Mobile transport convergence using deterministic Time-Sensitive Networks

White paper

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Introduction

Within the telecom industry, the coming 5G era is often portrayed as a time when new network deployments will bring new services and better user experiences. This view neglects the considerable investment that operators are still making in 4G LTE networks. In reality, 4G LTE and 5G technologies will evolve and coexist for years to come.

Beyond the fact that operators have already made huge investments in 4G LTE, there are several reasons why 4G and 5G will coexist. First, operators are driven to stay ahead of the competition by deploying new technologies. In the race to deploy 5G early, operators will roll out non-standalone variants of 5G that rely on an LTE packet core. Second, as operators turn to higher spectral bands for increased capacity to support the rollout of some 5G services, they will face less favorable propagation characteristics. This will require them to rely on radios that operate at lower frequencies, where LTE operates today, for extended coverage. Third, it will take some time for 5G coverage to be available nationally and device availability to become commonplace, so operators must continue to support 4G.

In short, existing LTE investments will play an important role in 5G networks for quite some time. This has implications for supporting infrastructure, including the transport networks that will need to handle multi-generational radio access network (RAN) traffic without the use of separate overlay networks.

Evolving transport requirements and the move to cloud RAN

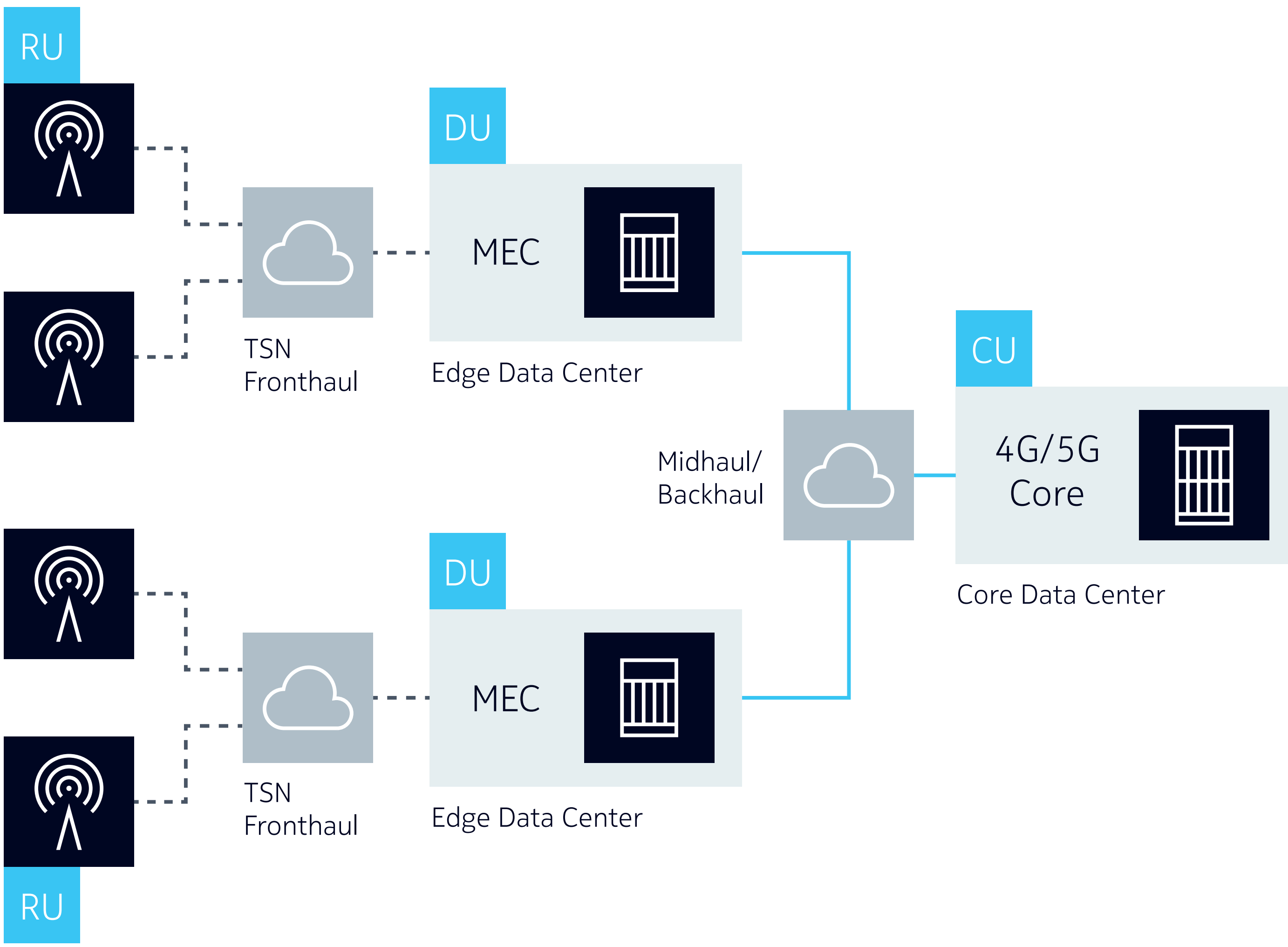
The rollout of 5G brings faster radios and denser deployments that will increase capacity demand by a factor of ten or more, with some client interfaces requiring up to 25 Gbps. 5G will also create the need to reduce end-to-end latency by a factor of 30 or more to support time-critical services that require latency of 1 ms or less. As a result, there is a push to move to centralized cloud RAN (C-RAN) architectures that take advantage of new 5G functional splits, Multi-access Edge Computing (MEC), and packet-based fronthaul protocols. By centralizing high layer baseband processing functionalities while keeping bandwidth intensive low layer baseband functions at the radio, operators can build more cost-efficient networks.

