



Fronthaul as a service

The opportunities of 5G centralized cloud RAN

White paper

By migrating to 5G, mobile network operators (MNOs) will reap the benefits of higher bandwidths, lower latencies and the ability to offer a myriad of new services. With 5G's centralized cloud RAN (C-RAN) architectures, they will also be able to drive down costs with open solutions and network virtualization. As they move forward with their C-RAN deployments, new opportunities will be created for a host of competitive fiber providers, datacenter and colocation providers, and tower and other utilities providers that offer transport services.

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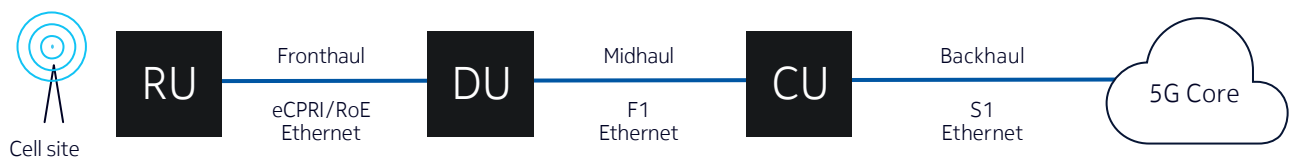
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Introduction

With the coming of 5G, mobile network operators (MNOs) will not only reap the benefits of higher bandwidths, lower latencies and the ability to offer a myriad of new services, they will also leverage centralized C-RAN architectures to take advantage of open solutions and network virtualization to drive down costs. Their C-RAN deployments will also create opportunities for a host of competitive fiber providers like Zayo or CenturyLink, datacenter and colocation providers like Equinix or Rackspace, tower providers like Zayo Group or Crown Castle, and utilities providers like Cellnex, CityFiber and TDF that offer transport services.

The 5G C-RAN architecture enables the disaggregation of the RAN so that operators can place functional elements where they provide optimal performance. Baseband functionality is split into two functional units: a centralized unit (CU) and a distributed unit (DU). Where these units reside depends on the specific architecture and geographical locations available. It can include putting them in sites other than the cell site where the radio unit (RU) is located. In a centralized 5G C-RAN the DU is hosted in an edge cloud datacenter or central office, and the CU can be collocated with the DU or hosted in a regional cloud data center. The connection between the RU and DU is referred to as “fronthaul” while the connection between the DU and CU is often referred to as “midhaul” (see figure 1).

Figure 1. 5G functional splits



5G radio access networks place unique requirements (high capacity, ultra-low latency, high precision synchronization, high resiliency, etc.) on fronthaul connections. Thus, transport providers that own fiber networks are in a prime spot to compete for an MNO’s fronthaul business. In dense urban areas, MNOs will need to build out small cells to add capacity and to improve coverage. Tower companies like Crown Castle have been increasing their fiber footprint to address this surge as C-RAN topologies expand.

While today, transport providers can offer dark fiber as well as lit fiber or wavelength services, the move to 5G brings new Ethernet-based radio protocols like eCPRI (with O-RAN compliance) and technologies like radio over Ethernet (RoE) that encapsulate the legacy CPRI traffic streams coming from 3G/4G radios over Ethernet. The newly standardized IEEE 802.1CM Time-Sensitive Networking (TSN) for fronthaul will enable transport providers to offer much more granular packet fronthaul services using deterministic Ethernet bridged networks to meet the latency, frame delay variation (FDV) and synchronization requirements imposed by 5G. The delivery of these Fronthaul-as-a-Service (FHaaS) offers relieves MNOs from building dedicated transport networks; they can instead benefit from lower service costs through the economies of scale from a shared transport network. However, this is only possible if the transport networks can provide a new breed of services that meet the very stringent requirements of eCPRI and CPRI transport.

