ITU) is a multi-wavelength access standard for a passive optical network (PON) that is capable of delivering a total network throughput of 40-80 Gbps. It utilizes the TWDM (Time and Wavelength Division Multiplexed) technology to support from 4 to 8 multiple wavelengths of 10 Gbps PON over a single fiber.

TSN-Enabled Ethernet

Enhanced Ethernet for deterministic time-sensitive communications can guarantee end to end latency of 1ms or less required by uRLLC. IEEE 802.1CM developed to meet timing and synchronization requirements of 5G Xhaul Incorporates centralized configuration, path control and reservation capabilities. Ethernet is extensively used in access networks and enterprise connectivity. Due to the ubiquitous nature of this technology, reusing the existing network provides significant cost benefits.

Time Sensitive Network (TSN) provides deterministic performance over the bridged Ethernet. Determinism is achieved by time-based control of queuing. With TSN, non-critical applications run over the same Ethernet infrastructure as time-critical communications. It is not difficult to see why TSN is a front-runner in fronthaul technologies. TSN provides transport of CPRI/eCPRI by providing timing synchronization, resource management, latency and reliability. The major TSN standards are: IEEE 802.1AS, IEEE 1588 (Timing and Synchronization), IEEE 802.1Qbu (Frame Pre-emption), IEEE 802.1Qbv (Traffic Scheduling) and IEEE 802.1CM (TSN Standard for Fronthaul).

Enabling reduced latency transmission for time-critical frames

Ethernet works on a shared medium, whereby if a frame has started transmitting into the transmission medium, the transmission has to be completely finished before another frame can start transmission. This poses risk of increased latency if a low-priority jumbo packet has begun transmission. It is important to prioritize fronthaul packets over other lower-priority packets.

TSN Standard defines two fronthaul profiles:

- Profile A – Bridging with strict priority queuing
- Profile B – Extends Profile A with frame preemption
  - – Fronthaul traffic is assigned a high priority traffic class
  - – Non-fronthaul traffic is assigned a lower priority traffic class which can be preempted

Frame preemption allows Fronthaul traffic to interrupt a low priority jumbo packet currently in transmission and resume the transmission after the transmission of the high priority packet. As shown below, in the absence of preemption, the high-priority packet A is stuck behind B - a low priority jumbo packet enduring increased delay. Preemption allows the transmission of packet A with a deterministic delay.

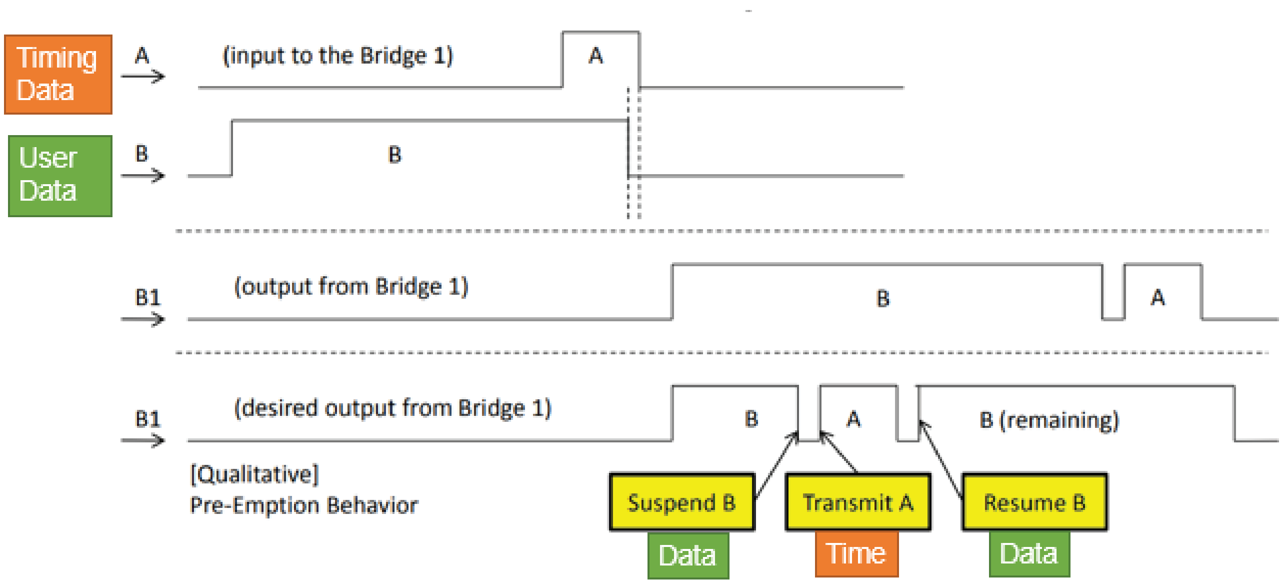


Figure 8: Illustration of frame preemption (Source: Yong kim, IEEE)