In addition, the introduction of new standardized packet fronthaul protocols such as evolved Common Public Radio Interface (eCPRI) offers a nearly tenfold increase in bandwidth efficiency over the existing CPRI and Open Base Station Architecture Initiative (OBSAI) fronthaul protocols and enables the move towards more open RAN architectures. Fronthaul will play a key role as operators look to deploy MEC to better monetize Ultra-Reliable Low-Latency Communication (URLLC) services enabled by 5G, make more effective use of network resources, simplify operations and better virtualize network assets to improve flexibility and scale.

An efficient solution to address increasing fronthaul bit rates is to establish a new functional split between the distributed unit (DU) and the radio unit (RU). This relaxes bit rate requirements by leveraging the efficient Ethernet-based eCPRI protocol for packet fronthaul. It also helps with the virtualization of DU functionally because the higher-layer radio functions are not under strict real-time constraints and therefore do not need to be implemented in dedicated hardware.

The telecommunications industry has devoted considerable effort to migrating to Ethernet fronthaul so that operators can reap these benefits. The key product of this effort is the new IEEE 802.1CM (Time-Sensitive Networking for Fronthaul) standard, which provides a deterministic, Ethernet-based network that meets the cost, capacity and performance requirements of 5G using new packet Time-Sensitive Networking (TSN) switches (Figure 1).