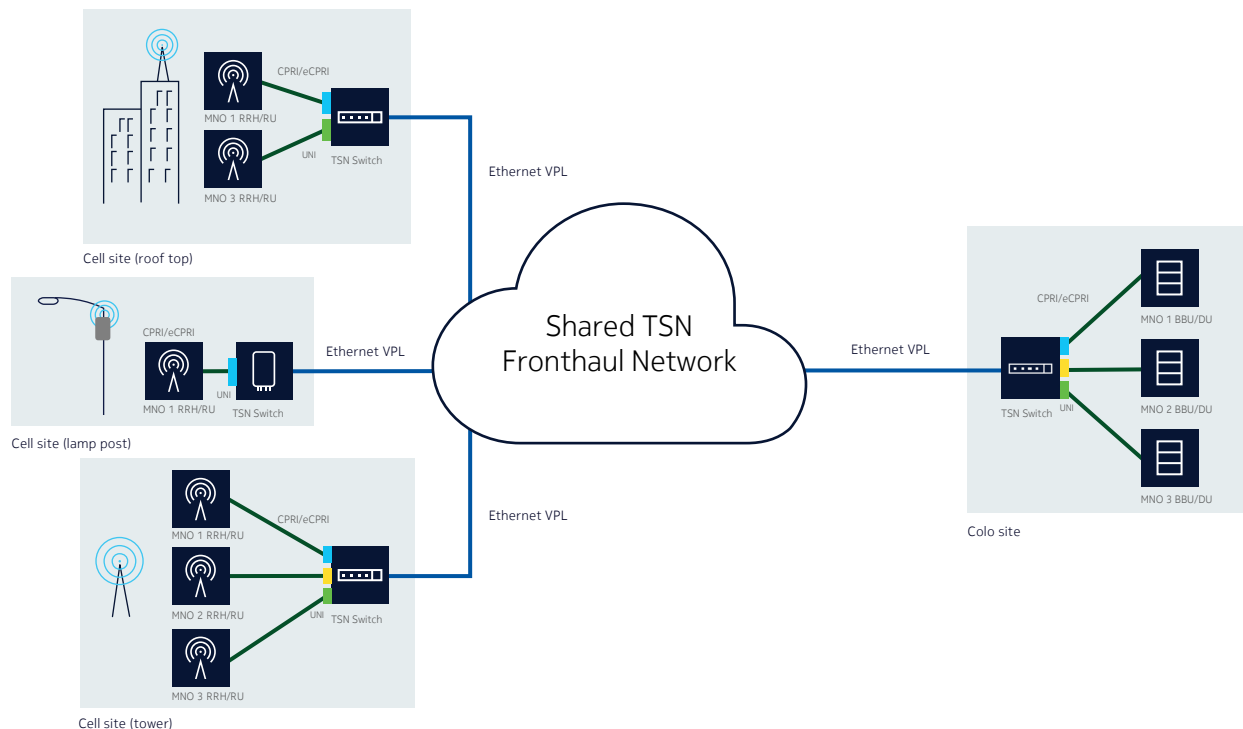
Traffic segregation among operators

In a shared transport network environment, it is critical to prevent MNOs from impacting each other's traffic streams while optimizing shared network resources. The MEF Forum (MEF) has defined constructs for the creation of Ethernet VPNs, which enables traffic separation for streams that are mapped using VLAN IDs within a shared TSN fronthaul network. To illustrate this, figure 2 shows a shared fronthaul network, owned by a transport provider such as Zayo, providing connectivity to several MNOs, such as AT&T Mobile and T-Mobile.

The network demarcation points in figure 2 are denoted by the user network interface (UNI) points, which define the shared fronthaul network as consisting of the fronthaul network elements (TSN switches) and fronthaul network cloud. This fronthaul network interconnects the 4G remote radio heads (RRHs) and 5G RUs at each cell site with their corresponding 4G baseband units (BBUs) and 5G DUs at the hub/colocation site.

The connectivity for a given MNO can be viewed as a data plane transport slice of the shared fronthaul network. Traffic from 4G and 5G radios having CPRI interfaces is mapped onto Ethernet by the TSN switches (e.g., the Nokia 1830 Time-sensitive Packet Switch) using standardized IEEE 1914.3 RoE framing (5G radios using O-RAN-compliant eCPRI interfaces are Ethernet-based already). The management of each transport slice is carried out by the fronthaul provider on behalf of each MNO. To ensure the appropriate provisioning of resources, close coordination is required between each MNO and the fronthaul provider. This can be accomplished by providing each MNO with APIs allowing for a range of management and control capabilities of their transport slices.