➤ Optical Transport Network (OTN)

OTN is technology based on SDH/SONET adapting to the great increase of data traffic in transport infrastructures. It is described in in ITU-T G.872 and the network interface is specified in ITU-T G.709. OTN is a highly scalable core network technology capable of time multiplexing the existing SDH stream with packet-switched data over the same frame. SDH/SONET, Ethernet, Synchronous Ethernet (SyncE), IP-MPLS, and MPLS-TP can all be accommodated by OTN. This technology provides a deterministic behavior similar to SDH/SONET.

OTN is more important than ever before given their high transmission capacities forming the basis of many transport networks. The OTN is intended to provide robust management features that support payload rates from 1.25Gbps to 100Gbps and up. While OTN2.0 is limited to 100G, OTN3.0 scales “Beyond 100G” with added support for new client signals such as 25GE for mobile front haul applications in addition to 40GE, 100GE, 200GE, 400GE, FlexE. OTN3.0 also supports flexible choice of FEC to suit the reach requirements.

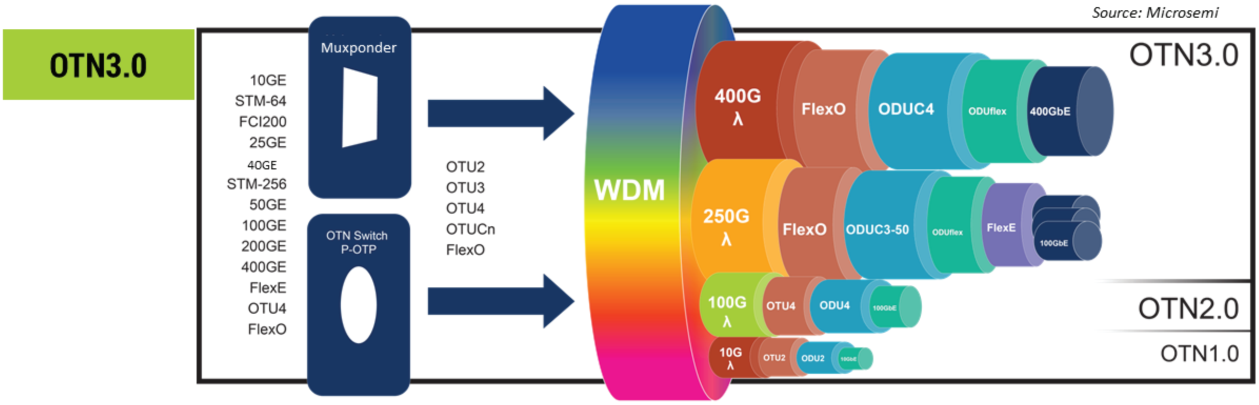


Figure 9: OTN Generations

Benefits of OTN

OTN provides several advantages as listed below:

Efficient Sub-Lambda Grooming: DWDM layer is capable of handling traffic at a wavelength layer. Since DWDM by itself does not offer any way to consolidate partially filled wavelengths, this leads to a lot of bandwidth wastage. OTN solves this problem by providing sub lambda grooming through an OTN cross-connect.

Reduced Build and Operational Costs: On a cost per Gbps of switching capacity, routers tend to be much more expensive than OTN fabrics. By substituting OTN for a significant part of the switching capacity (the transit traffic), the overall costs reduces significantly. Also, OTN fabrics consume less power compared to routing fabrics. They also consume less power than SDH fabrics since they groom traffic at 1Gbps granularity instead of 2Mbps.