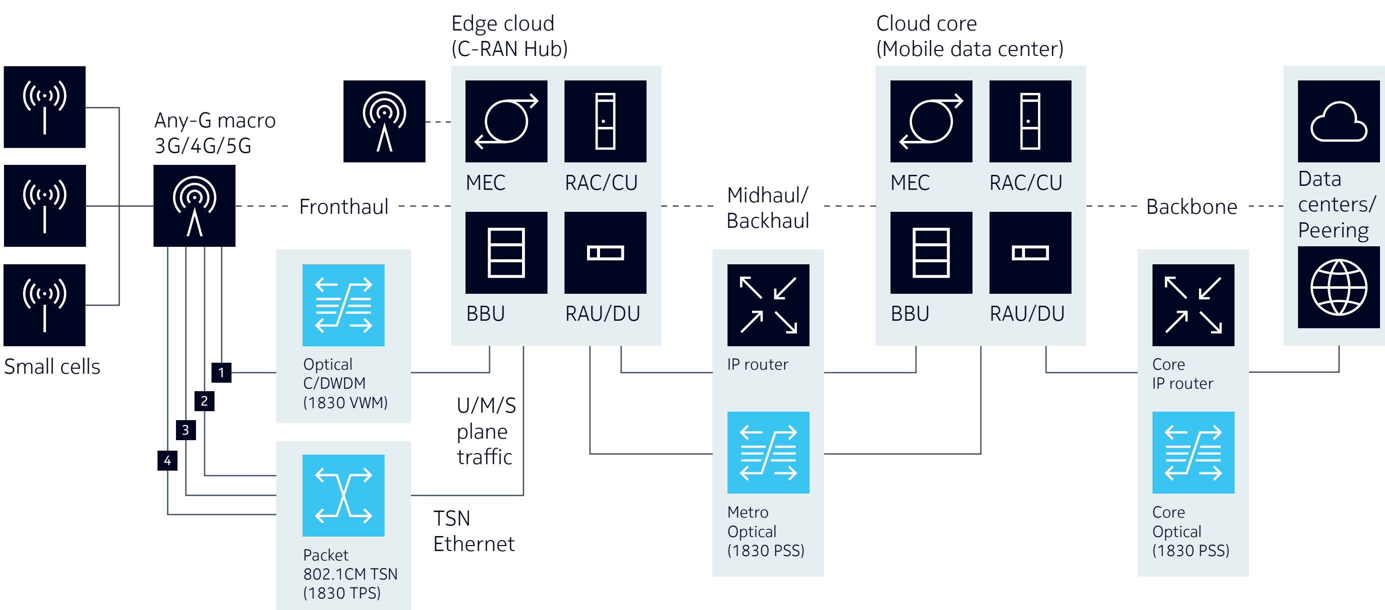
Figure 1. Cloud RAN architecture with IEEE 802.1CM compliant time-sensitive fronthaul



Expansion of Nokia Optical Anyhaul with packet TSN switching

The fronthaul segment of the Nokia Optical Anyhaul solution was traditionally based on transparent passive and active coarse wavelength-division multiplexing (CWDM) and dense wavelength-division multiplexing (DWDM) solutions. Nokia has now expanded the solution with a new 1830 Time-sensitive Packet Switch (TPS) family that complies with the IEEE 802.1CM standard, which addresses packet fronthaul (Figure 2).

Figure 2. Converged "Any-G" access with Nokia Optical Anyhaul



1 CPRI/OBSAI 2 CPRI/OBSAI (via IEEE 1914.3 RoE conversion) 3 eCPRI 4 F1 (HL Ethernet)

The new switch family introduces two 1830 TPS variants. The 1830 TPS-12 supports full outdoor deployments at cell sites, and the 1830 TPS-24 supports centralized hub sites with temperature hardening in a compact one rack unit space. Offering packet switching functionality, these switches provide statistical multiplexing, bandwidth management granularity and per-eCPRI-flow quality of service (QoS) and operations, administration and maintenance (OAM). They also support IEEE 802.1CM profiles that enable bridged Ethernet networks to carry time-sensitive 4G and 5G fronthaul traffic streams using CPRI/OBSAI and eCPRI. These capabilities enable converged transport of all mobile traffic streams.

Mobile fronthaul places new demands on Ethernet transport networks, especially for delay, delay variation, packet loss and reliability parameters. Although Ethernet has been evolving to meet stringent audio and video requirements in industrial control and automotive applications, fronthaul transport requirements are also increasing. To address these challenges, the IEEE 802.1CM working group has defined TSN for fronthaul (including both Class 1 CPRI v7.0 and Class 2 eCPRI), which defines profiles for bridged Ethernet networks that will carry 4G and 5G fronthaul streams. The group has also worked to define standardized synchronization requirements and TSN mechanisms for minimizing delay and controlling delay variation.

