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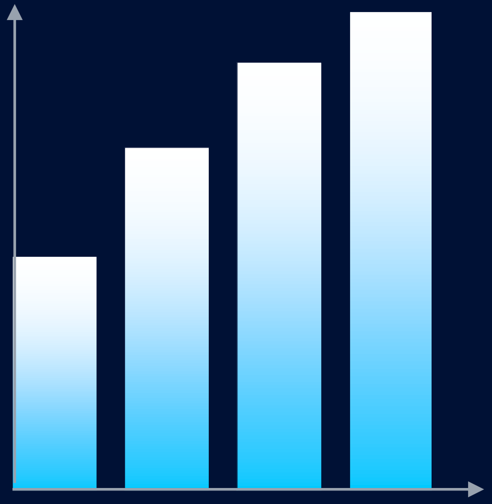
# IX FÓRUM 16

Incentivando o diálogo sobre os Pontos de Troca de Tráfego Internet

# Market update



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# 5G subscription growth continues

## 5G driving increasing share of revenue

**218**
operators have launched 5G networks across 87 countries

**49%**
Nokia has delivered 5G in half of countries launching 5G

**180**
5G commercial deployments worldwide

**40%**
Nokia supplies over 74 live 5G networks

Source: GSA, July 2022

### 5G subscribers

**>500m** 2021

**1.2B** End of 2022 (forecast)

Source: Omdia, July 2022

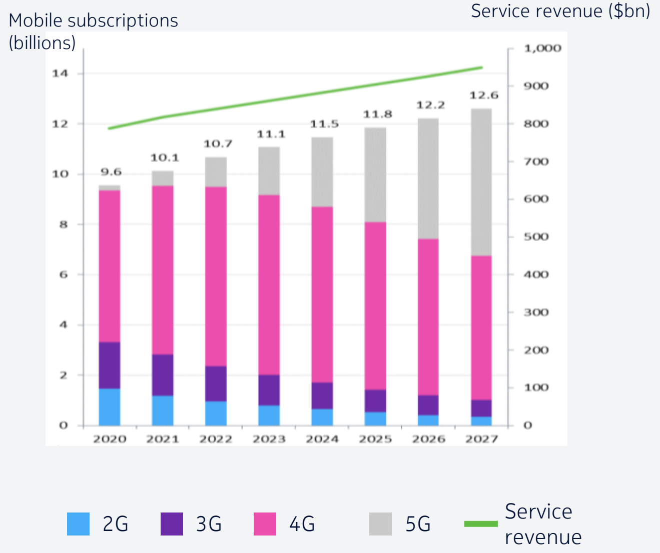
### 5G global population coverage

**20%** 2021

**60%** End of 2026 (forecast)

Source: GSMA, Mobile Economy 2021

### Global mobile subscriptions and revenue 2020 - 2027




Source: Mobile Subscriptions and Revenue Forecast Report 2022 – 27 by Omdia

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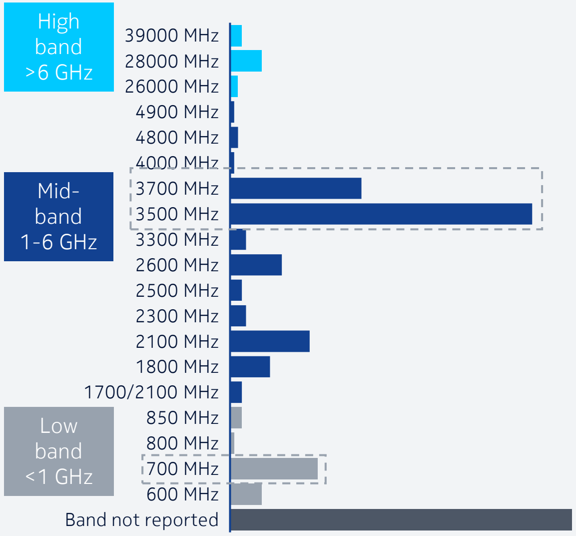
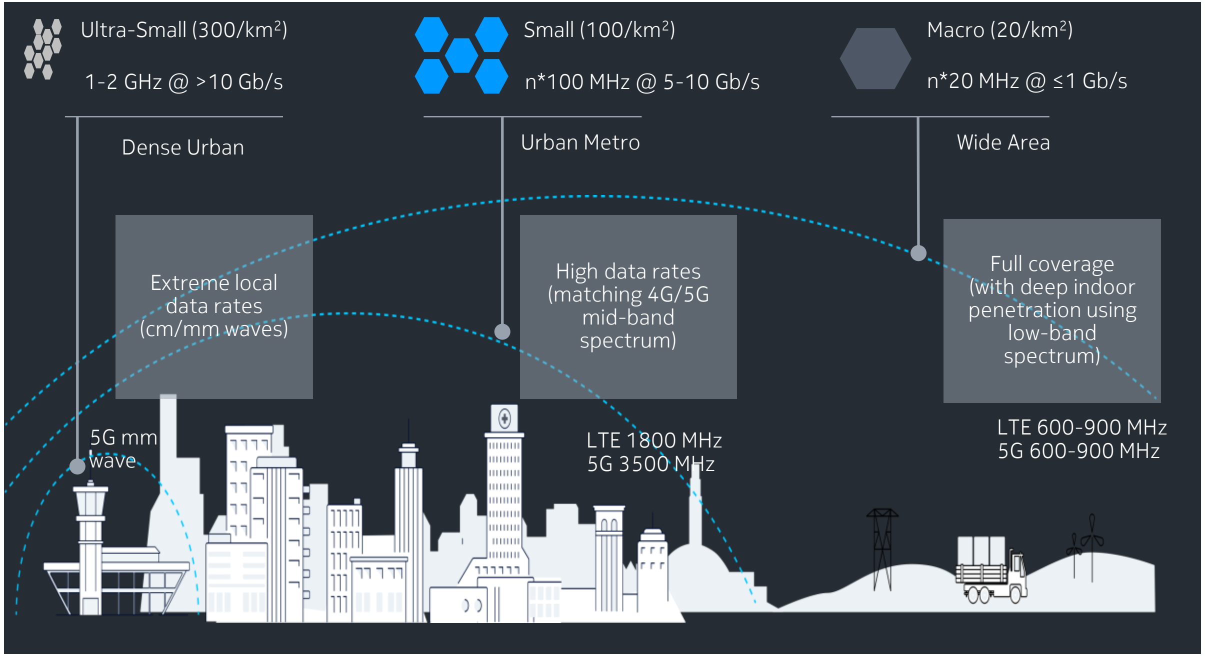
# 5G rollouts aligned with existing RAN and transport resources

## Focus on low to mid-band spectrum

### 5G launches by frequency Q3 / 2021




Source: GSMA Spectrum navigator, Nov 2021







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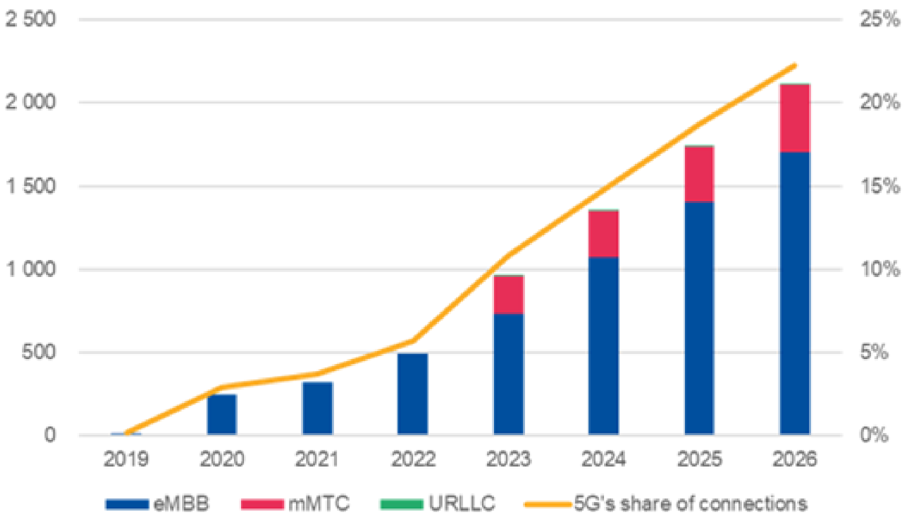
# Strong growth in 5G capacity demand

## Delivering positive indications on 5G monetization

### Worldwide 5G connections by type
### Led by eMBB and driving need for more transport capacity




Source: IDATE DigiWorld, February 2021

### 5G driving higher usage vs LTE

24 million 5G subscribers
**32,7%**
of total mobile base

5G data / month
**3x**
LTE usage (8.6->26.4 GB)

**70%** of total mobile data traffic on 5G

Higher 5G usage vs. LTE

| VR | Video | Gaming |
|---|---|---|
| 7x | 3.6x | 2.7x |

All operators report regular increases in wireless revenue

Source: South Korea Ministry of Science & ICT

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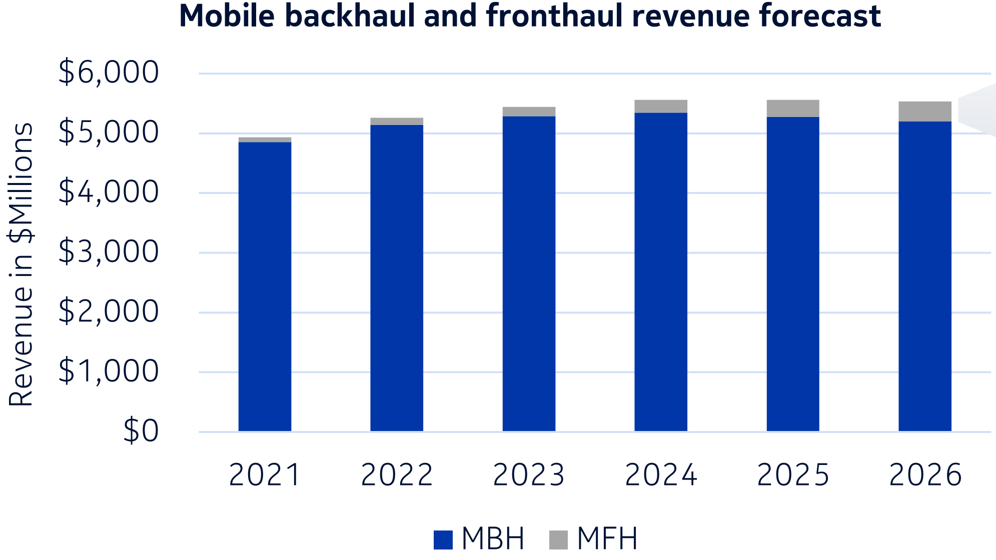
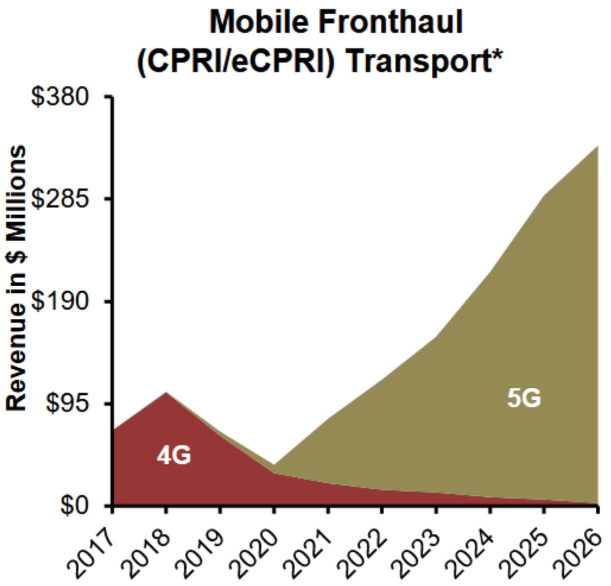
# Anyhaul opportunities continue to be dominated by backhaul