Transport-style Reliability: OTN incorporates the following reliability features:

- Comprehensive OAMP includes messages related to Loss of Signal/Frame (LOS/F), alignment errors (TIM), frame errors (BIP-8, BEI), alarm indications (AIS, BDI) that can enable fault diagnostics at the OTN layer
- Support for a range of protection schemes is available: OCh 1+1, OCh-SPRing, ODU-1+1 linear, ODU-SNC/I, ODUSNC/N, ODU-SNC/S, and ODU-SPRing are analogous to popular linear and ring protection protocols in SDH/SONET
- Support for mesh-based automatic restoration with a GMPLS control-plane that offers additional flexibility by reducing the need for pre-allocated protection bandwidth on a backup path and for manual intervention by a network operator

Tandem Connection Monitoring (TCM): OTN supports six levels of TCM. With six levels of TCM, the network can be partitioned into six level of hierarchy from a management perspective. Some of these levels might be defined by a single operator to manage his large network, or for managing multi-vendor subnets within his own networks or for hand-offs between multiple operators.

Forward Error Correction (FEC): OTN supports FEC based on Reed-Solomon (255/239) with 16-byte parity. OTN FEC, can correct eight bytes of error per sub-row or detect up to 16 byte errors (without any correction) resulting in a 6.2 dB improvement in SNR. The availability of an enhanced FEC function can result in tangible cost savings in the access by reducing the need for external amplifier elements (often unmanaged) or more expensive long-reach interfaces.

Transparent service transport: OTN can achieve truly transparent service delivery because it uses asynchronous mapping. For example, if OTN is being used to transport an SDH client, it will neither modify any of the SDH overhead bits nor will the timing information be touched. This is especially important in the context of security-sensitive transport requirements.

Packet switching bypass: 5G requires a simple and effective transport of client traffic with the lowest possible latency. In such cases, even if the client happens to be a packet interface, it is particularly advantageous to use OTN as the transport protocol in the access network. This is because OTN does not have a store-and-forward architecture like in the case of packet switching thus avoiding unnecessary delays, jitter and service impairments. This approach also frees up capacity in packet switching fabrics for applications that actually require intermediate processing thus lowering the overall cost of the access network.

ODUflex for Bandwidth Reclamation: ODUFlex is particularly suitable to accommodate a range of new and custom client signal rates in the Access networks. With ODUflex, the container can be the exact size of its client, leaving the remaining space for other client signals. ODUFlex can carry both Constant Bit Rate (CBR) and Variable Bit Rate (VBR) packet-based clients. CBR clients are mapped using Bit-Synchronous Mapping Procedure (BMP) and packet-based client signals are accommodated by using Frame-mapped Generic Framing Procedure (GFP-F). ODUFlex is then mapped into a number of time slots in a High-Order ODU (HO-ODU) by using Generic Mapping Procedure (GMP). The clear advantage of ODUflex is that unused bandwidth on existing fiber can be reclaimed and the operator can avoid burning an additional fiber pair to meet new traffic requirements. This is critical in access networks with fiber exhaust issues.

MPLS-TP

MPLS-TP is designed to meet transport network operational requirements. It borrows critical elements from IP/MPLS such as its forwarding mechanisms, while including additional functionality such as performance monitoring, OAM, Tandem Connection Monitoring (TCM) and protection switching. MPLS-TP feature set is implemented as per RFC 56541. These are divided into general, layering, control plane, and protection and recovery.

Three key characteristics of MPLS-TP that are relevant:

- Reduced dependency on "routable" IP protocols thus lowering vulnerability to network layer cyber-attacks
- Provides superior OAM capabilities with pro-active and reactive fault management and performance monitoring.
- Uses LSPs (Label Switched Paths) and PW (Pseudo-wires) to deliver connection-oriented services. Network provisioning via centralized Network Management System (NMS) is possible without using a control plane.

MPLS-TP provides support for static traffic-engineered "pinned-down" service from a centralized network management system (NMS). This is perfectly compatible with traditional transport-style operations that assure enhanced reliability, predictability and determinism. Both service and protection paths can be pre-configured with the operator having full knowledge and visibility into service topology, network resource availability and provisioning from a hierarchical management system. Another benefit of this model is the ability to isolate and manage sub-networks as virtually independent regions. "Troubled" regions can be isolated by the NMS with critical traffic re-routed away from these parts of the network to maximize network uptime and productivity, while minimizing threat impact.