The Nokia 1830 TPS family introduces new capabilities to address 4G/5G mobile transport challenges:

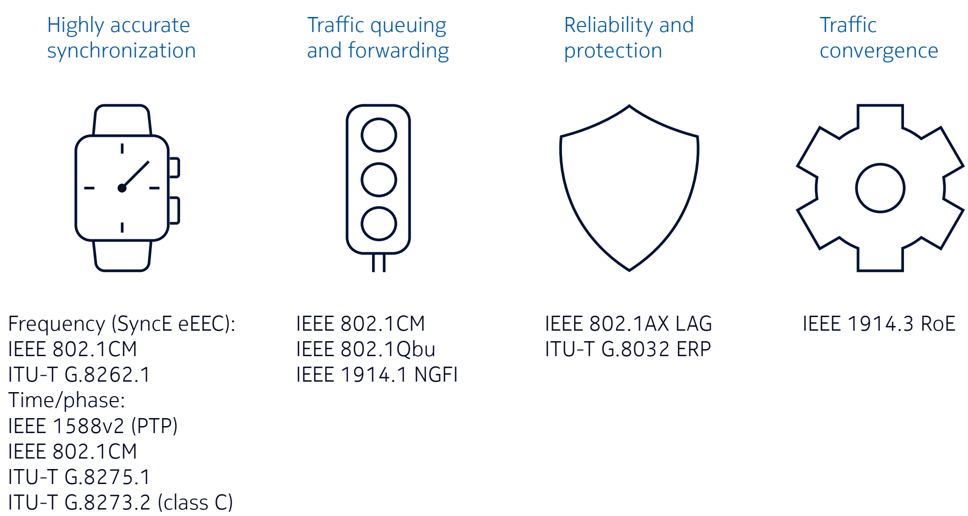
1. Capacity: The TPS family supports radios with higher numbers of antennas (mMIMO) using the new 5G eCPRI protocol and by providing statistical muxing of packet flows. It maximizes bandwidth efficiency by supporting multi-rate client ports of 1G, 10G, 25G and 100G with packet aggregation on 100G line ports.
2. Latency: Fronthaul traffic shares the Ethernet network with other traffic streams, so the TPS family supports IEEE 802.1Qbu frame preemption to minimize latency. This capability enables time-critical frames to request that the transmission of a non-time-critical frame be suspended to allow for the transmission of one or more time-critical frames.
3. Traffic convergence: The 1830 TPS family provides two modes that support IEEE 1914.3 Radio over Ethernet (RoE) encapsulation. Transport agnostic mode maximizes interoperability, while transport-aware mode maximizes bandwidth efficiency by up to 40 percent, in part by leveraging Nokia's RAN expertise. These modes fully leverage the widely deployed CPRI protocol to maximize existing 4G LTE investments while packetizing CPRI traffic to enable efficient aggregation with other packet-based protocols, such as 5G eCPRI. The 1830 TPS also supports other Ethernet streams, such as those from Carrier Ethernet services or cell sites that need Ethernet backhaul or midhaul. These capabilities enable converged access of all traffic without the need for overlays.
4. High-precision frequency and phase/time synchronization: The previous synchronous CPRI protocols carried frequency and phase/time synchronization data. The new eCPRI protocol does not include synchronization, so these capabilities must now be addressed by other means, such as through network-based synchronization distribution. In addition, the disaggregation of the radio components is making synchronization requirements more stringent.

   IEEE 802.1CM defines various categories of relative and absolute synchronization accuracy requirements for specific mobile applications (such as intra- and inter-band Carrier Aggregation, mMIMO and Tx Diversity) that can be implemented by the networking equipment. The Time Alignment Error (TAE) of the most stringent category, Category A+, is the relative time error between streams within the same mMIMO RU. The most relaxed category, Category C, relates to the absolute end-to-end Time Error from GM/PRTC to the RU, across the network.