## Fronthaul grows with 5G

80% of backhaul driven by 5G




Source: Dell 'Oro Jan 2022

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# RAN evolution

Mobile Innovations

RAN Functional Splits

Cloud Architecture

Network Slicing




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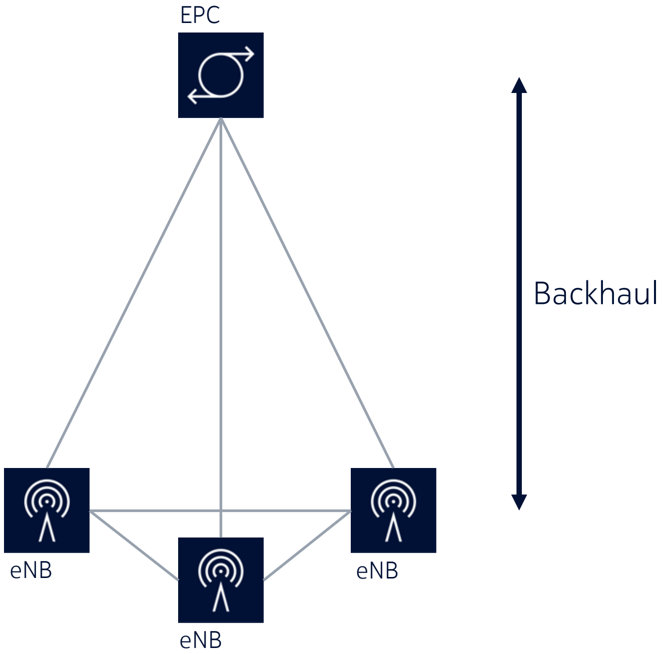
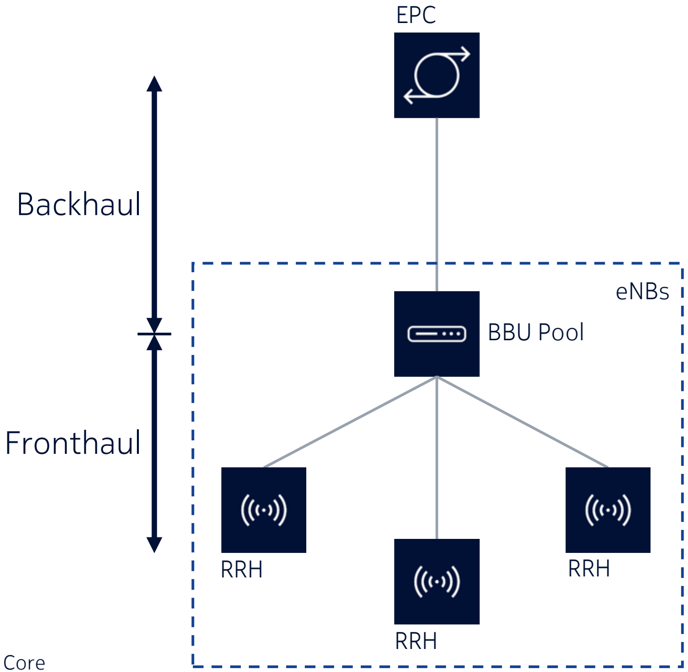
# CRAN architecture introduces the Fronthaul network

## RAN Densification: Searching for Better Radio Coordination




Traditional RAN

EPC: Evolved Packet Core
RRH: Remote Radio Head
BBU: Baseband Unit




Centralized RAN

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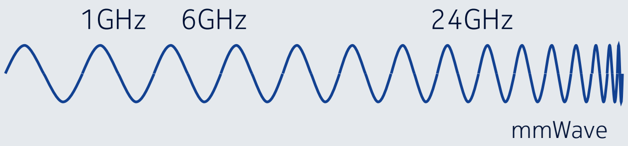
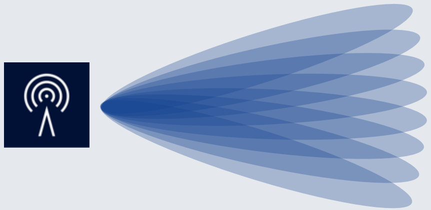
# 5G New Radio Main Technology Innovations

## Targeting a 10X increase in throughput

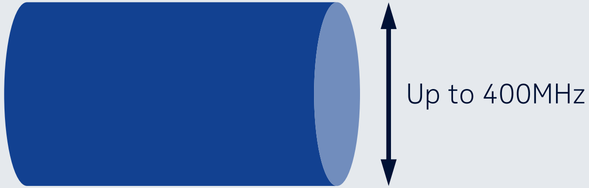
### New Spectrum Options




### Massive MIMO



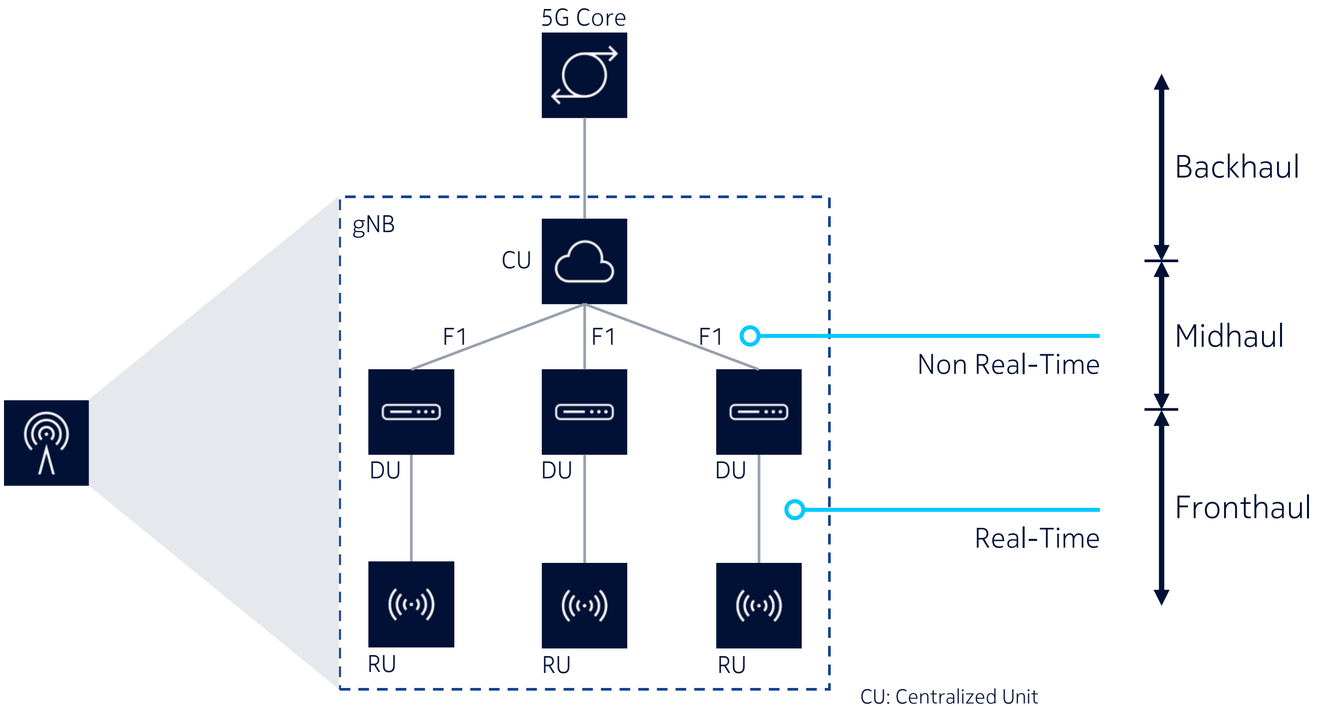
### Larger Radio Channels




### Cloud RAN (or vRAN)

# 5G NR (New Radio) Architecture Review

## Based on three layers to enable Cloud RAN

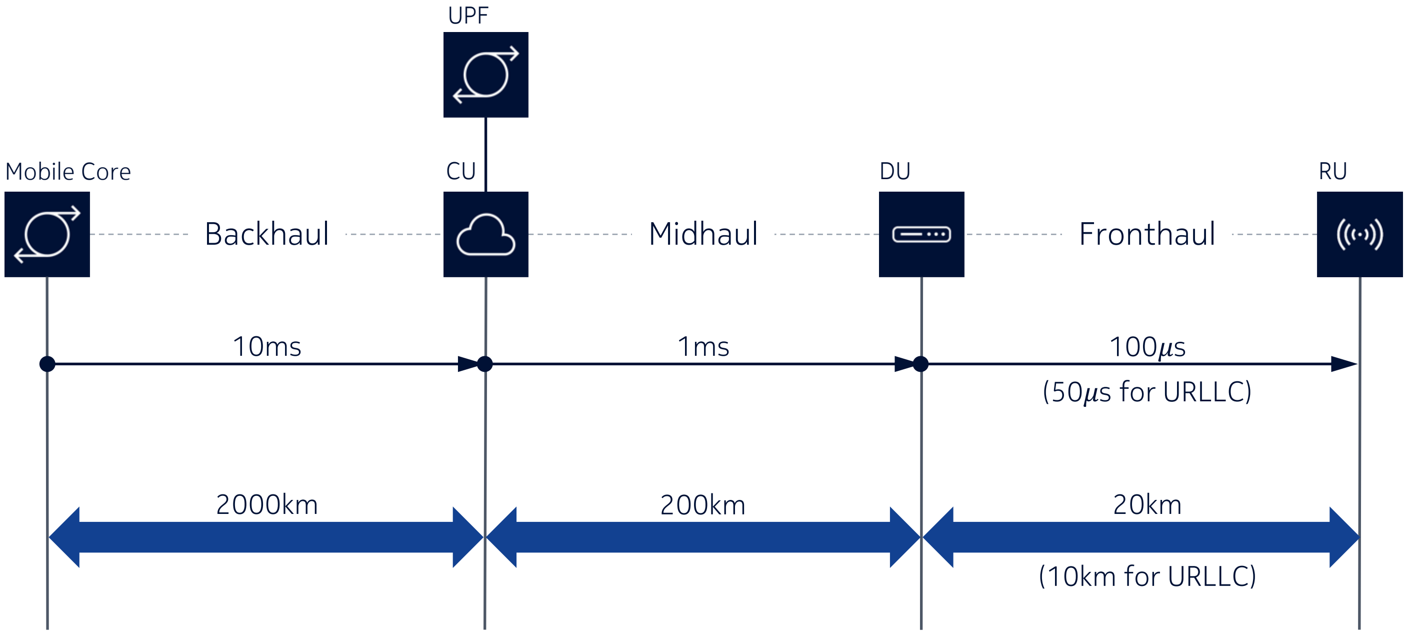



CU: Centralized Unit
DU: Distributed Unit
RU: Radio Unit

# Recommended One-Way Latency

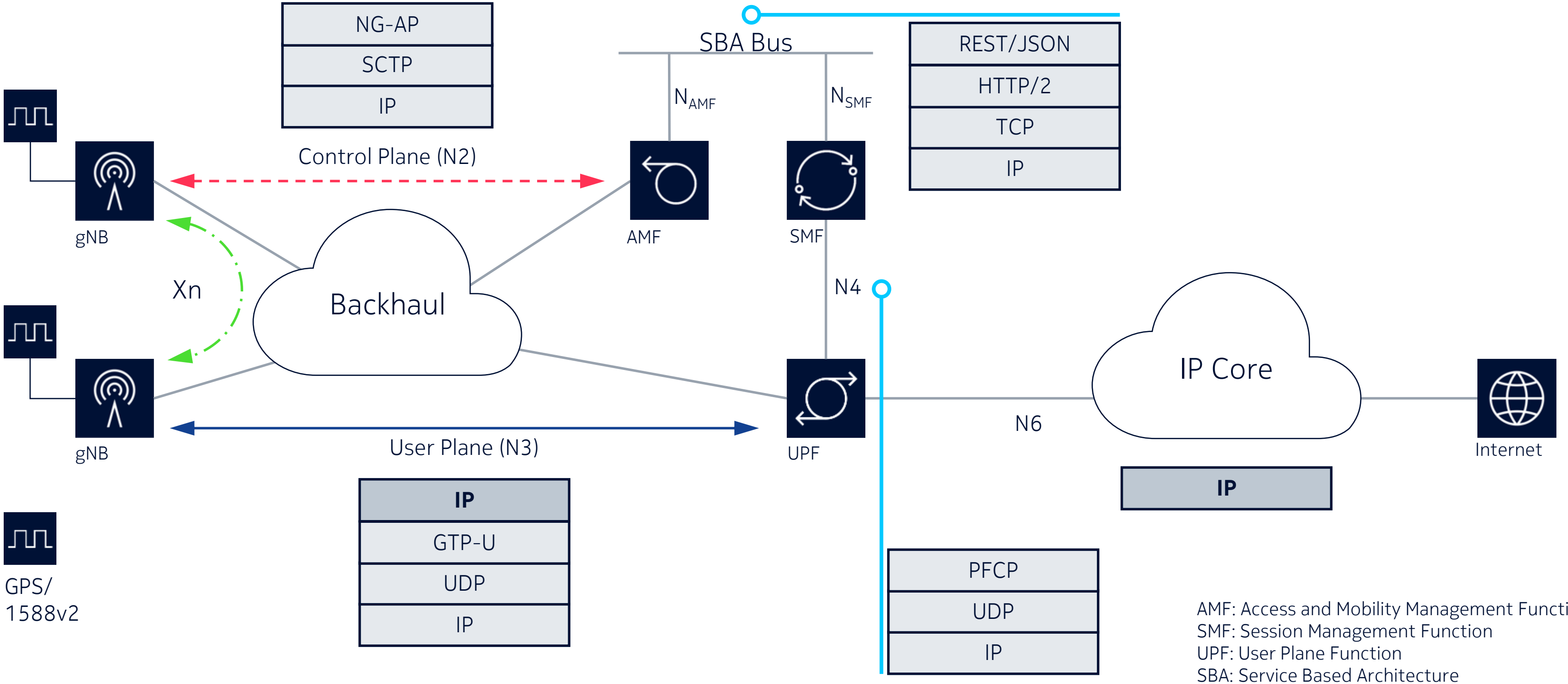
## Direct implication on inter-node distances