Failure statistics suggest that transport networks average approximately 4x the fiber cuts witnessed in core networks within a year. Moreover, most service providers seem to know a-priori which fiber segments are more prone to failures. Also, transport networks often provide anywhere between two and five alternate paths for several traffic demands that can be utilized by the network operators to assure higher availability for SLA driven services. New MPLS-TP implementations incorporate novel multi-segment "stitching" method by combining MS-PW stitched protection with 1:1 linear LSP and PW protection for supporting arbitrary meshed topologies. This advanced feature is especially useful for backhaul networks with dispersed clusters and possibilities of more than two alternate fiber paths for services within/between clusters.

Connection oriented architecture is useful to provide scalable enterprise service with complete transparency to E-LINE service. The built-in link integrity and RFC 6378 implemented in hardware ensures scalable sub 50ms solution. COE also helps is offering support for legacy circuit emulation services.

➤ IP/MPLS

To enable a 5G network, virtualization and control of IP routes is necessary. Control of MPLS using MPLS-TP was done in 4G. IP is needed for virtualization and PTN/CE for statistical multiplexing and for cost reduction. Carriers need to converge their networks to a single infrastructure to reduce Opex and support IP-based networking services as well as traditional layer 2 transport services. As an example as shown in the below illustration – in a shared nx1G/100G network, a combination of PTN and IP for access traffic aggregation and deploying the OTN deeper in the network is effective.

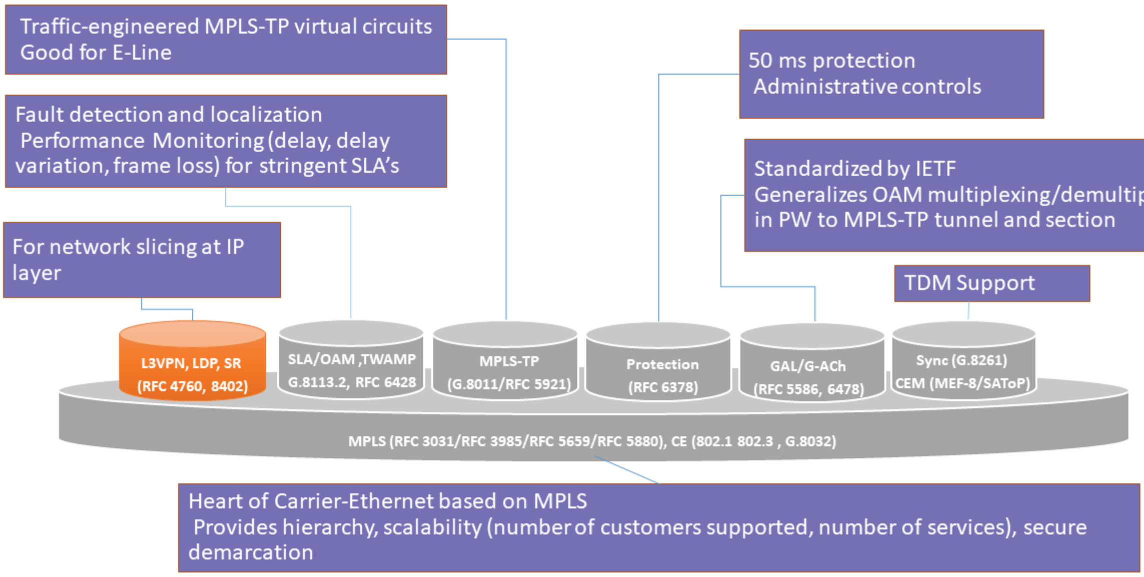


Figure 10: IP PTN for Access Backhaul

Network Slicing

Network slicing created using SDN/NFV and a network orchestrator helps to dynamically create new slices based on consumer needs with varying pricing while achieving the necessary isolation. A 5G end-to-end network with network slicing technology improves the time to market, accelerates the revenue growth and reduces total cost of ownership. 4G networks had only one network slice. In 5G networks, there are three slices, the IoT (mMTC) Slice, Broadband (eMBB) Slice and Low latency (uRLLC) Slice. Network slicing will maximize the flexibility of 5G networks, optimizing both the utilization of the infrastructure and the allocation of resources.

