5G-ready Mobile Fronthaul

TEJAS® NETWORKS

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 fronthaul performance. Mobile fronthaul effectively moves the radio elements close to the end users, plays a pivotal role in meeting these stringent latency demands. The paper presents an overview of the fronthaul transport technologies and a recommended 5G fronthaul architecture.

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 remote surgeries, autonomous cars, smart grid or factory automation. 5G operates at a higher frequency spectrum which results in increased number of base stations. The traditional RAN architecture houses the Base Band Unit (BBU) and Remote Radio Unit (RRU) in each cell site. The RAN architecture is split into fronthaul, and backhaul. Fronthaul is the link between the controller and the radio head or small cell.

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.

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.

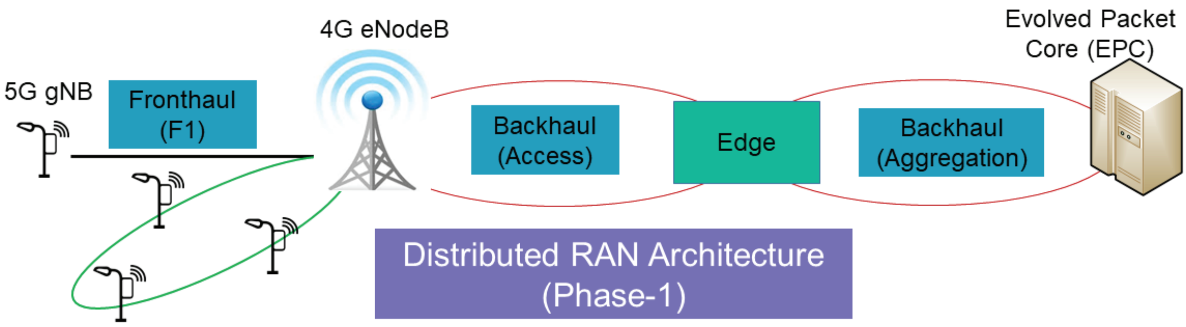


Figure 1 : Distributed RAN Architecture (Phase-1)

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 stadiums, commuter hubs, office, huge apartments 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 and backhaul) to meet the lower latency and synchronization requirements.

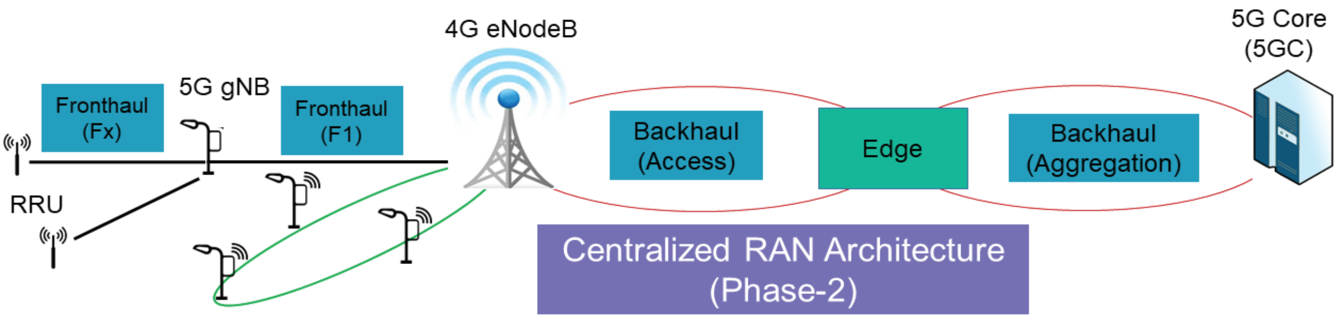


Figure 2 : Centralized RAN Architecture (Phase-2)

Key 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. 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.