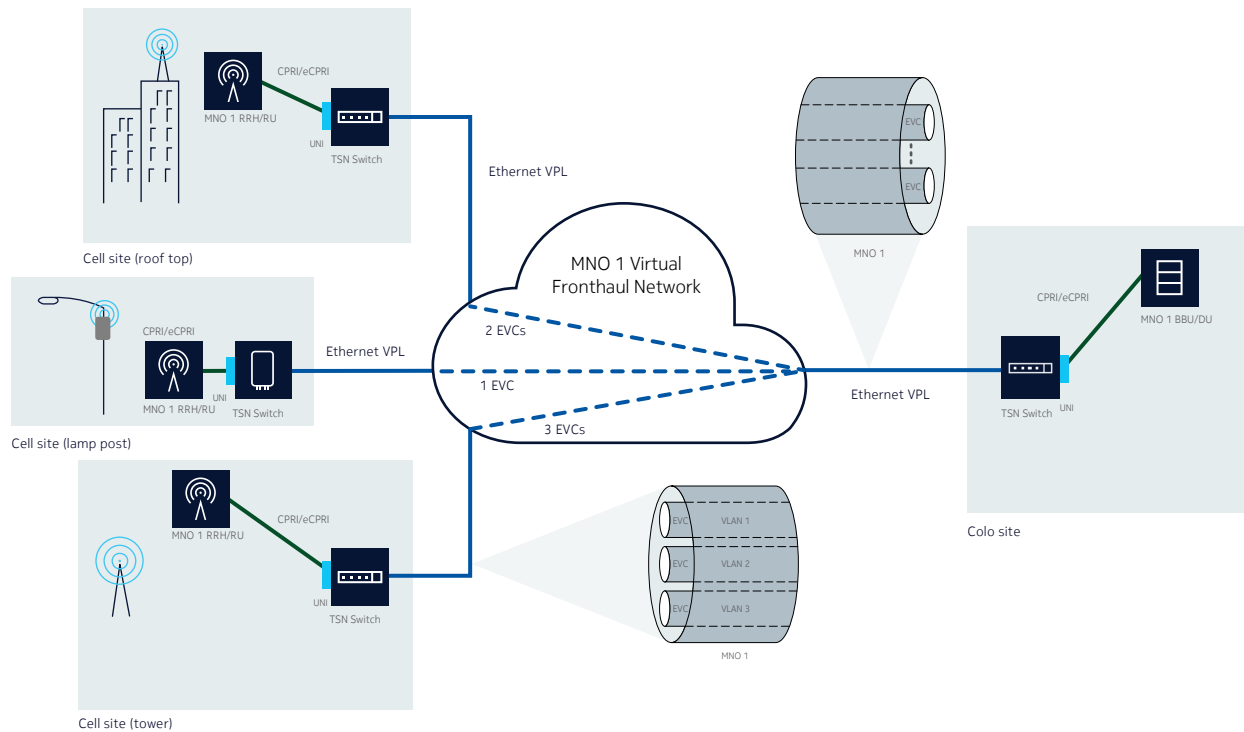
Figure 2. Transport slicing in a shared fronthaul network



Within the shared TSN fronthaul network, each MNO effectively has their own virtual fronthaul network. Figure 3 presents the view of the virtual fronthaul network focusing solely on MNO 1. The transport slice for this operator consists of a MEF-defined Ethernet virtual private line (EVPL) service where the fronthaul TSN switches, which are part of the shared TSN fronthaul network, interconnect the RRH/RU ports (e.g. 25GbE ports) with the corresponding ports on the BBU/DU for this mobile operator. A specific Ethernet virtual connection (EVC) within the fronthaul network is configured for all service frames for MNO 1. In this example, there are six 25GbE ports connected to a single, service multiplexed port. In order to not exceed the multiplexed port rate, there is an appropriate allocation of bandwidth across the EVCs.