Fiber Latency=5$\mu$s/km

# 5G Backhaul Interfaces

## Same protocol stack as 4G with split control and user plane

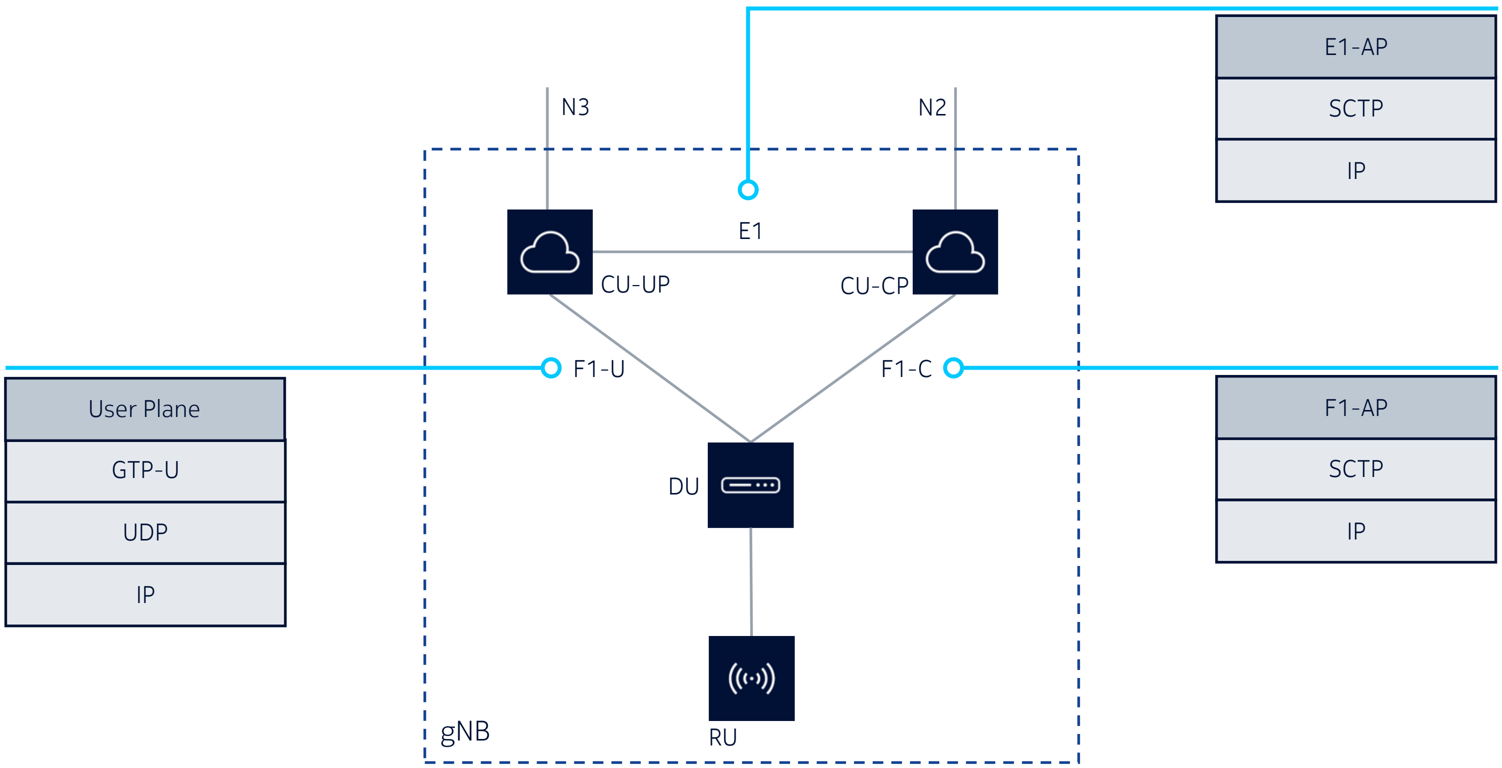



AMF: Access and Mobility Management Function
SMF: Session Management Function
UPF: User Plane Function
SBA: Service Based Architecture
gNB: gNodeB (Radio)

# New Midhaul Interfaces: E1 and F1

## Enabled by the high layer split (option 2)



# 5G Network Slicing

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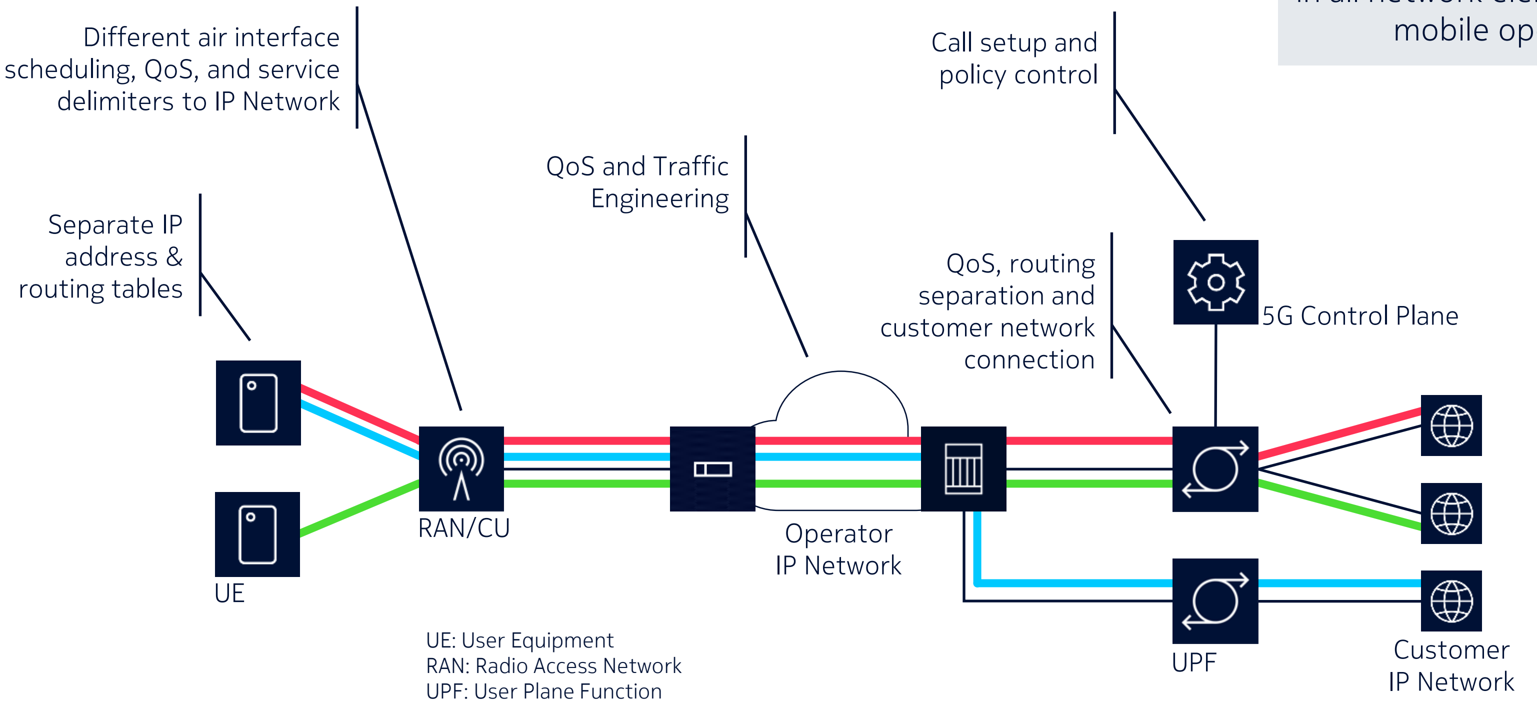
# What is 5G Network Slicing?

“Network controlled, SLA-backed clientless VPN”

Slices need to be provisioned in all network elements by the mobile operator




UE: User Equipment
RAN: Radio Access Network
UPF: User Plane Function

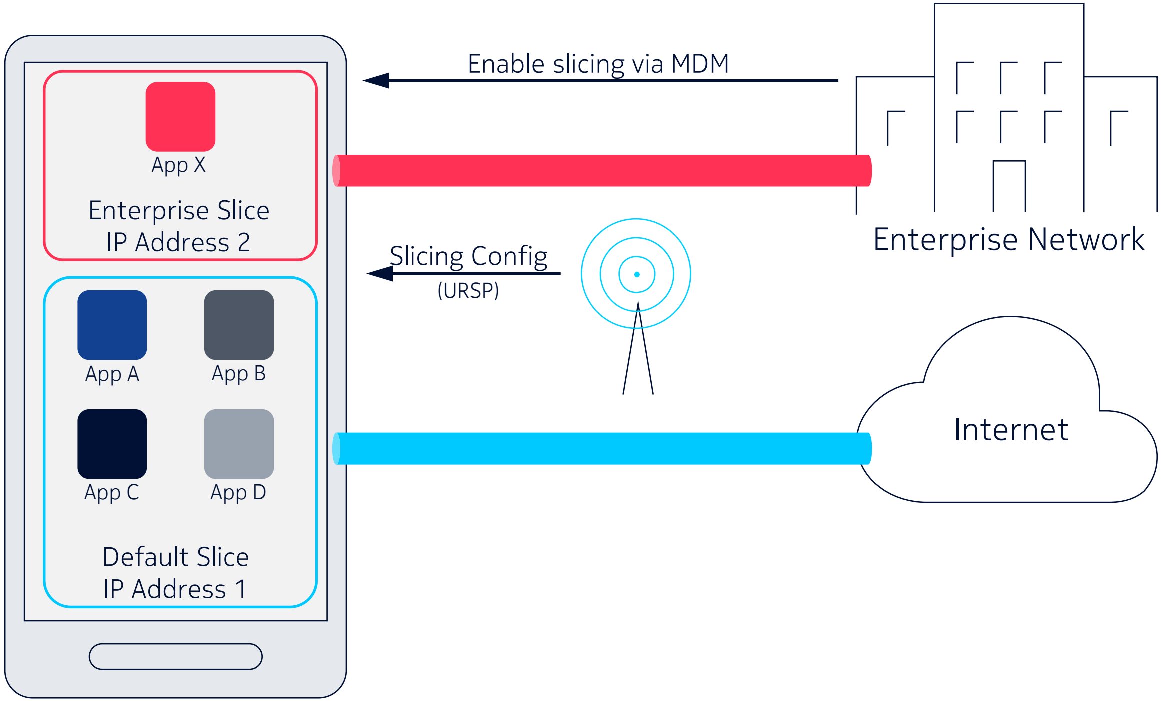
 

# Using 5G Network Slicing

## Protected Enterprise app use case

URSP Slicing Selection

| |
|---|
| Precedence 1<br>App: “App X ID”<br>Slice ID: SST:1/SD:2<br>DNN: Enterprise<br>Precedence 2<br>App: match-all<br>Slice ID: SST:1/SD:1<br>DNN: Internet |