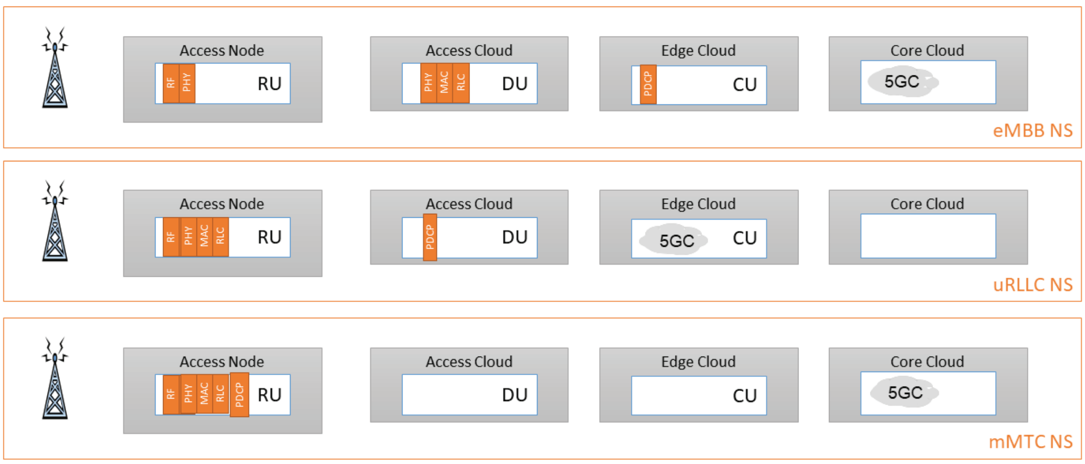


Figure 11: 5G end-to-end network with Network Slicing

The virtual network part of the slice can be realized using SDN. A typical telecom network consists of the access network which connects directly to the end user (Example: 4G/5G over wireless medium or xPON over optical access) while the rest of the network, barring the physical and MAC layers, will be integrated or "virtualized" in a server appliance. The data plane function of the switches cannot be virtualized as it demands line-rate processing and the switches are therefore implemented in a disaggregated leaf-and-spine architecture. On the other hand, control plane processing and core networking functions can be fully virtualized. While SDN technology is required to set up, manage and control the complete virtual network, NFV technology may be employed to virtualize specific network functions.

Tejas 5G Solution

The exponential growth of data transfer requirements increases the bandwidth requirements of the backbone transport network. These requirements have continued to drive fiber deployments deeper into the network. Fiber links using dense wave division multiplexing (DWDM) can create up to 96 independent channels for increased throughput. Though a diverse range of technologies are available, a unified solution that balances the bandwidth, latency requirements along with the cost of deployment is the need of the hour. The Optical Transport Network (OTN) is a mature technology which is implemented in Tejas Networks' UltraFlex platforms. These have been deployed for many years and are delivering transport guarantees in the network. In addition, in the not-so-distant future, with virtualization there is an effort to move all routing control plane to cloud and keeping only data plane on custom built hardware. Timing synchronization is another aspect which needs COE or OTN to reduce clock jitter to deliver sub-ms accuracy clock synchronization between 5G gNBs (ITAE|~260ns). This is better provided over MPLS-TP and OTN while user data plane can be offered using IP/MPLS. Tejas solutions are architected with this foresight.

Illustrated below are few implementations:

➤ Tejas DRAN based Solution

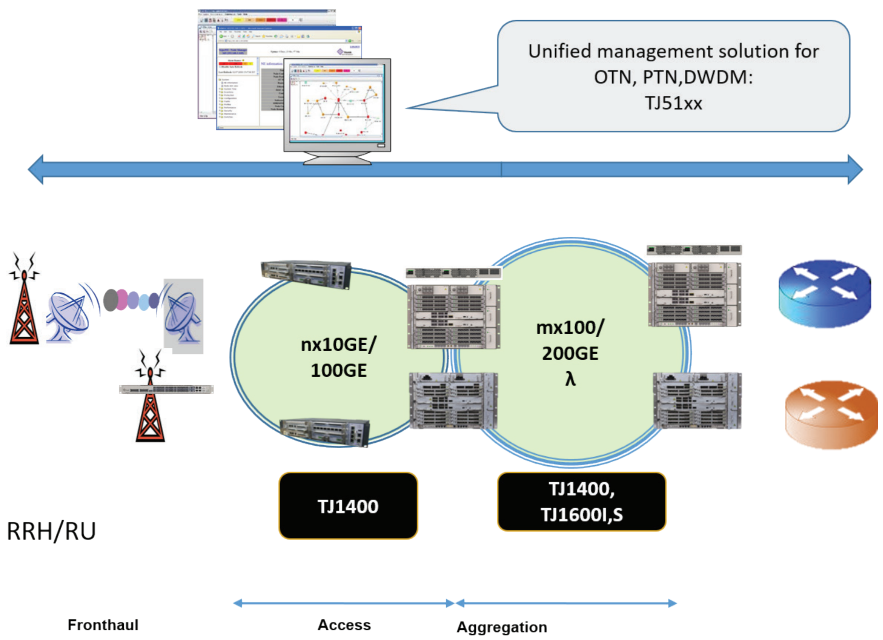


Figure 12: Tejas DRAN Transport Architecture

Access Backhaul

10G UNI + NGPON + 4G/5G BBU + nx10G (+OADM) / 100G NNI redundant/non-redundant product

L3VPN over PTN to handle Xn and EN/MR-DC

Aggregation Backhaul

nx100GE + mx100GE/200GE redundant product

➤ Tejas CRAN/VRAN based Solution

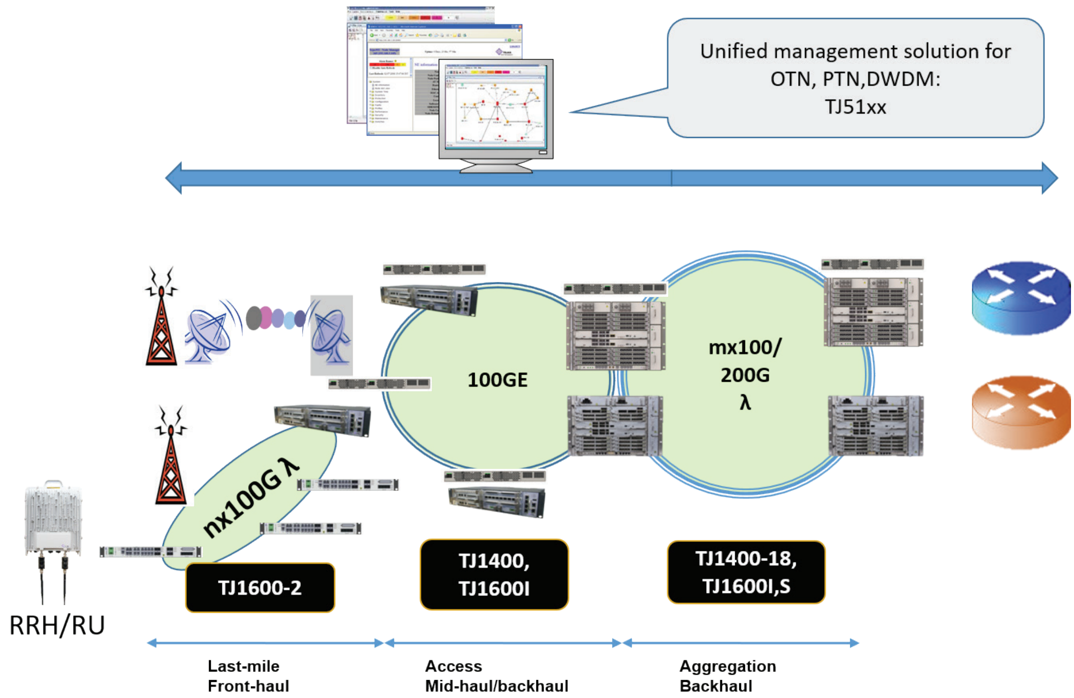


Figure 13: Tejas CRAN/VRAN Transport Architecture

Fronthaul: nxCPRI/ eCPRI/ O-RAN UNI + nx100G NNI with OTN/ DWDM

Access Backhaul/Midhaul: 10/25G UNI + nx10GE /100G NNI TJ1400-7, TJ1600-I (to mux existing traffic), L3VPN over PTN to handle Xn and EN/MR-DC

Aggregation Backhaul: nx100GE + mx100GE/200GE redundant product

➤ Tejas xPON based Solution

GPON being a pervasive technology used to handle traffic over a fiber from the service hub to homes and enterprises. Reuse of the existing infrastructure is a key motivator for xPON technologies to be used to build mobile X-haul networks. For small cells, xPON delivers better cost-efficiency through hub-and-spoke fiber topology. XGS-PON which supports symmetric 10G transmission can be deployed for higher bandwidth requirements. Higher-speed xPON (NG-PON2) can meet bandwidth requirements of 5G F1 fronthaul. Tejas modular transport solution can ensure NG-PON2 as a blade further helping in 5G small cell backhaul and partly 5G F1 midhaul.