If allowed by the service level agreement (SLA), the mobile operator may shift bandwidth depending on the time of day. MNO 1 configures the EVCs from the office tower to the DU to a full 25Gb/s per RU during office hours and to an amount much less than that for the EVCs from the RUs in the suburbs. For the evening hours, it schedules the reverse bandwidth relationship. The MEF 47 Carrier Ethernet for Cloud Implementation Agreement allows for real-time modification of selected subsets of UNI or EVC per UNI service attributes. The QoS attributes supported by this re-programming are part of the MEF elastic service attributes.

Figure 3. MNO 1 transport slice with MEF EVCs

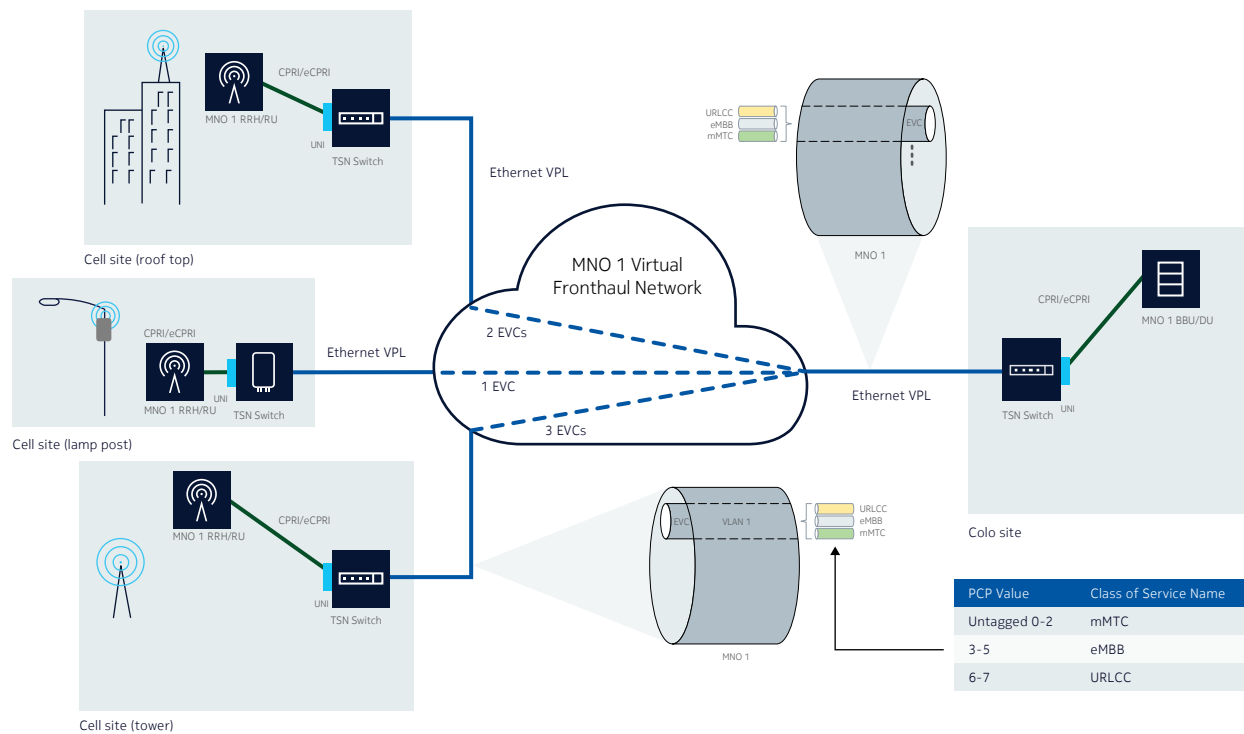


In a 3GPP or NGMN context, there is much discussion about support for 5G services, which are often classified as:

- 1) Massive machine-type communications (mMTC) for applications such as industrial or residential IoT
- 2) Enhanced mobile broadband (eMBB) for higher bit rate services such as streaming video
- 3) Ultra-reliable low-latency communications (URLLC) for time-critical applications such as remote medical procedures.

Due to the variation in performance requirements, separate connections are envisaged for each service class as depicted in figure 4, which expands on the details for one of the EVCs. With a packet-based fronthaul network (eCPRI), if service frames have their priority code point (PCP) value set, they can be mapped at ingress to a given class of service (CoS) name, as shown by the table in figure 4.