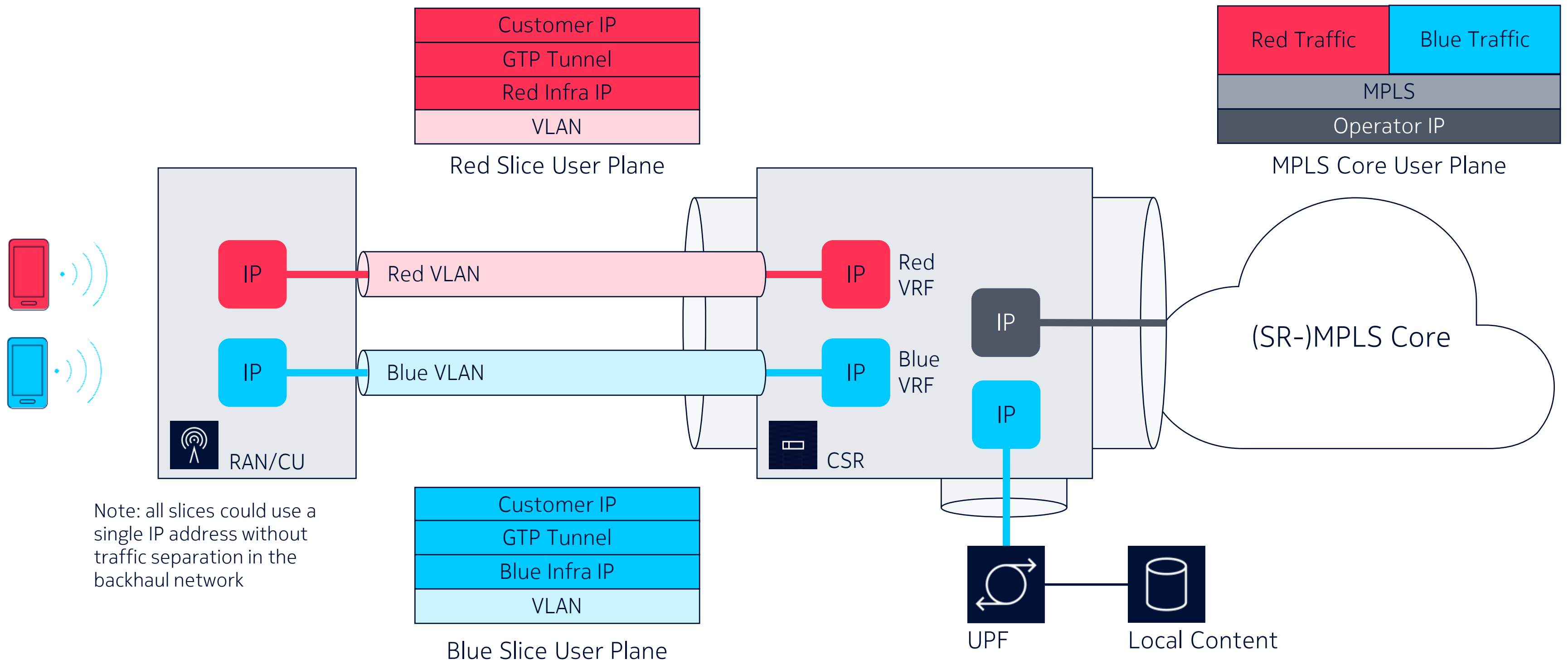



URSP: UE Route Selection Policy

Android Implementation: https://source.android.com/devices/tech/connect/5g-slicing

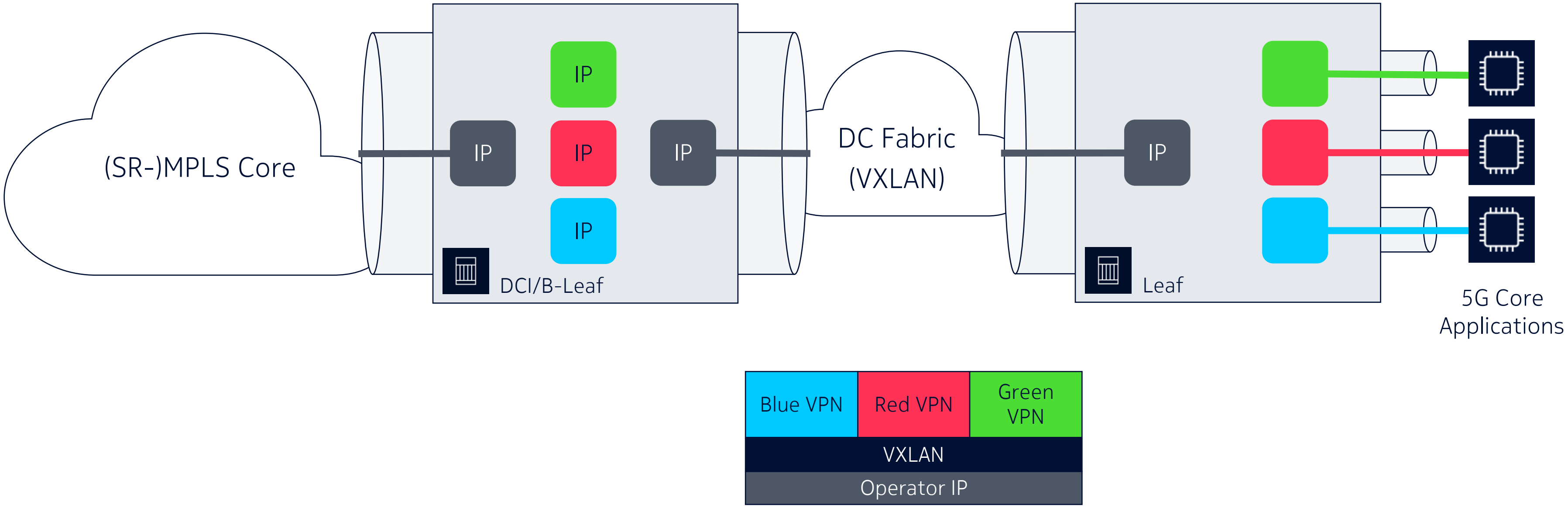
# Building 5G Network Slicing

## Ingress User Plane classification – MPLS example



# Building 5G Network Slicing

## Interconnection to the 5G Core in the Data Center

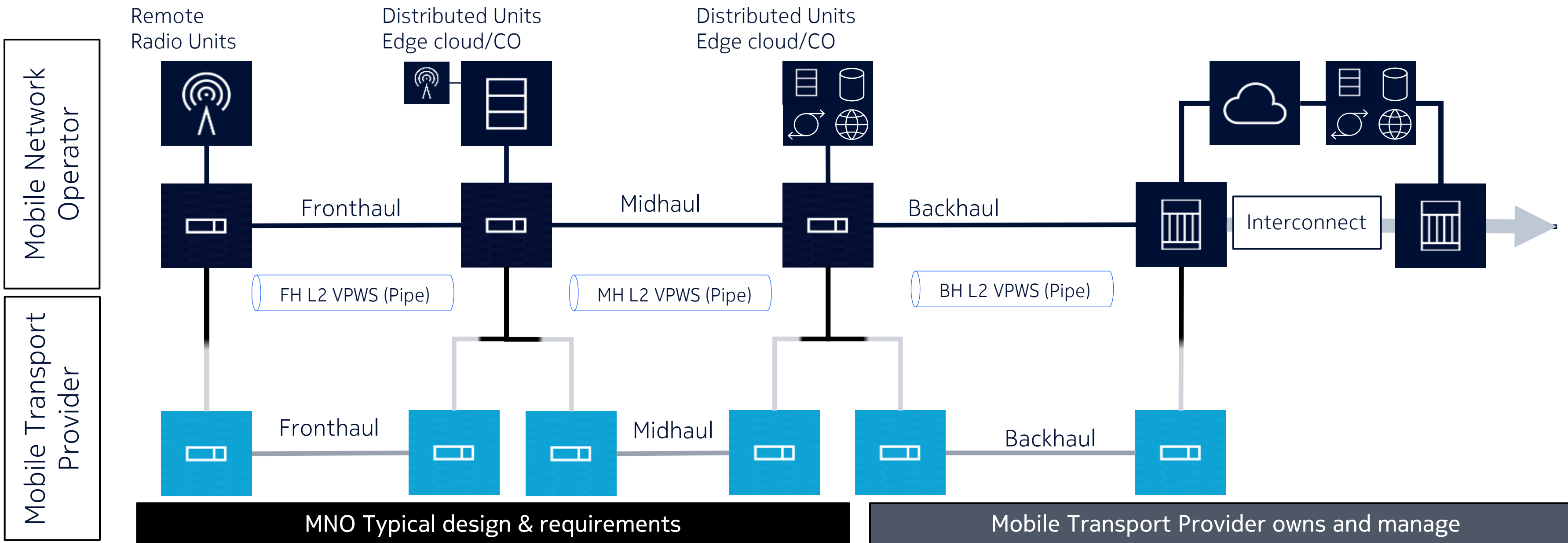


# Mobile Transport Provider Perspectives

# 5G – Anyhaul

## MNO + Mobile Transport Provider – Architecture overview




| MNO Typical design & requirements | Mobile Transport Provider owns and manage |
|---|---|
| • IP Network with IP-VPN/EVPN Services<br>• Responsible for QoS, Sync, OAM and Network Slicing<br>• Up to 7 type of SLA (queues) per service<br>• L3 OAM (TWAMP/TWAMP-Light) | • L2 P2P service (VPLS, VPWS, EVPN, etc)<br>• No interaction on Sync (2021), IP Addressing of RAN/CORE, etc<br>• QoS mapping on transport (MNO to MTP)<br>• L2 OAM (ETH-CFM to guarantee MNO agreed SLA) |