   The Nokia 1830 TPS family complies with ITU-T G.8262.1 (SyncE eEEC), ITU-T G.8275.1 and ITU-T G.8273.2 Class B and Class C T-BC on a per-node basis. It therefore meets Categories A, B and C of IEEE 802.1CM at the network level.
5. Delay asymmetry: The 1830 TPS family uses new hardware capabilities such as 1 ns timestamping accuracy, compensation for dynamic latency asymmetry caused by RS-FEC on 25GbE interfaces, T-TC for immunity against noise transfer and lower |TE|, and a combined T-TC + T-TSC clock. It also uses bidirectional Precision Time Protocol (PTP) Optical Timing Channel (OTC) to eliminate asymmetrical delays.
6. Reliability and protection: The 1830 TPS family supports single or dual homing path protection, Link Aggregation Group (LAG) protection, and Ethernet Ring Protection (ERP) options to ensure high availability of mission-critical traffic flows.

7. Full OAM: The 1830 TPS family supports Ethernet OAM to provide management capabilities for installing, monitoring and troubleshooting Ethernet networks. It supports the IEEE 802.1ag standard, which defines protocols and practices for OAM for paths through 802.1 bridges and local area networks, ITU-T Y.1731 performance monitoring, and MEF17/30.1/35.1 to meet the requirements of MEF SOAM PM. For optical layer diagnostic and monitoring, the 1830 TPS provides support for digital diagnostic monitoring (DDM).
8. Openness/flexibility: Nokia is a platinum member of the Open Compute Project (OCP), which is driving the move to more open environments. The 1830 TPS family carries the OCP Inspired designation, which means that the switches comply fully with OCP specifications to enable new levels of efficiency, openness, flexibility and scale.
9. Interoperability and standards alignment: The 1830 TPS family is designed based on approved international standards aimed at achieving the goals of multi-vendor interoperability (Figure 3). The switches comply with IEEE 802.1CM-2018, eCPRI, IEEE 1914.3 and IEEE 1914.1. The structure-unaware tunneling mode of IEEE 1914.3 provides complete transparency to any vendor’s CPRI and OBSAI signals without terminating line coding.