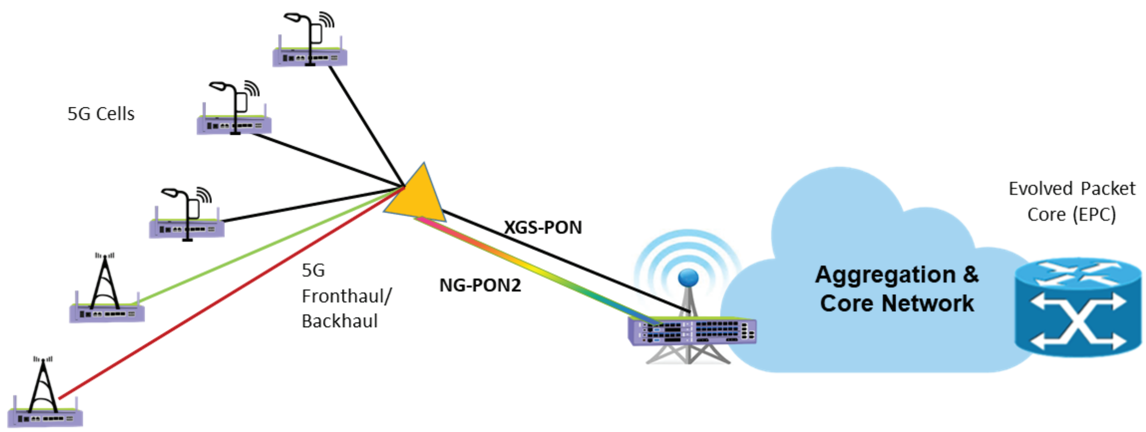
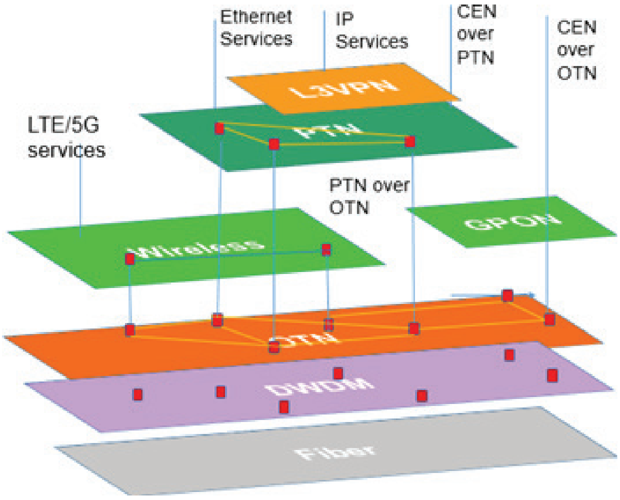


Figure 14: Tejas xPON based Transport Architecture

Tejas Unified Management Solution

Tejas has a central SDN/EMS/NMS which makes it ideal for implementing slicing through OSS as required in 5G. 5G X-haul networks enable a flexible and software-defined reconfiguration of all networking elements in a multi- tenant and service-oriented unified management environment. Tejas supports programmability and automation capabilities through the TJ5500 hybrid domain controller which combines the programmability with integrated FCAPS for a multi-layer network, multi-technology network. Full FCAPS support is enabled from the UI for provisioning end-to-end DWDM services, end-to-end OTN, MPLS-TP and xPON. It supports a standard NBI interface for programmability of DWDM, OTN, SDN and xPON services. Many use cases consisting of multi-layer service provisioning scenarios can be automated. Tejas hybrid controller is already integrated with many leading OSSes/ Orchestrators in the industry. Tejas also supports VLAN based MEF services and MPLS-TP services through the NBI on the Tejas domain controller.