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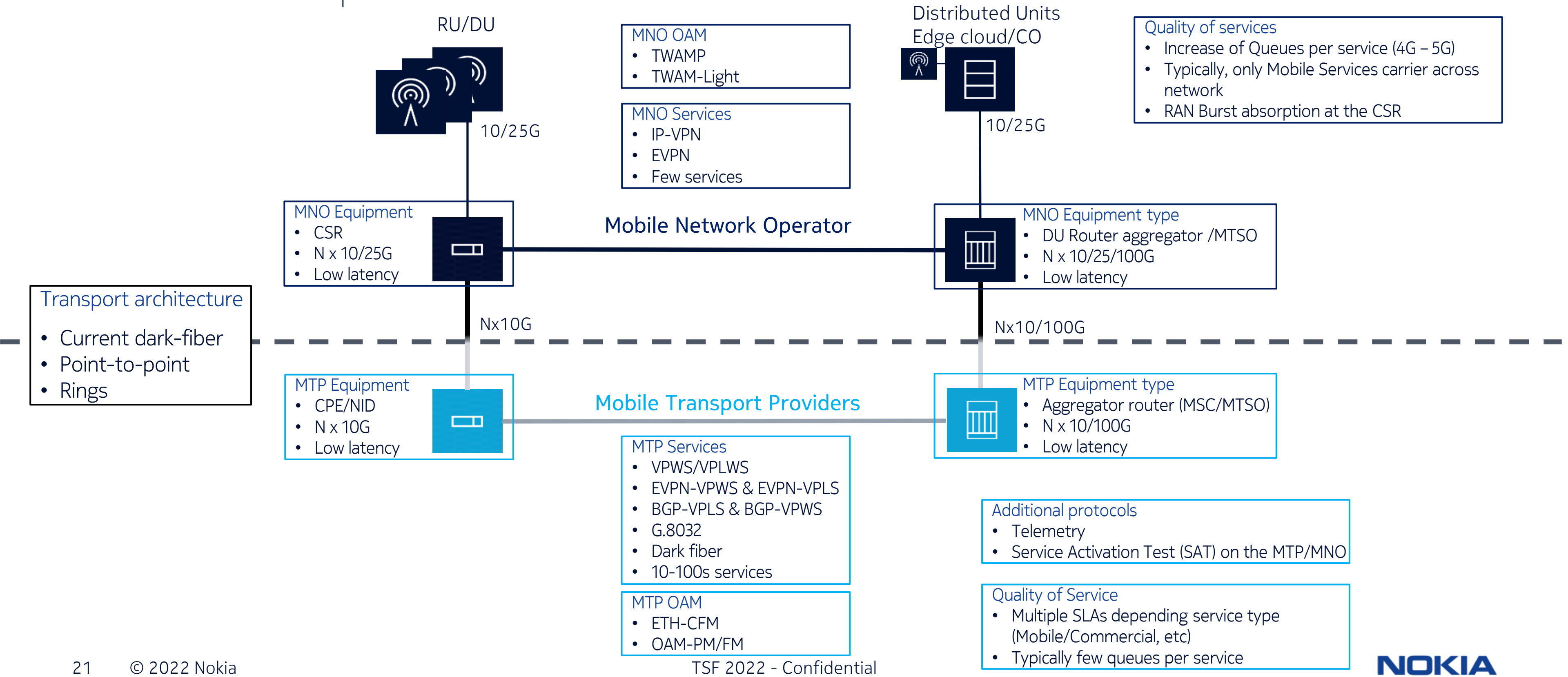
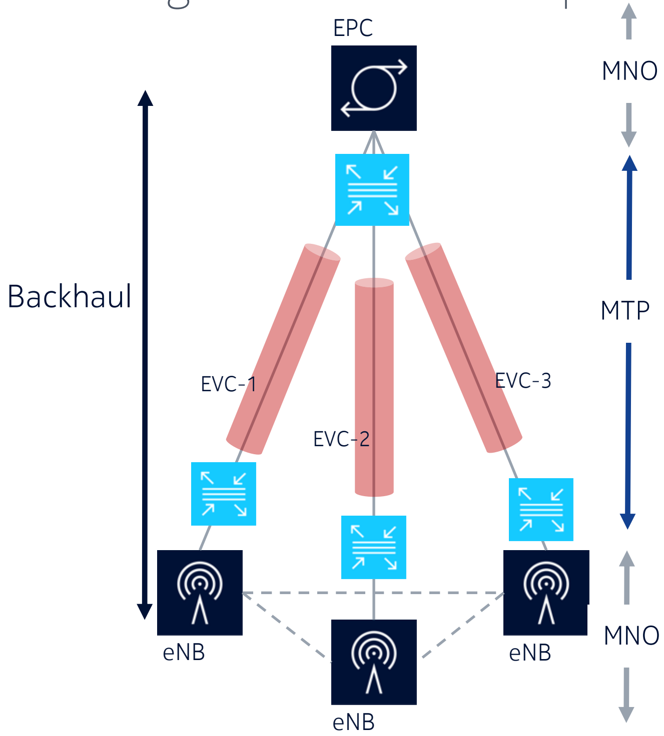
# 5G Transport Bottom-up architecture

## MNO vs MTP Requirements

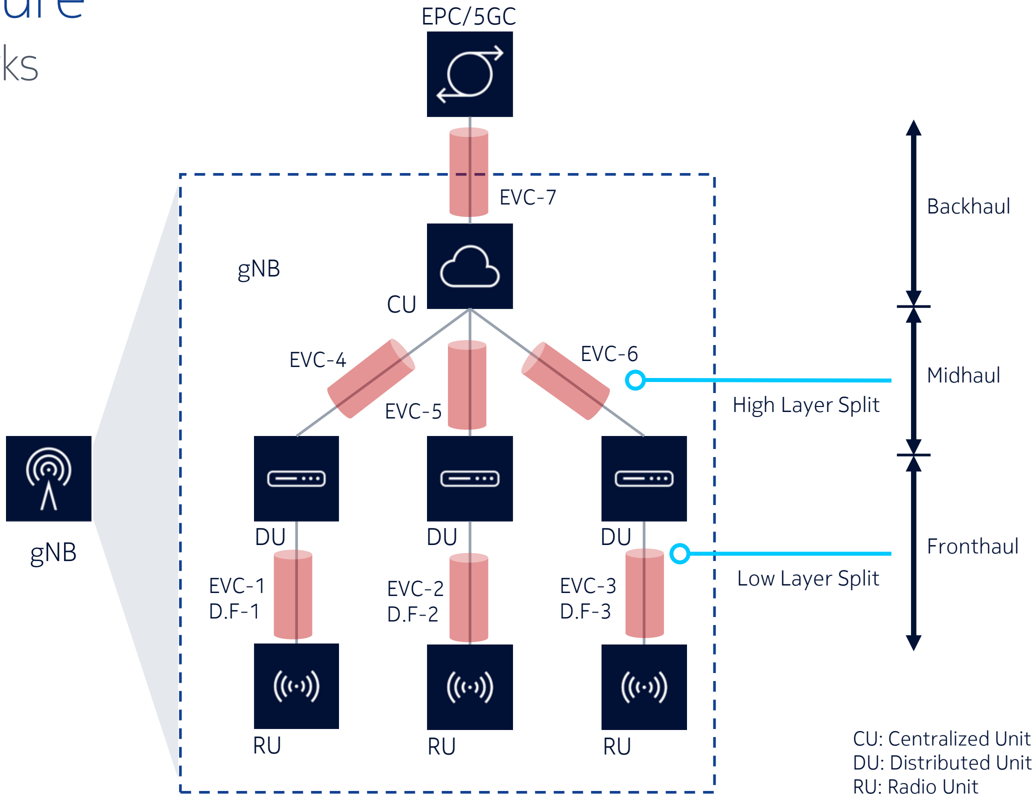


# 5G NR (New Radio) Architecture

## Changes on Mobile Transport Networks




**4G Transport overview**




CU: Centralized Unit
DU: Distributed Unit
RU: Radio Unit

Note: 3GPP considers the DU to include RU

**5G Transport overview**

*MTP: Mobile Transport Provider*

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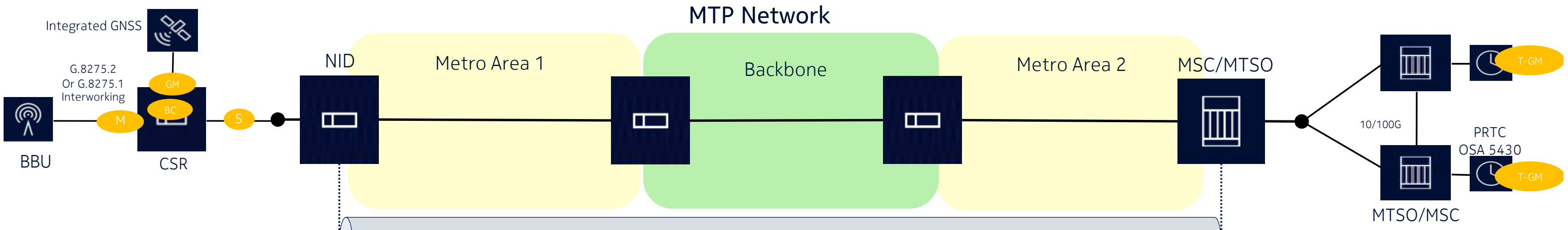
# 5G Impact on MTP Services

## Overview





**Bandwidth**

NNI - From 1G to 10G at the CSR/NID & From 10G to 100G at the MTSO

**QoS**

Access Egress QoS Treatment | Network Ingress QoS Treatment | Network Egress QoS Treatment | Access Ingress QoS Treatment

Access Ingress QoS Treatment | Network Egress QoS Treatment | Network Ingress QoS Treatment | Access Egress QoS Treatment

- From 1 Queue per FC to 4 Queues per FC
  - This may change >2022 due Network Slicing
- Additional Queues request to the MTPs
- Increment of CBS/MBS at the NID, MTSO AND Network in General


**SYNC**

From no SYNC Interwork to an “APTS Transport Support / 1.5uS TE”

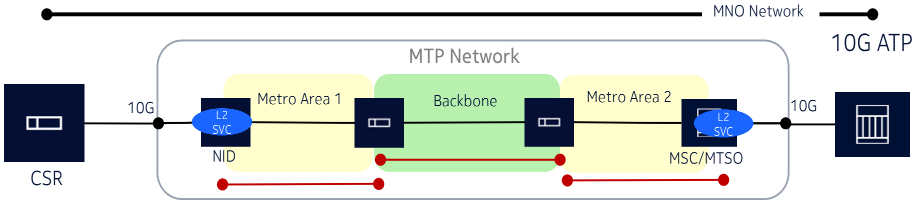

**Acceptance Test Plan**

Stringent ATP, specially at the BW performance, impacting BCM implementations
Network must be able to instruct schedulers to operate on on-the-wire frame size

# New Acceptance Test Plans

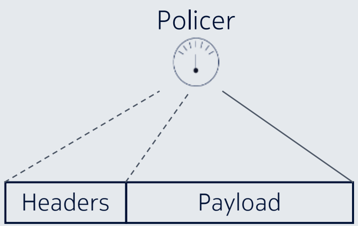
## Packet Byte Offset



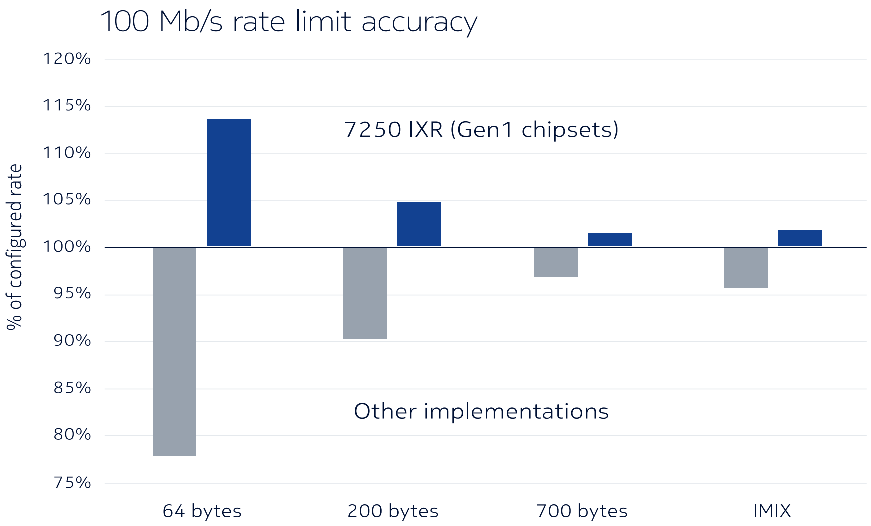

### Problem Statement

Size of headers is dependent on service and egress encap options and egress schedulers operate on actual size of the frame which includes the internal headers and as a result the net results might be off by as much as ~15% as a result of 8B internal header on a 64B frame.