Figure 3. 1830 TPS compliance with fronthaul-related standards

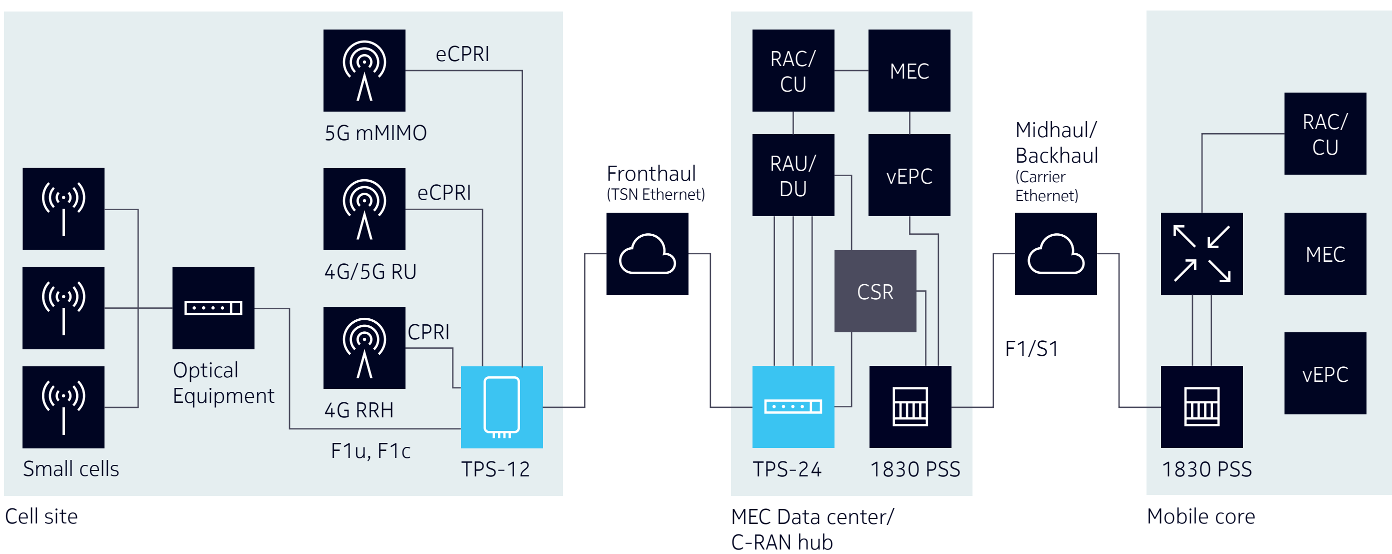


Transport convergence with Nokia Optical Anyhaul

Mobile broadband demand is continuing to drive the need for more capacity. This is fueling investments in LTE and LTE-Advanced (LTE-A) networks as well as 5G. Operators need a scalable, converged transport network that can tap these investments and leverage existing infrastructures to cost-effectively deliver extremely scalable capacity while getting maximum value from fiber resources.

The coexistence of 4G and 5G will mean that operators need converged mobile transport solutions that can cost-effectively support a mix of RAN architectures. These solutions must be able to support all fronthaul protocols and interfaces (CPRI, OBSAI, eCPRI, NGFI, S1, F1) used for 4G and 5G (Figure 4).

Figure 4. Converged transport of all fronthaul traffic using TSN Packet Optical Switches



The Nokia 1830 TPS family provides transformative business benefits by enabling operators build new converged transport access networks that:

- Converge all traffic types, eliminating the need for costly overlay networks
- Enable flexible and cost-effective access for extreme mobile broadband (eMBB), Internet of Things (IoT) and URLLC services
- Provide deterministic transport of fronthaul streams over Ethernet network
- Provide connectivity between 3G, 4G and 5G cell sites and C-RAN hubs
- Enable fast plug-and-play service activation using the Nokia WaveSuite Commissioning Expert solution

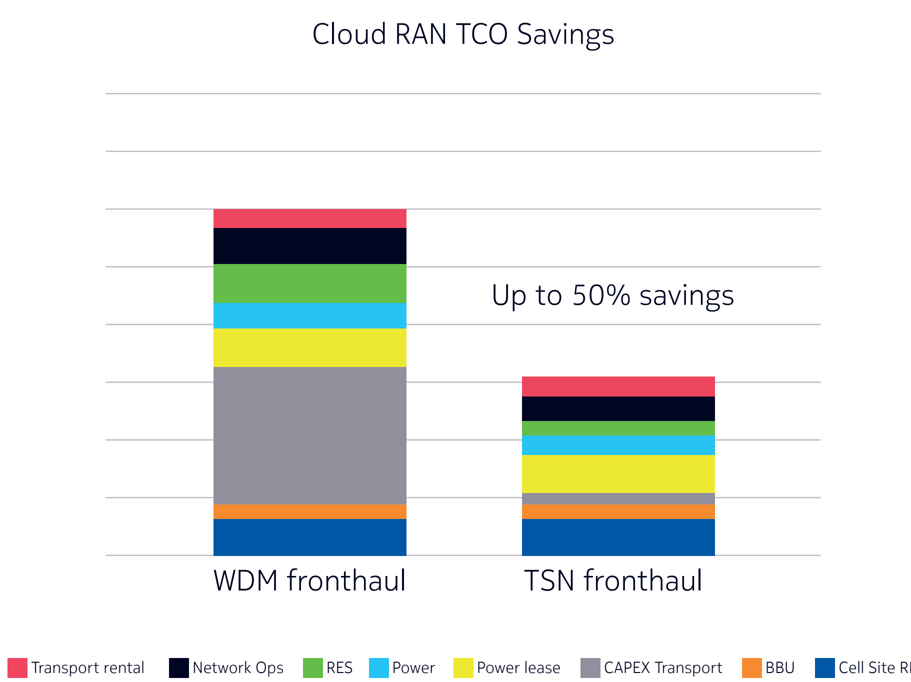
The 1830 TPS delivers these benefits by enabling operators to take advantage of several unique technology advancements