Figure 4. 5G services mapped based on priority within EVCs



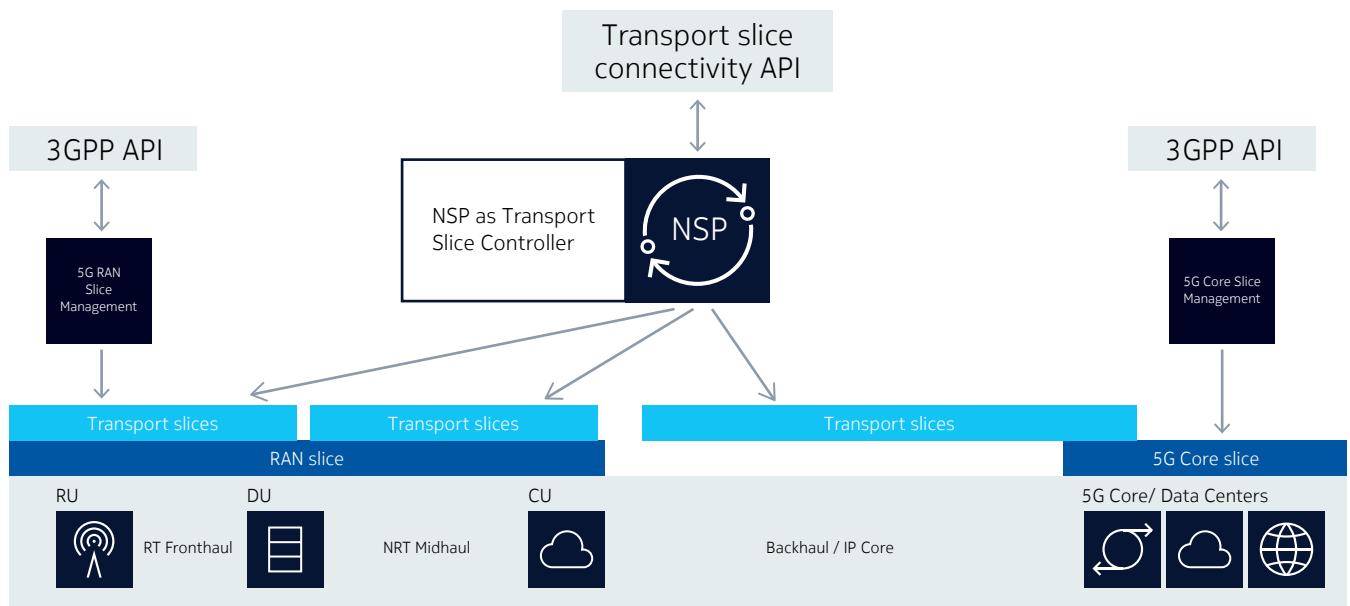
The need for increased service automation and control

Splitting the shared fronthaul network by Ethernet VPN/VLAN and by CoS for each MNO is only part of what needs to be done. Transport slicing also requires tight control of the resources within many nodes, and of the links participating in the transport slices, to prevent MNOs from impacting each other's resources. The operator of the shared transport network must also be able to:

- Segregate user interfaces so that they are only manageable/visible to the MNO in charge of that user
- Constrain shared resources by MNO (e.g., MAC addresses, bandwidth on shared interfaces and/or devices)
- Provide network monitoring statistics to MNOs for different resources (e.g., port, EVC, CoS) to ensure SLAs are being met, both on-demand and proactively
- Control resources (e.g., latency, queues) to ensure QoS levels are met.

Providing these capabilities with the huge number of transport slices that will ultimately be needed means evolving from manual provisioning systems and CLI commands to more automated configuration of transport slices. This can be accomplished by providing service APIs to an end-to-end network orchestrator interoperating with SDN-enabled slice controllers spanning the RAN, transport and core networks to uphold end-to-end SLA requirements (as shown in figure 5). Once a slice creation request is received the transport slice controller, which is a function within the Nokia Network Services Platform (NSP), identifies the fronthaul network elements and VLAN IDs used to define and create the service UNIs. The transport slice controller, thus, creates dynamic transport slices with specific capabilities to address service requirements while optimizing network resources.