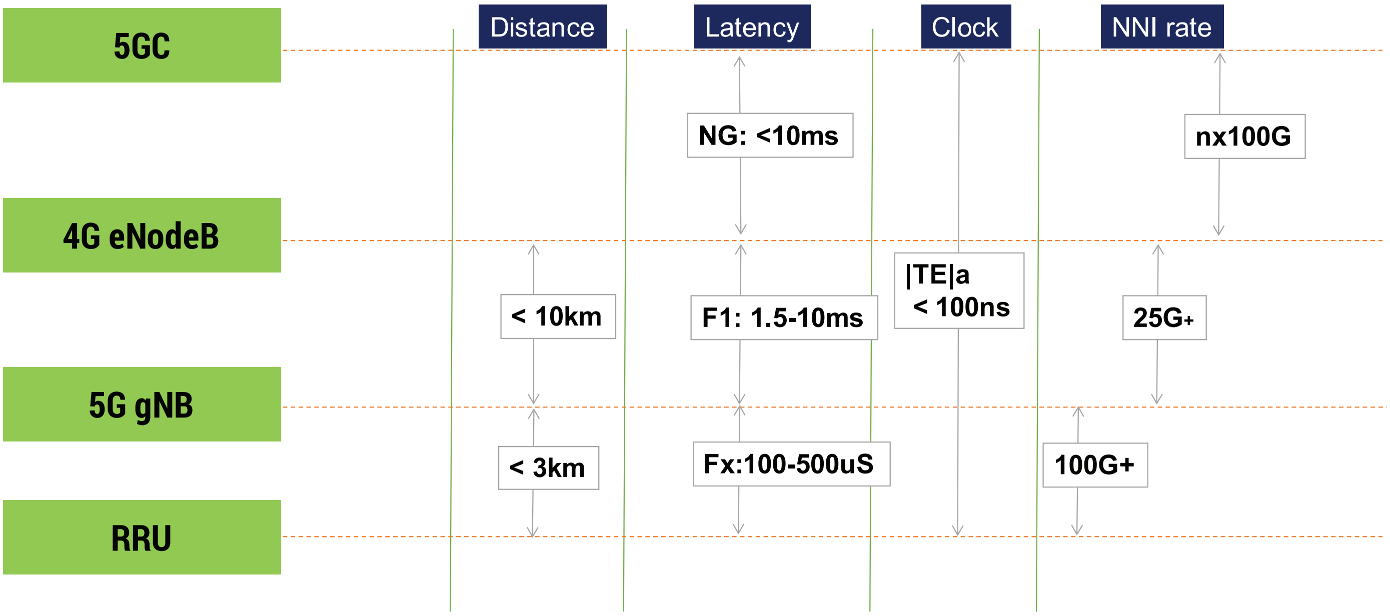


Figure 3 : Latency requirements across the 5G network

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:

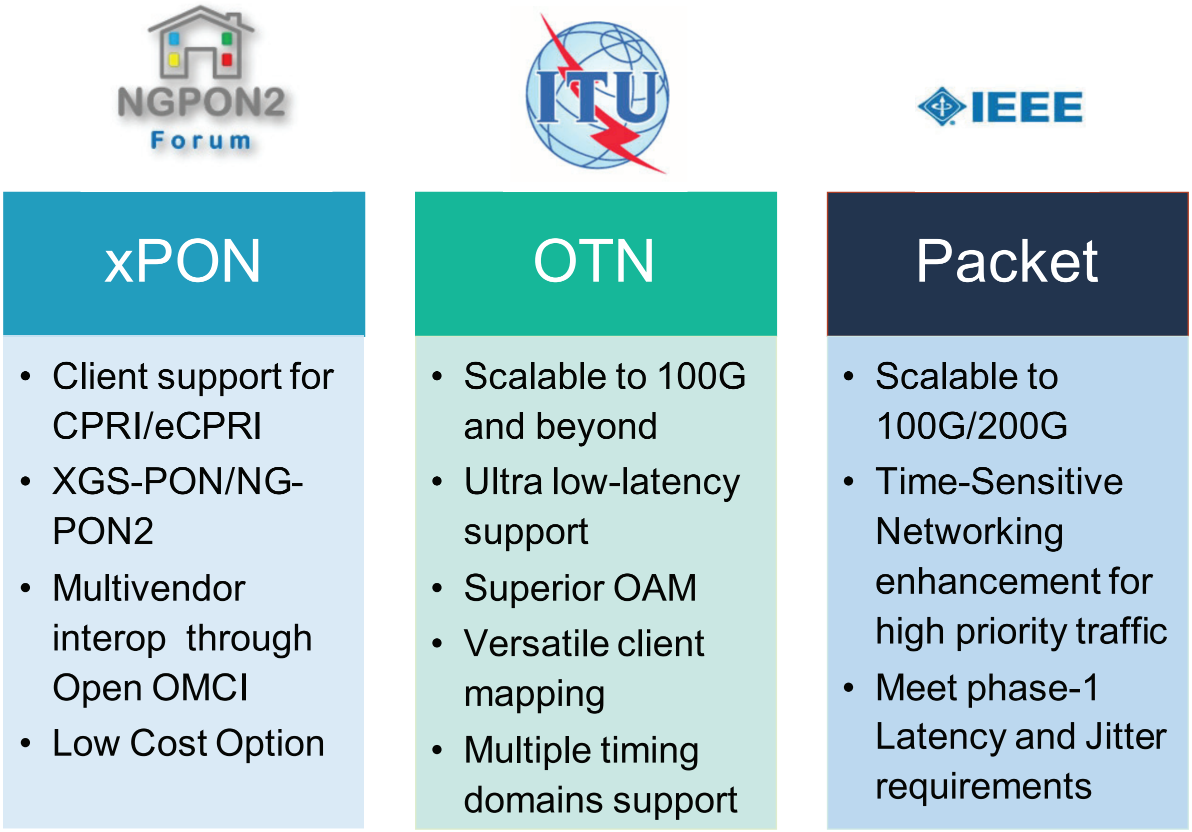
- Either all frame sizes to be less than 2000 bytes (Profile A)
- Pre-emption of low priority frames by high priority ones (Profile B)

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.