Layer 3: IP VRFs (L3VPN), Layer 2.5: LSP/PW Labels, Layer 2: VLAN, Layer-1: ODU/ODUFlex/ODUCn, Layer-0: lambda

Figure 15: Multi-domain Virtual Networks

SDN integration with Open Source Controllers

Tejas devices can integrate into ONOS (Open Network Operating System) controller through the Netconf/Yang interface. ONOS™ is a popular open source controller which is architected from ground up for service providers. It addresses key service provider requirements like scalability, high availability and high performance. Besides it is a vendor neutral controller and provides open interfaces both on north bound and south bound. It follows a modular architecture build around micro-services, which enables customizations to the functionality by plugging in 3rd party modules/plug-ins into the ONOS™platform. There is a large open source community working on the ONOS™ project.

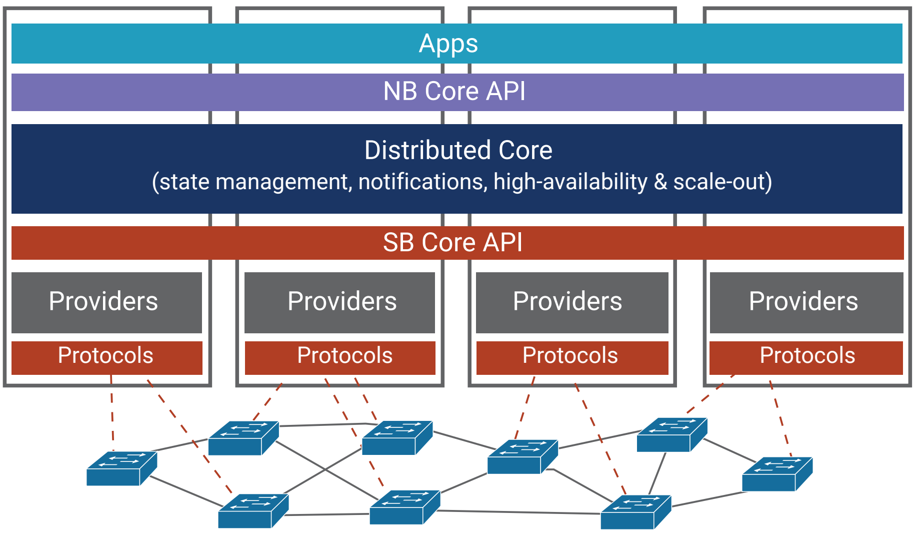


Figure 16: Open Network Operating System

Enabling Automation at the Orchestrator Level

Tejas opens the APIs and network data to 3rd party orchestrators to support the automation of various workflows through a standard-based open interface. Through these interfaces, the orchestrators can get all the relevant data from the network related to network inventory, topology for each individual layer (DWDM, OTN, SDH/SONET, xPON, Ethernet), service discovery, outstanding alarms and poll for performance data. The orchestrators can also register with the Tejas controller to listen to notifications for various network events, which enables real time sync.

Conclusion

5G transport network needs to significantly reduce latency in addition to providing higher capacity in a cost effective manner. Service providers need to build the appropriate transport infrastructure to meet the demands of 5G applications. MPLS-TP implementations when combined with OTN are the best choice to meet the stringent performance demands and compelling economics requirements of a next-generation, packet-optimized optical transport infrastructure. An optical transport network architected with OTN adds more flexibility for transport SDN implementation as well. Tejas X-haul transport solutions provide more flexibility in the architecture to support MPLS-TP for connection oriented Ethernet (COE) services and with IP/MPLS for connection-less service. Tejas offers ability to separate control plane and data plane separately in MPLS-TP as required in future slicing architecture with a centralized connection admission control (CAC) and simultaneously offer data and control plane design based on IP/MPLS.

Tejas' innovative UltraFlex range of 5G-ready products not only cater to greenfield implementations of 5G but also to support the move from legacy systems to 5G. Tejas solution also has the ability to migrate to OTN which enables much larger data plane scalability at low latency which is not possible with only IP/MPLS solutions. Our existing optical networking products for Metro Core and Long-haul segments support high-speed 400G+ interfaces with multi-terabits of packet and OTN switching capabilities. In addition, Tejas products are designed to support advanced optical fronthaul standards such as CPRI/eCPRI on Access and Aggregation products to ensure that they can serve as versatile and universal mobile backhaul platforms from 2G/3G to 4G/5G network rollouts. Tejas modular solution is flexible to have 5G CU, DU as a blade in the same platform. Tejas is continually upgrading its products to support converged broadband access and packet transport products that integrate 5G base station (gNB) and xPON technologies (NG-PON2) along with high-capacity optical backhaul function for highly efficient and cost- effective 5G deployments.

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