Figure 5. Transport slice automation



Nokia Optical Anyhaul solution

The Nokia Optical Anyhaul solution includes the 1830 Time-sensitive Packet Switch (TPS) and 1830 Photonic Service Switch (PSS) portfolios, which allow network operators to take advantage of new packet fronthaul, midhaul and backhaul business opportunities represented by the huge growth in demand coming with 5G (figure 6). These portfolios can extend the network to customer premises sites providing a chargeable, managed service for applications including packet fronthaul, midhaul and backhaul, enterprise connectivity, and collocation connectivity, all helping to monetize the network and fiber assets.

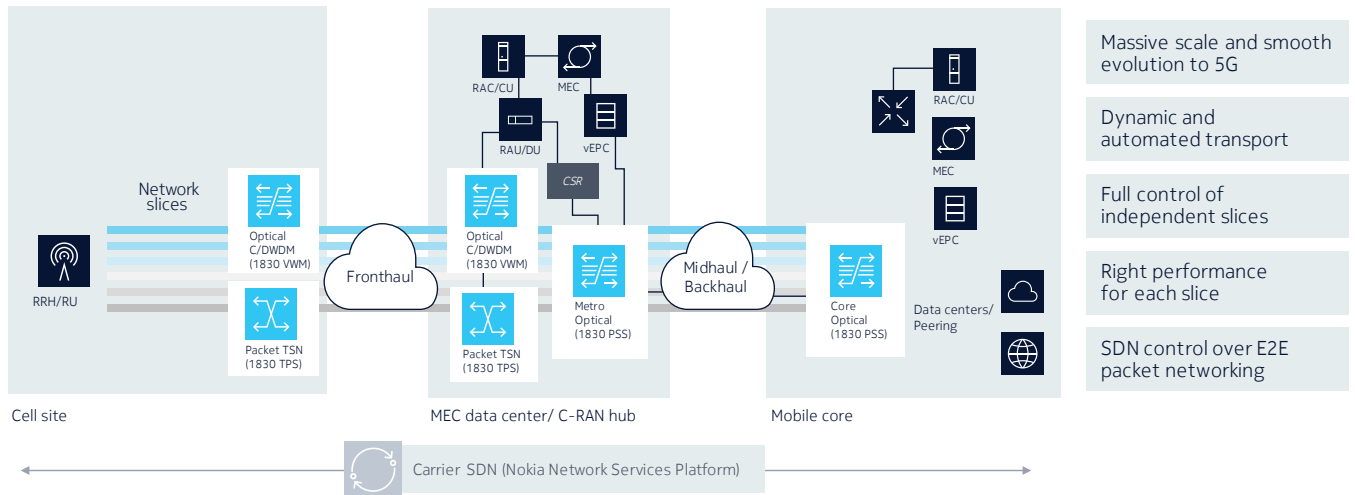
The mobile transport network elements and customer equipment are supported by the Nokia NSP enabling SDN networking and Nokia WaveSuite Service Enablement applications to provide rapid equipment and service deployment and fully instrumented service assurance. This lets network operators monitor the performance of their fronthaul services, define different service tiers, monitor adherence to SLAs, and identify any trouble spots. The solution uses intelligent network partitioning/slicing to create virtual networks. Each virtual network is a secure and independent network partition owned by the virtual network provider. Service providers can rapidly assess service performance against SLA objectives using flexible per-service views and reports detailing attributes including service availability, service latency/delay and service utilization.

The Optical Anyhaul solution provides service assurance leveraging an Ethernet Service OAM (SOAM) framework compliant with MEF 30.1 (SOAM Fault Management) and MEF 35.1 (SOAM Performance Monitoring) that themselves leverage IEEE 802.1ag CFM and ITU-T Y.1731. The Ethernet SOAM infrastructure with MEs, MEGs and MEG levels is ideally suited to allow monitoring of the different EVCs at different administrative levels, even though they are sharing the same Ethernet bridging domain.

The fronthaul transport provider can grant the different MNOs a mix of different MEG and administrative levels each having certain SOAM capabilities. The MNOs can in turn grant different levels to their subscribers. These MEGs are used between subscriber sites and among the different service providers that may be interconnected when delivering an end-to-end EVC or EVC+CoS combination to a subscriber.