### Solution - PBO




- Automatically adapts which headers are included in the policer based on the service type
    - ”On the line” size at egress
- Configurable knob to manually change the size in bytes
- Enabled at VLAN or Port levels



CU: Centralized Unit
DU: Distributed Unit
RU: Radio Unit
ULL: Ultra Low Latency

# 5G requirements on mobile transport network

## 5G Fronthaul Segment – eCPRI and/or CPRI

### Transport

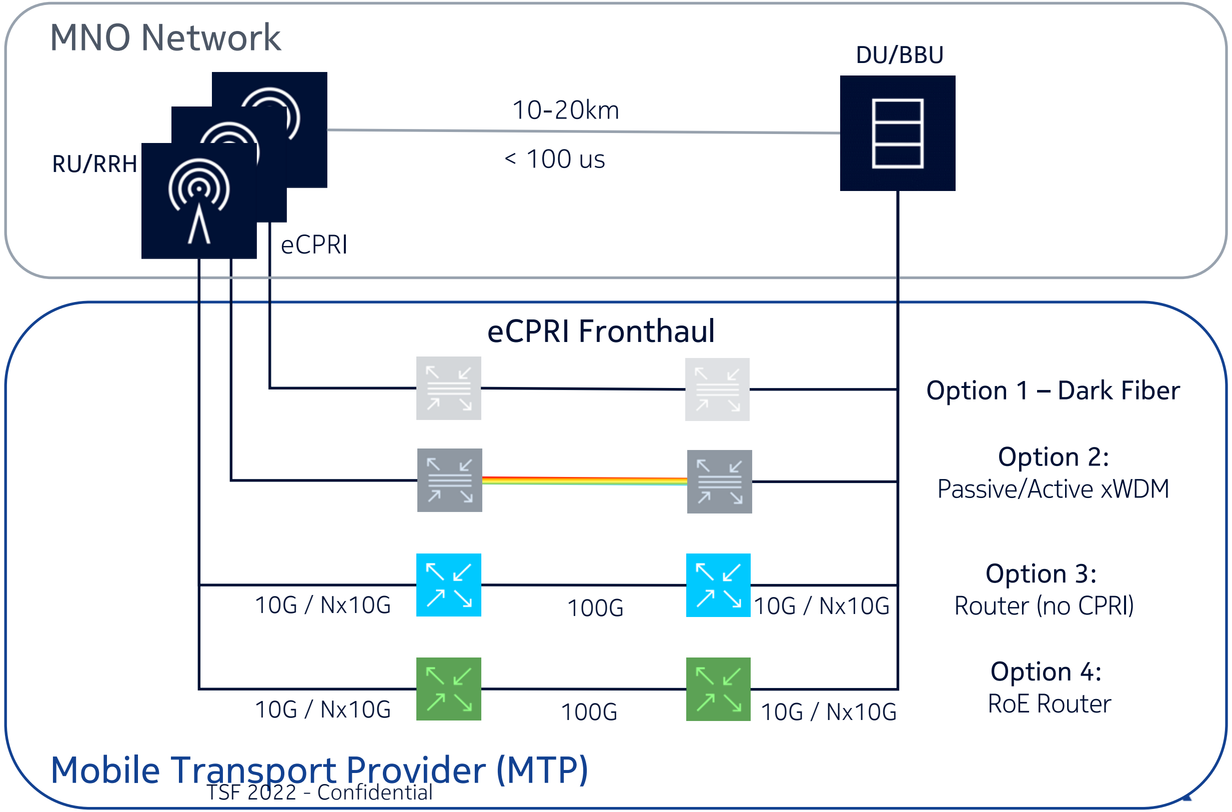
- Ethernet, fiber-only and/or xWDM
- Could leverage fiber/products for additional services
- P2P and/or Rings for Fronthaul

### Mandatory Services

- MTP must provide a L1/2/3 service to the MNO with any of the following:
  - Dark Fiber
  - Router (VPLS/VPLS/EVPN/IP-VPN)
  - RoE Device (CPRI, eCPRI with VPLS/VPWS, etc)

### Optional Services

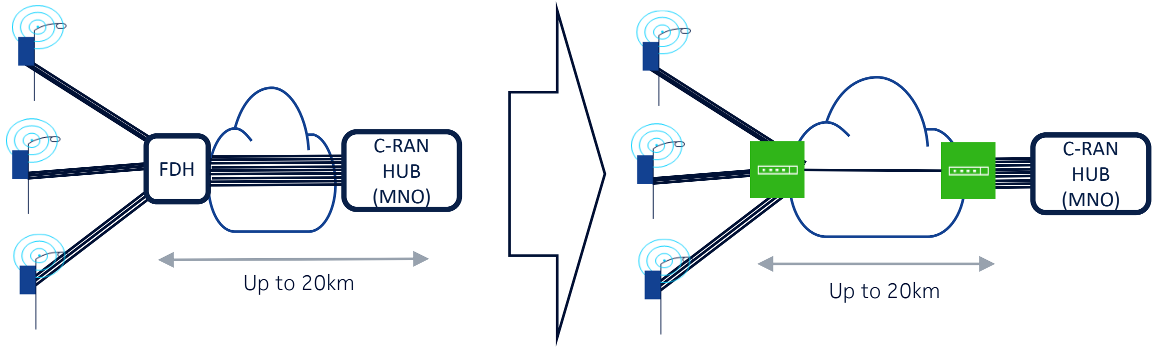
- Service Assurance (OAM FM/PM)
- Fast restoration
- Redundant path (with fiber through VPLS/VPWS/IP-VPN services)



# Fronthaul as a Services (FaaS)

## How MTPs can provide a new type of service for FH

**Transport provider network for FH**




- Too many fiber required,1 fiber pair for each Radio
- Fiber nightmare at the HUB site
- Expensive to build, longer time to market
- New small cell triggers new end to end fiber build

- Customer keeps leasing fiber for the cell site
- No transport equipment needed at cell site
- Transparent to MNO (Two end devices connected over dark fiber)
- Managing network is easy and inexpensive

# FaaS Drivers

**CBRS encouraging Utilities and Enterprises to build Private 5G network.**

1 Free spectrum is inspiring small players to deploy wireless network.

**vRAN is allowing to run DU and CU on cloud.**

2 vDU and vCU can be deployed on container using private or public cloud, lowering deployment cost and allowing pay as you grow model.

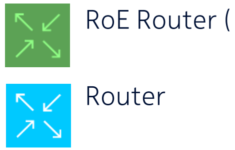
**RDOF is motivating ISP to expand and become WISP.**

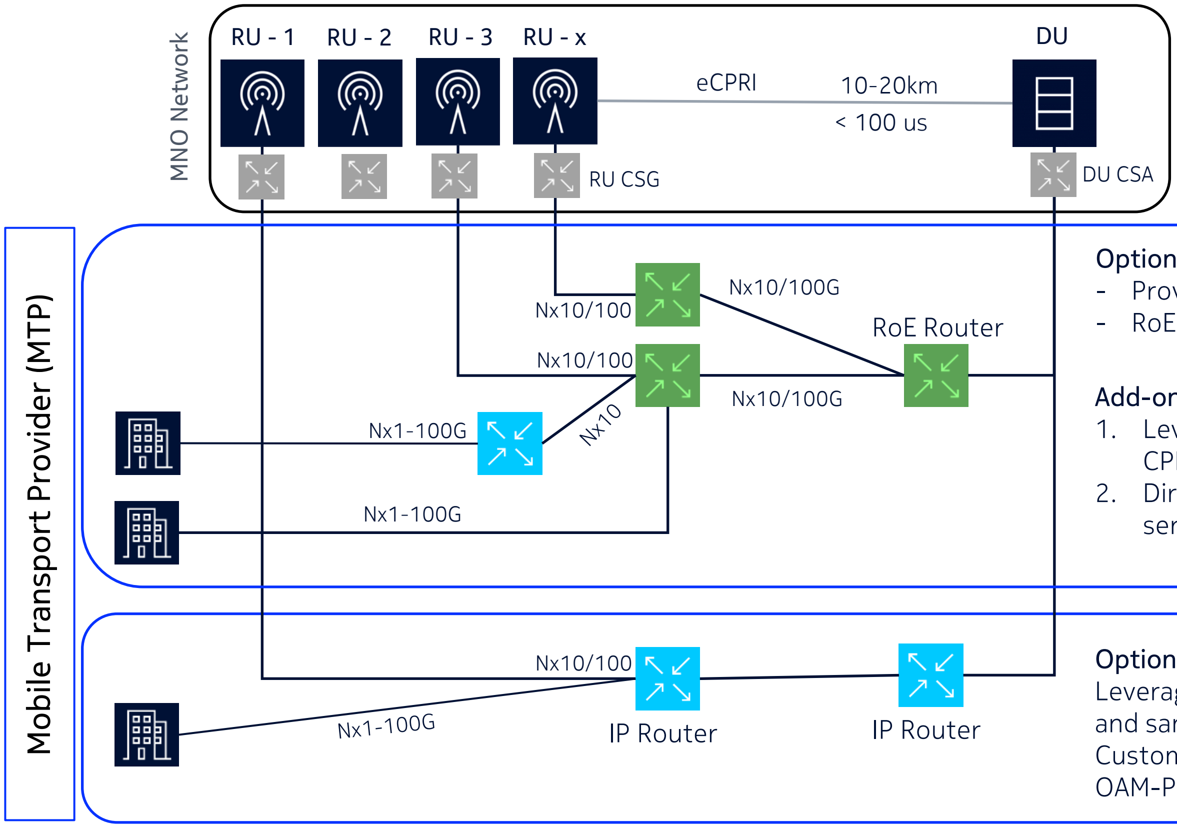
3 Govt is providing funding to provide connectivity in rural USA and FWA is best technology to do it cost effective way.

# Fronthaul (eCPRI) from the MTP perspective

## Services




**Option 1- L2/L3 Service with RoE Router**

- Provides TSN Certified service (FaaS)
- RoE capable

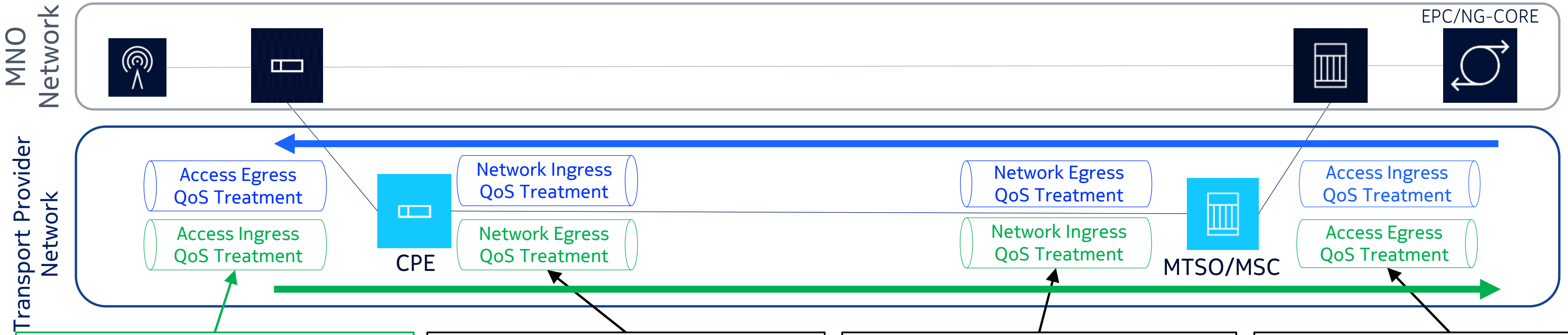
**Add-ons:**

1. Leverage RoE Router additional ports and add a CPE/NID for Business Services
2. Direct connectivity to the RoE Router with additional services (EVPN/VPLS, etc) for Commercial Services

**Option 2 – ULL IP Router for transport, OAM and Slicing**

Leverage ultra-low latency routers (~2-3 uS latency) and same platform for mobile/Business/Residential Customers with Segment Routing to the edge
OAM-PM and Network Slicing (Business / Mobile)

# QoS Overview from the transport provider perspective




**Classification**: mapping of traffic into forwarding classes according L2/L3/L4 header bits.

**Buffer acceptance:** accept packets according to queue filling levels.

**Scheduling**: schedule packets out of queues according to queue parameters. Defines in or out of profile traffic.

**Buffer acceptance:** accept packets according to queue filling levels and in/out of profile.

**Scheduling:** schedule packets out of queues according to queue parameters.

**Marking:** map the forwarding class and in/out profile into IP DSCP bits or MPLS EXP bits.

**Classification**: mapping of traffic into forwarding classes according to IP DSCP or MPLS EXP bits.

**Buffer acceptance:** accept packets according to queue filling levels and in/out of profile.

**Scheduling:** schedule packets out of queues according to queue parameters.

**Buffer acceptance:** accept packets according to queue filling levels and in/out of profile.

**Scheduling:** schedule packets out of queues according to queue parameters.

**Marking:** map the forwarding class and in/out profile into IP DSCP bits or L2 dot1P bits.

**Downstream**

- Real world deployment scenarios shows that mobile traffic is very bursty
- It has been observed in some operators that some buffering occurs in **upstream**
- Many TCP ack are received at the same time at the servers from the terminal
- When servers have a high bandwidth connection, traffic sent can be very high
- If downstream traffic is not absorbed by the transport, TCP windows will be reduced and traffic throughput will be degraded