Transport Technologies:

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



xPON

- Client support for CPRI/eCPRI
- XGS-PON/NG-PON2
- Multivendor interop through Open OMCI
- Low Cost Option

OTN

- Scalable to 100G and beyond
- Ultra low-latency support
- Superior OAM
- Versatile client mapping
- Multiple timing domains support

Packet

- Scalable to 100G/200G
- Time-Sensitive Networking enhancement for high priority traffic
- Meet phase-1 Latency and Jitter requirements

Figure 4 : Optical transport technologies for fronthaul

XGS-PON/NG-PON2

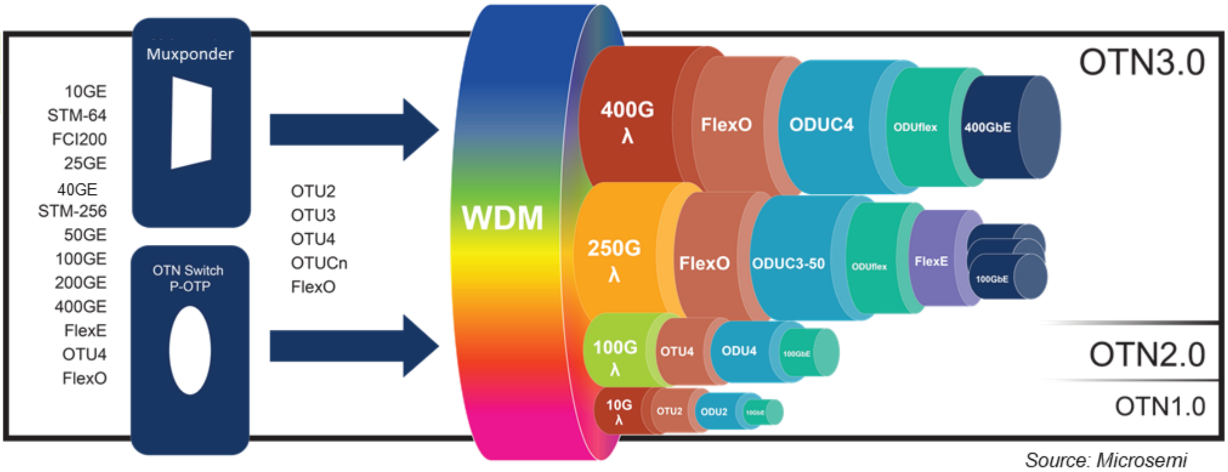
GPON (Gigabit Passive Optical Network) is a widely deployed technology used to manage and share traffic over a fiber from the service hub to homes and enterprises. Thus, reuse of the existing infrastructure is a key motivator for xPON technologies to be used to build mobile fronthaul networks. Though 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.

OTN3.0

OTN (ITU-T G.709) was designed to provide support for optical networking using wavelength-division multiplexing (WDM). OTN is more important than ever before given their high transmission capacities forming the basis of many fronthaul 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.



Source: Microsemi

Figure 5: OTN3.0

TSN for Time-sensitive applications

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 fronthaul Incorporates centralized configuration, path control and reservation capabilities.

TSN-enabled Ethernet Fronthaul network

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.