By employing standardized SOAM capabilities, the Nokia Optical Anyhaul solution allows service providers to offer mass-market Ethernet services. The solution provides specific hardware capabilities to allow scaling Ethernet OAM functions across EVCs and EVC+CoS combinations, while preserving the partitioning and security functions. Nokia paid particular attention to ensuring that the accuracy of the frame loss and frame delay measurements is not degraded in such shared environments.

Figure 6. Transport slicing within Nokia's proven Optical Anyhaul solution



Business benefits

The move to 5G centralized C-RAN architectures creates new opportunities for transport providers, colocation providers and tower providers. Versus solely offering traditional dark or lit fiber services, providers can offer new packet fronthaul transport services using the Nokia 1830 Time-sensitive Packet Switch. They will benefit from the following advantages:

- **Flexible bandwidth** — since packet fronthaul services offer superior bandwidth scalability to MNOs of all sizes, they can quickly switch between 1, 10, 25, and 100 Gbps as needed. The bandwidth can also be scaled remotely using software without having the transport provider visit the site.
- **Lower investment cost** — as MNOs are not required to make upfront investments, they are able to pay as they go. They benefit from no fiber deployment requirements and eased site infrastructure requirements. MNOs also benefit from faster time to market.
- **Service granularity** — packet fronthaul services have more granularity and can be competitively priced at lower rates than dedicated fiber or wavelength services, thereby increasing the overall value.
- **Service diversity** — different classes of service are supported ensuring diverse 5G services can be delivered while retaining efficient network resource utilization.
- **Simpler to implement and manage** — a quick, economical turnkey solution that helps mobile operators to add coverage and capacity. It leverages the ubiquity of Carrier Ethernet and comes equipped with innovative tools that give MNOs control and visibility over their share of the network. It also makes troubleshooting and network monitoring a lot easier.

Conclusion

The move to centralized C-RANs enabled by the new 5G functional splits, along with growing demand for new mobile services, will give rise to new opportunities for transport providers that can rapidly and efficiently carve out network resources. They can take advantage of new packet TSN technology to transport fronthaul traffic over packet using deterministic Ethernet bridged networking. They can benefit from economies of scale, to offer fronthaul services at lower cost points than MNOs that build their own dedicated transport networks. Furthermore, using intelligent and dynamic transport slicing, each MNO's virtual network performance can be monitored to ensure all SLA performance metrics are met.

Abbreviations

API	Application programmable interface
BBU	Baseband unit
CLI	Command line interface
CoS	Class of service
CPRI	Common public radio interface
C-RAN	Cloud RAN
CU	Centralized unit
DU	Distributed unit
eMBB	Enhanced mobile broadband
EVC	Ethernet virtual connection
EVPL	Ethernet virtual private line
FDV	Frame delay variation
FHaaS	Fronthaul as a service
GbE	Gigabit Ethernet
GNSS	Global navigation satellite system
ME	Maintenance entity
MEC	Multi-access edge computing
MEF	Metro Ethernet Forum
MEG	Maintenance entity group
mMTC	Massive machine-type communications
MNO	Mobile network operator
NSP	Network services platform
PCP	Priority code point
QoS	Quality of service



RAN	Radio access network
RoE	Radio over Ethernet
RU	Radio unit
SDN	Software-defined networking
SLA	Service level agreement
TSN	Time-sensitive networking
UE	User equipment
UNI	User-network interface
URLLC	Ultra-reliable low latency communications
VLAN	Virtual local area network

About Nokia

We create the technology to connect the world. Only Nokia offers a comprehensive portfolio of network equipment, software, services and licensing opportunities across the globe. With our commitment to innovation, driven by the award-winning Nokia Bell Labs, we are a leader in the development and deployment of 5G networks.

Our communications service provider customers support more than 6.4 billion subscriptions with our radio networks, and our enterprise customers have deployed over 1,300 industrial networks worldwide. Adhering to the highest ethical standards, we transform how people live, work and communicate. For our latest updates, please visit us online www.nokia.com and follow us on Twitter @nokia.

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Nokia OYJ
Karakaari 7
02610 Espoo
Finland
Tel. +358 (0) 10 44 88 000

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