- RAN-agnostic multiservice support (including CPRI, RoE, eCPRI and Ethernet) in one platform
- Best-in-class nanosecond synchronization (frequency and phase/time)
- Carrier-grade OAM and high resiliency/availability in a compact form factor
- Ultra-low-latency TSN switching and frame preemption (IEEE 802.1Qbu)
- Highest level of traffic aggregation (statistical muxing and WDM)

Business case: TCO savings

Nokia conducted a five-year total cost of ownership (TCO) analysis of the various techniques used to transport a mix of LTE and 5G traffic from the cell site to the central hub to understand the benefits of aggregation in the mobile transport network using different 5G functional splits within distributed, centralized and hybrid RAN architectures. The study examined several transport technologies, including cell site routers, active WDM multiplexers and packet TSN switches. As shown in Figure 5, it concluded that using packet TSN technologies in combination with cloud C-RAN architectures offers the greatest capital and operational savings from packet aggregation efficiencies, centralization gains and site simplification savings. These savings lower TCO by up to 50 percent compared to active WDM fronthaul solutions, largely because of a significant reduction in the number of required WDM interfaces and more efficient packet aggregation onto 100G interfaces.

Figure 5. Using packet TSN fronthaul to implement cloud RAN reduces TCO by up to 50 percent



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Conclusion

Nokia has built on its significant contributions to the advancement and approval of the IEEE 802.1CM-2018 standard to deliver a new packet optical TSN fronthaul solution: the 1830 Time-Sensitive Packet Switch.

The 1830 TPS family expands the Nokia Optical Anyhaul portfolio and improves operators' ability to deploy a variety of distributed, centralized and cloud RAN architectures. It supports very high bit rates, high-precision synchronization minimum latency and maximum reach while retaining the bandwidth scalability of WDM multiplexing. These capabilities enable operators to use one converged transport access network to optimize performance and deploy services faster.

With the 1830 TPS family, operators can lower TCO by moving to C-RAN architectures with cost-effective packet TSN transport that delivers centralization gains in the form of space, power and operational cost savings. They can also create bandwidth aggregation efficiencies and improve resource utilization while creating a path to 5G that leverages existing 4G LTE RAN investments.

Abbreviations

C-RAN	cloud RAN or centralized RAN
CPRI	Common Public Radio Interface
CWDM	coarse wavelength division multiplexing
DDM	digital-diagnostic-monitoring
DU	distributed unit
DWDM	dense wavelength-division multiplexing
eCPRI	evolved Common Public Radio Interface
eEEC	enhanced equipment slave clock
eMBB	extreme mobile broadband
ERP	Ethernet Ring Protection
GM/PTRC	grandmaster/primary reference time clock
IoT	Internet of Things
LAG	Link Aggregation Group
LTE	Long Term Evolution
LTE-A	LTE-Advanced
MEC	Multi-access Edge Computing
MIMO	multiple-input and multiple-output
mMIMO	massive MIMO
NGFI	Next Generation Fronthaul Interface
OAM	operations, administration and maintenance
OBSAI	Open Base Station Architecture Initiative
OCP	Open Compute Project
OTC	Optical Timing Channel
PTP	Precision Time Protocol
QoS	quality of service
RAN	radio access network
RoE	Radio over Ethernet
RS-FEC	Reed Solomon Forward Error Correction
RU	radio unit
T-TC	telecom transparent clock
T-TSC	telecom time slave clock
TAE	time alignment error
TCO	total cost of ownership
|TE|	time error
TPS	Time-sensitive Packet Switch
TSN	Time-Sensitive Networking
URLLC	Ultra-Reliable Low-Latency Communication
WDM	wavelength-division multiplexing

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Nokia Oyj
Karaportti 3
FI-02610 Espoo, Finland
Tel. +358 (0) 10 44 88 000

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