**Upstream**

- Must accommodate different traffic flows with different SLAs in the backhaul
- Need even more tight SLA with H-QOS if backhaul network is shared with multiple customers

**Solution**

- Have equipment with good buffer capability
- Well engineered buffer depth

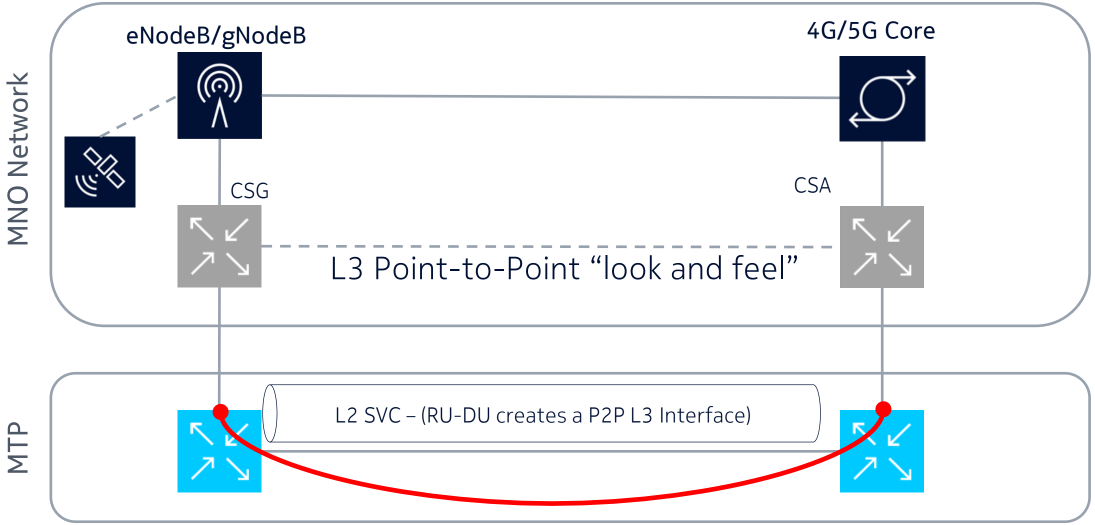
- Good priority scheduling capabilities per services, per vlan, per port with hierarchy
- Shaping capability in ingress to absorb micro burst from radio

# 5G impact on the MTP perspective

## 4G Sync

Background:

- MNO gets sync to the RAN in 2 ways:
    1. GPS at each cell-site location (MNO/TP routers does not participate)
    2. Leverage SyncE/1588v2 for Freq/Phase across the network (OC, BC)
- *2019-2021:MTP does not need to provide any sync to the MNO.*
- This is the case for 4G and initial 5G deployment



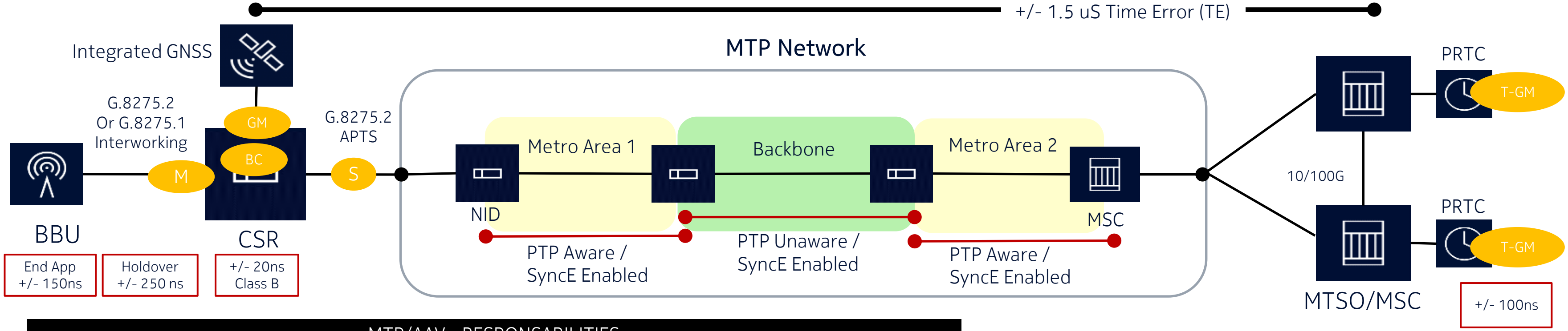

 



*MTP: Mobile Transport Provider*

# 5G impact on the MTP perspective

## New synchronization requirements → Transport APTS




**MTP/AAV - RESPONSABILITIES**

- Transport among the EVCs the MNO synchronization messages, complying with a “Partial timing support” specs:
  - Maximum absolute phase and time Time Error (TE) limit of <= 1.5uS
  - Maximum TE must be less than or equal to 1.1uS
- The EVC should not create excessive asymmetry or PDV

**Recommendations for the MTPs**

- Carry sync messages on the NC Queue or create a new ”sync queue” at the MNO and MTPS
- Implement a Full Timing support (Freq/Phase)
  - G.8275.1 with Ethernet encap and BC at the key locations to reduce accumulation of PDV
  - SyncE on the NNI ports toward MNOs
- PTP Messages should have highest priority to minimize those packets sit on queues, also, keeping low traffic loads (allows periods of extra load during reroutes)
- Reduce as much as possible the PTP unaware network elements to reduce the PDV
- Review the QoS policies “across the network” to mitigate the “network path buffer size”

**MTP/AAV - RESPONSABILITIES**

The network limit value and the metric processing parameters that apply for partial timing support packet network are as follows:

- maxlpktSelected2wayTEl < 1100 ns
- Selection window = 200 s
- Selection percentage = 0.25%
- Selection method: percentile average packet selection (see clause I.3.2.2 of [ITU-T G.8260])
- Window step size: =< 20 s



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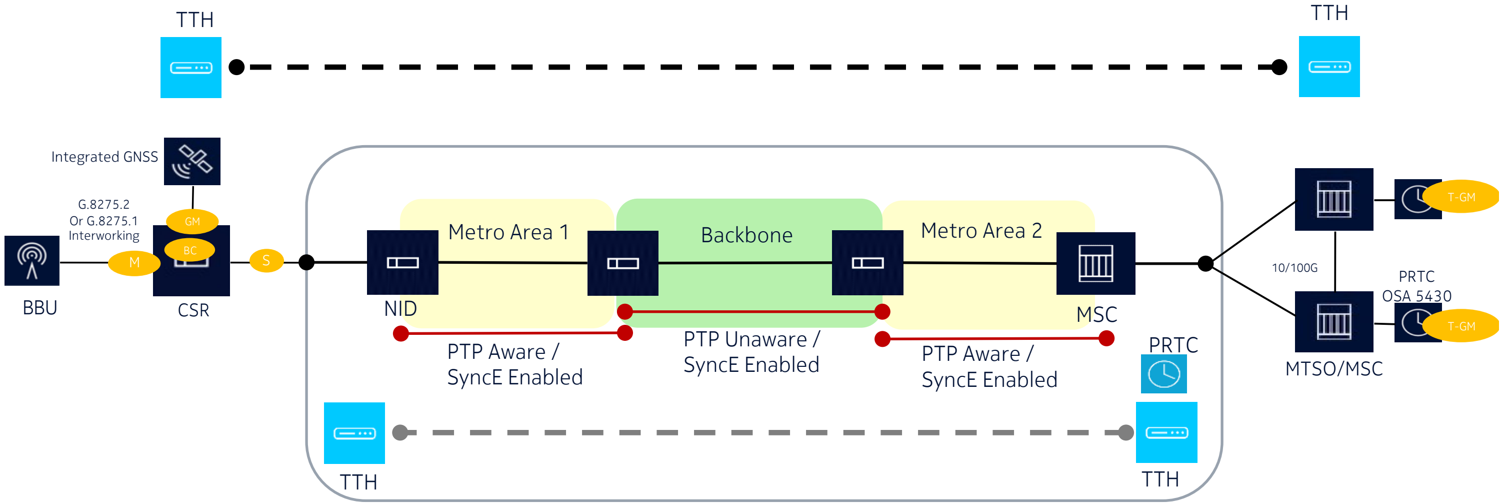
# 5G impact on the MTP perspective

## Measuring the sync across MNO and MTP



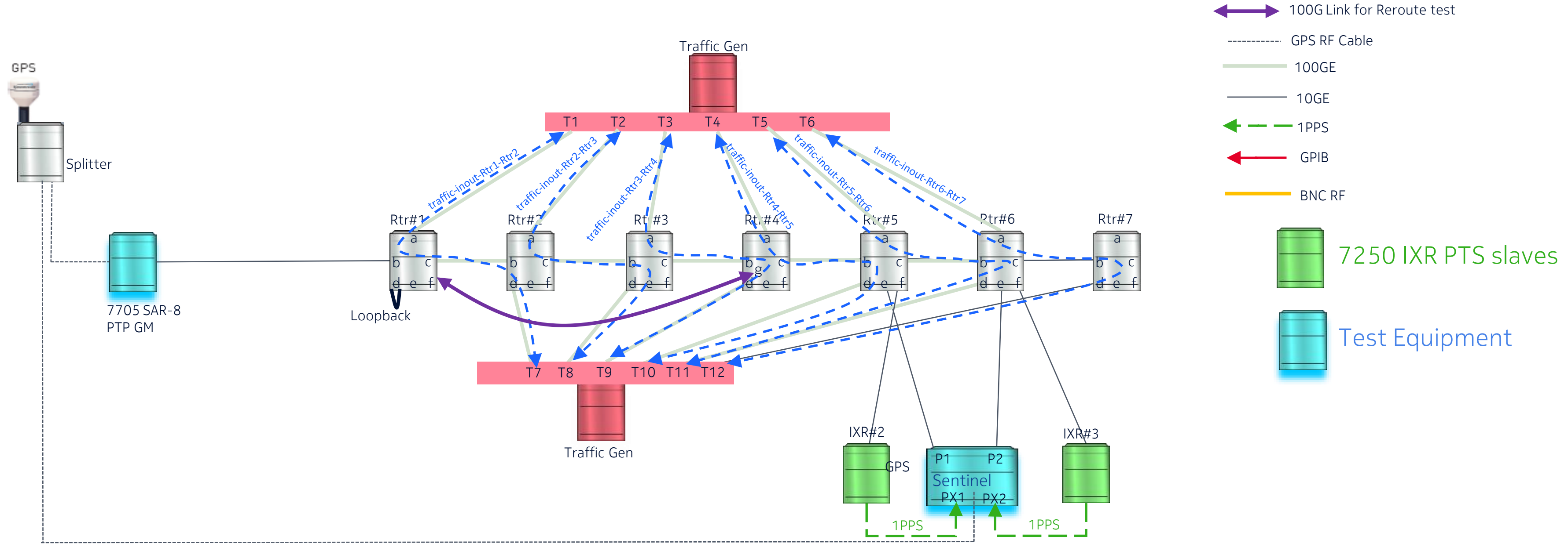

| Measuring the APTS SLA on the MTP network |
|---|
| 1. Rely on specialized GPs based test devices at both ends of the connection. Tests must need to be run occasionally due the impact of new services added onto the existing network<br>2. Deploy APTS like clocks at the ingress/egress of the network where EVCs are provided/terminated (MSC/MTSOs?).<br>3. Provide a Full Timing support for the EVCs (G.8275.1 / ETH Encap), then connect that accurate time into the OAM timestamping to allow measurement for the requirements of G.8271.2 |

Notes:

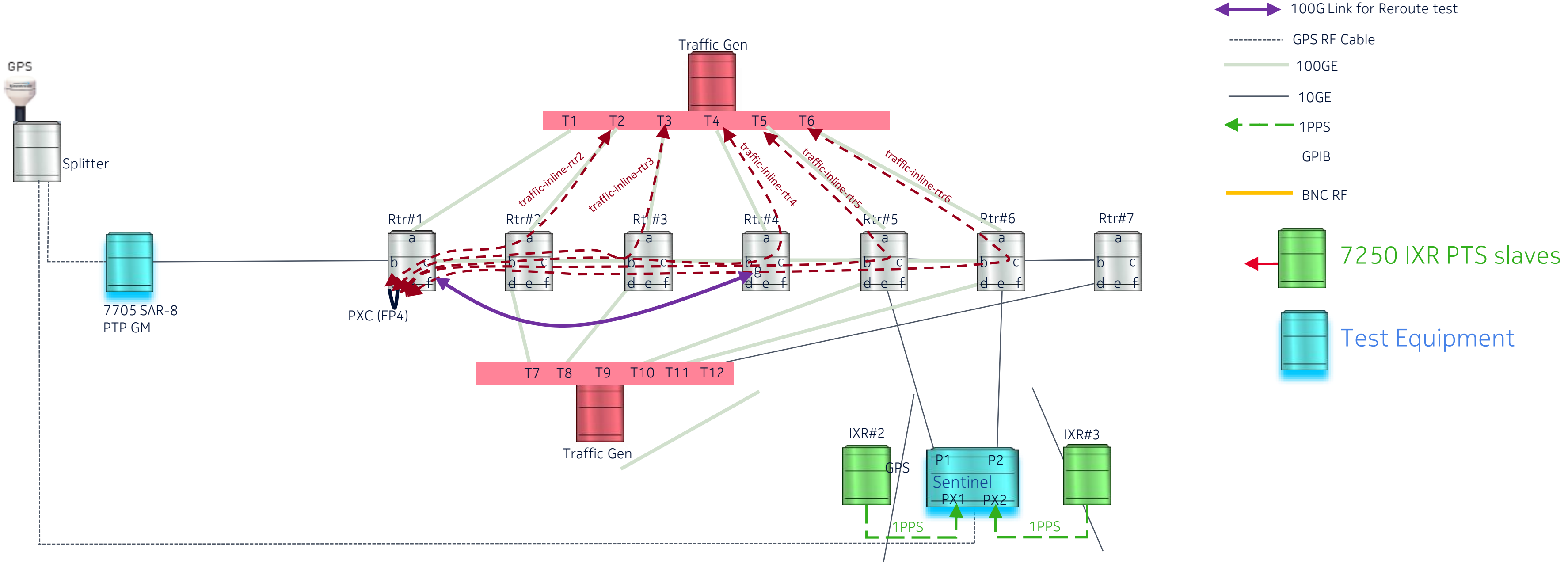
- Option 2 and 3, opens the door to sell SaaS to the MNOs
- TTH doesn't have to be bookended

TTH = Timing Test Head

# G.8271.2 Study in/out traffic flows

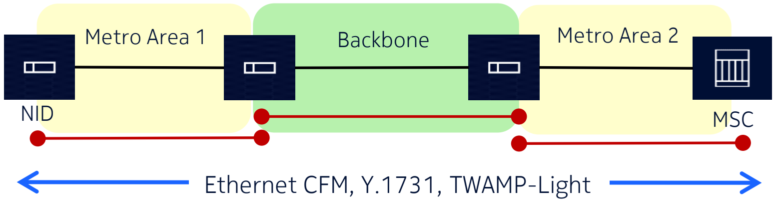


# G.8271.2 Study inline traffic flows




# 5G transport impact

## OAM




| Requirements | |
|---|---|
| Y.1731 | Single-ended or dual-ended |
| TWAMP/STAMP | IPv4/IPv6 |
| ETH-CFM | Must support 1ms CCM interval.<br>CCM can be optional |


| Metric Type (MEF10.2.1/MEF35) | Ethernet (ITU-T) | IP (IETF) |
|---|---|---|
| Frame Delay | ETH-DMMv1 | TWAMP Light |
| Loss & Availability | ETH-SLM | TWAMP Light |

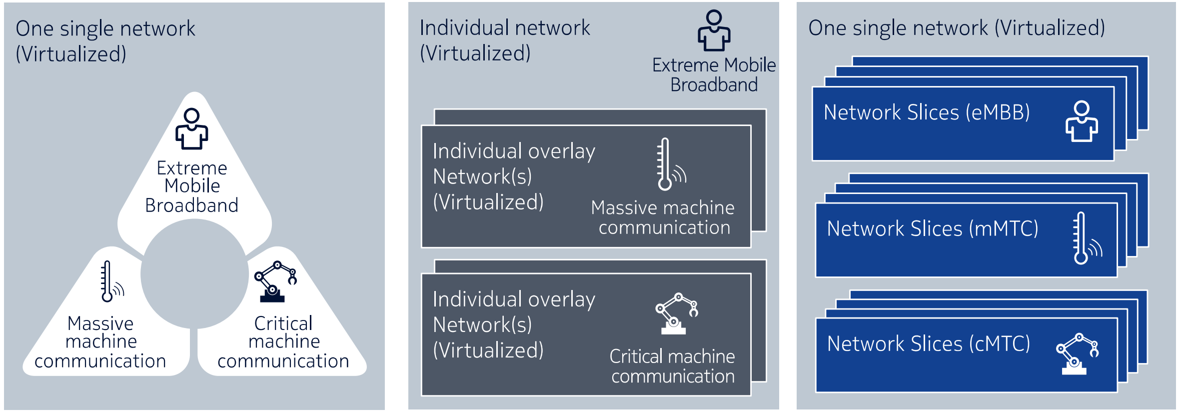
| MNO Requirements to the MTPs | |
|---|---|
| Data Transfer | • 4 hours data retention<br>• Flexible data transfer options |
| PM Session State | Multi-protocol support as originator and reflector |
| PM Variables (per EVC) | • 1-Minute measurement internal<br>• 50ms sample rate<br>• 5-minute collection interval |
| PM Rate | Packets-per-second must scale to EAN/EAD service capacity |

| OAM-PM Dimensioning per EVC | |
|---|---|
| OAM-PM SLM | 50ms interval = 20pps |
| OAM-PM DMM | 1s interval = 1pps |
| CCM | 1s (must be optional) = 1pps |
| Total PPS | 22 pps/service with CCM<br>21 pps/service without CCM |

# Network slicing

## Helping to improve the monetization of the network

**Single network** | **Dedicated networks** | **E2E Network Slicing**




**Single network:** Best-effort support of eMBB, cMTC and mMTC

**Lacks flexibility –** lacks flexible customer separation and service differentiation.

**Dedicated networks:** Customized dedicated networks for mMTC and cMTC

**Purpose-built networks -** Increased cost and scaling challenges.

**E2E Network Slicing:** Customized network slices for eMBB, mMTC and cMTC

**Full network slicing -** Maximum flexibility and optimized cost

Source: Nokia / Bell Labs Consulting white paper: Unleashing the economic potential of network slicing

### Network slicing benefits:

- Enables differentiated services, new use cases and better monetization
  - Slicing per application or customer
  - Possibility to offer local, regional and / or nationwide services
- Speeds time to market and increases flexibility.
  - Slices can be created with minimal effort
  - Offers enterprises benefits of customized private networks without having to build and operate thus saving cost
- Improves network resource utilization, assurance and security
  - Offer new type of managed & controlled connectivity, isolate, assure & match SLA

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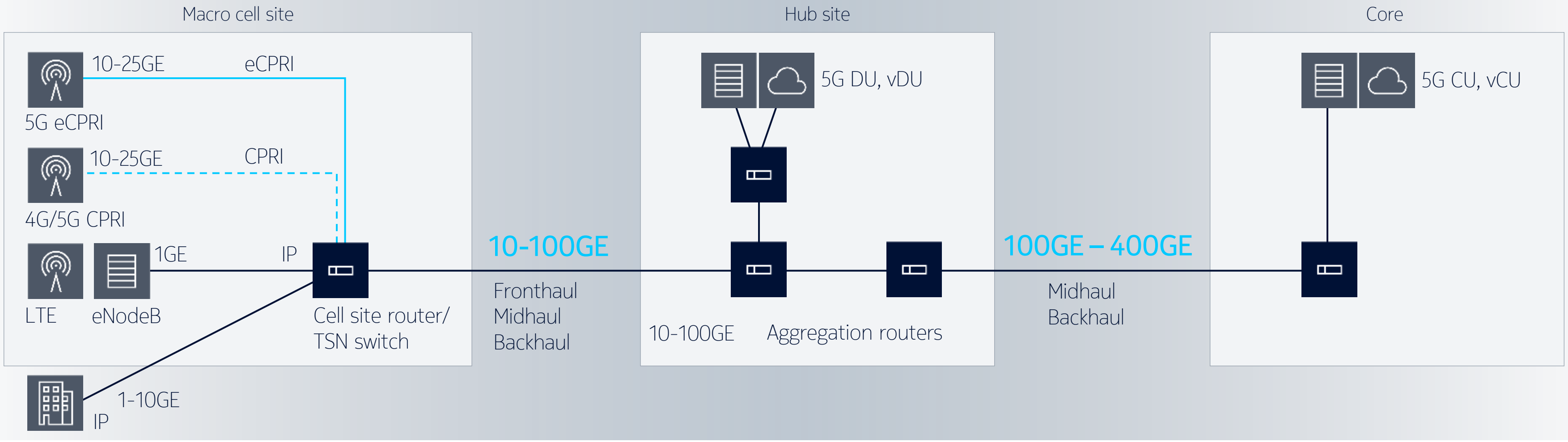
# Transport networks must address growing bandwidth demand

Capacity

| Capacity | 2015-2019 | 2020-2024 | 2025 and beyond |
| --- | --- | --- | --- |
| ~70% of radio sites | 75-155 Mbps | 300-600 Mbps | 1-2.5 Gbps |
| ~25% of radio sites | 250-500 Mbps | 1-2.5 Gbps | 5-10 Gbps |
| ~5% of radio sites | 1-2.5 Gbps | 5-20 Gbps | 20-20 Gbps |
| % of sites legacy CSR cannot address | 5% | 30% | 100% |

By 2025, all cell sites will need capacity upgrades







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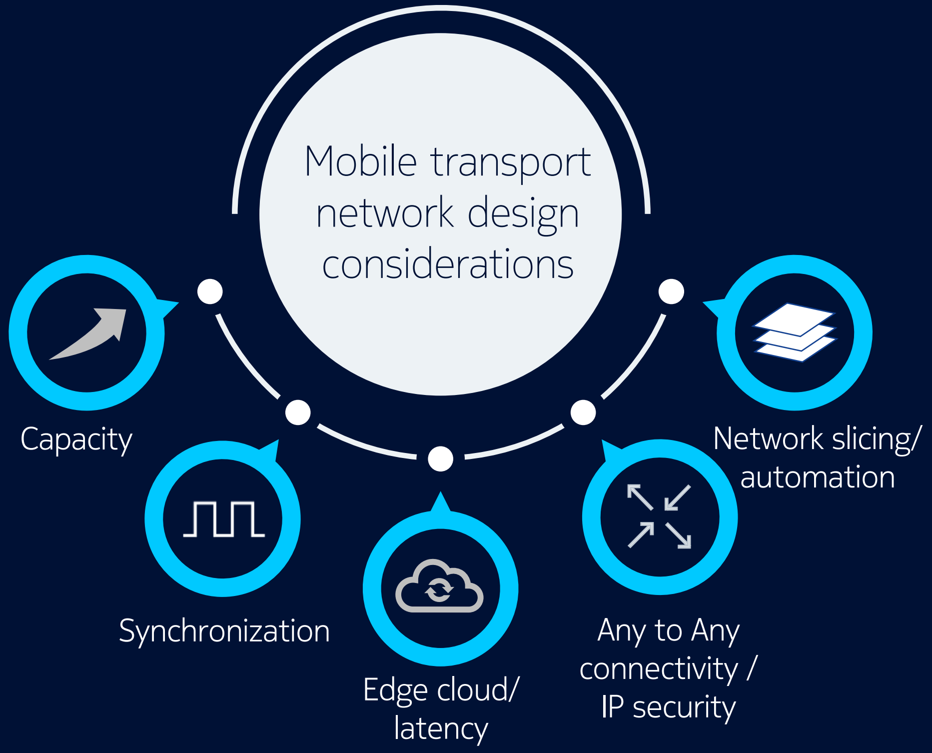
# Transport requirements



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