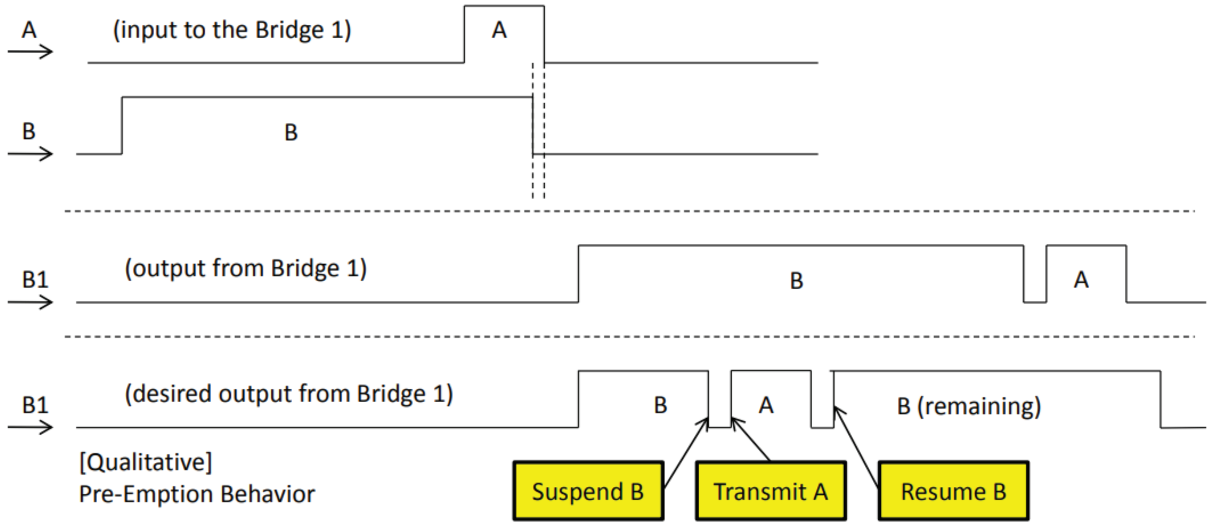


Figure 6 : Illustration of frame preemption

Source: Yong kim, IEEE

Tejas Fronthaul Approach

Tejas Networks develops comprehensive optical transport products that cater to the end-to-end 5G infrastructure market. Our existing optical networking products for Access, 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 eCPRI on Access and Aggregation products that serves as versatile mobile fronhaul and backhaul platforms for 5G network rollouts. Tejas is continually upgrading its products to support converged broadband access and packet transport products that integrate 5G base station (gNB) and ten gigabit xPON technologies (NG-PON) along with low latency Fronthaul and high-capacity optical backhaul functions.

The various 5G use cases present distinct challenges in 5G fronthaul implementation. Bandwidth and latency requirements have continued to drive fiber deployments deeper into the network. Tejas fronthaul 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.

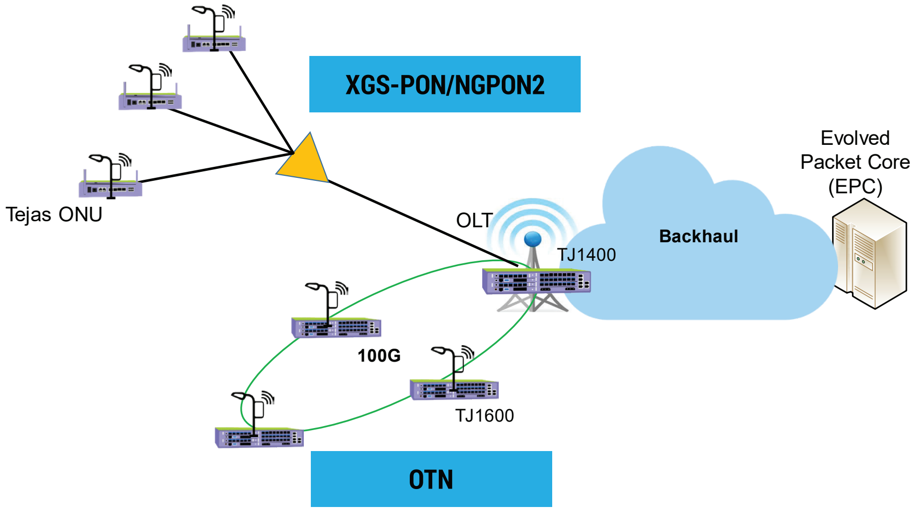


Figure 7 : Mobile Fronthaul Architecture

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. OTN is the right technology of choice for implementing the mobile fronthaul architecture. It scales to very high bit rates, offers low latency and helps build multi-operator networks.

TJ1400 Ultra-Converged Broadband products offers a converged platform for broadband access (xPON, LTE) and packet optical transport (PTN, OTN, CE2.0) services; upgradable to next-generation technologies (NG-PON, 5G) through simple software upgrades. XGS-PON / NG-PON2 utilizes WDM with multiple 10G wavelengths are a good choice for low cost networks.

Conclusion

Mobile fronthaul solutions for 5G networks needs to satisfy the requirements of throughput and delay sensitive services. Building the right transport infrastructure is paramount to meet the demands of advanced 5G applications. The initial 5G deployments are based on the distributed architecture (phase 1) which transitions to centralized architecture only in phase 2. OTN coupled with WDM is the preferred technology to meet the fronthaul requirements of phase 1 and phase 2. XGSPON/NG-PON2 is a viable option for lower cost rollouts. Tejas' Software-defined hardware approach allows for easy upgrade to next-generation technologies (NG-PON, 5G) through simple software upgrades. 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 transport.

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