NOKIA

Key Technologies for 5G Transport Networks

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Network Infrastructure – IP Routing

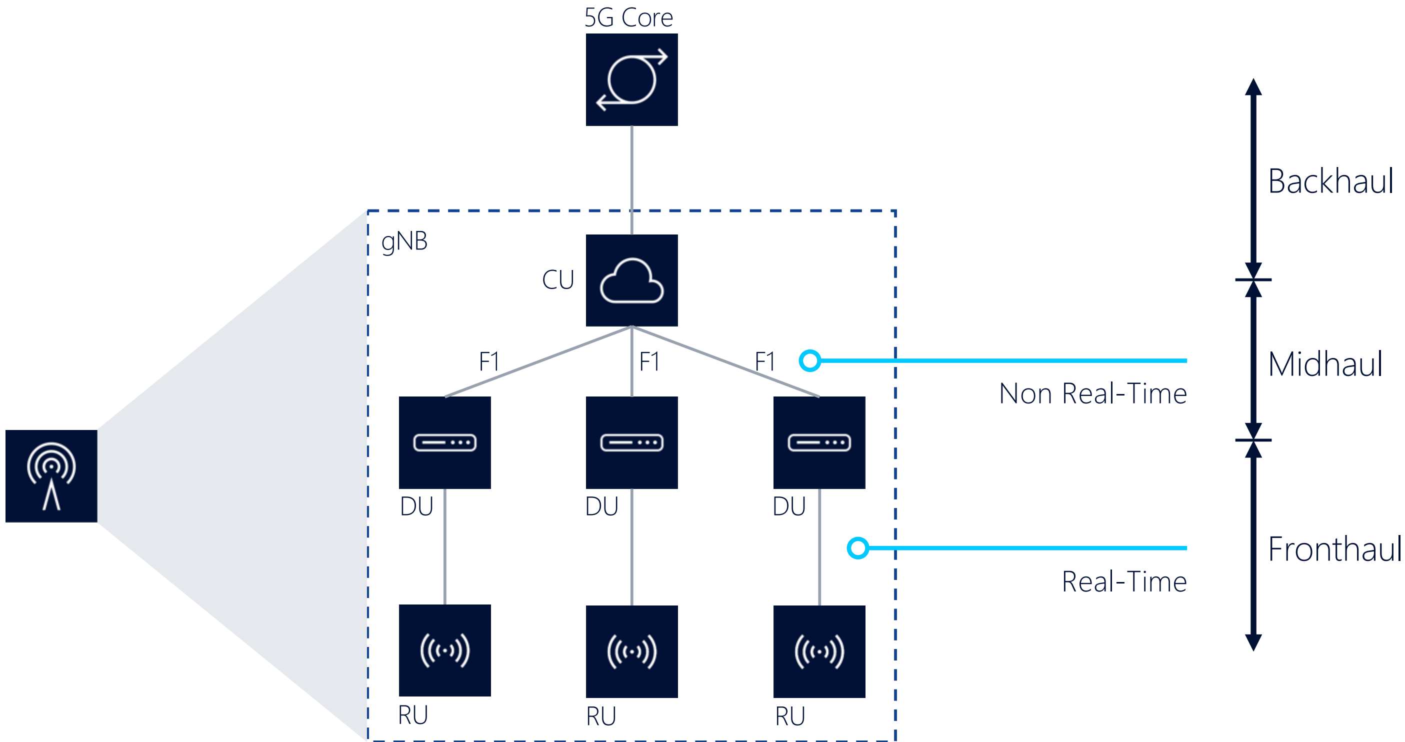
Please check the NANOG 75 session "5G: an IP Engineer Perspective" for a complete overview of 5G transport:

https://youtu.be/PbvB77W5xtY

NANOG 84

5G NR (New Radio) Architecture Review

Based on three layers to enable Cloud RAN

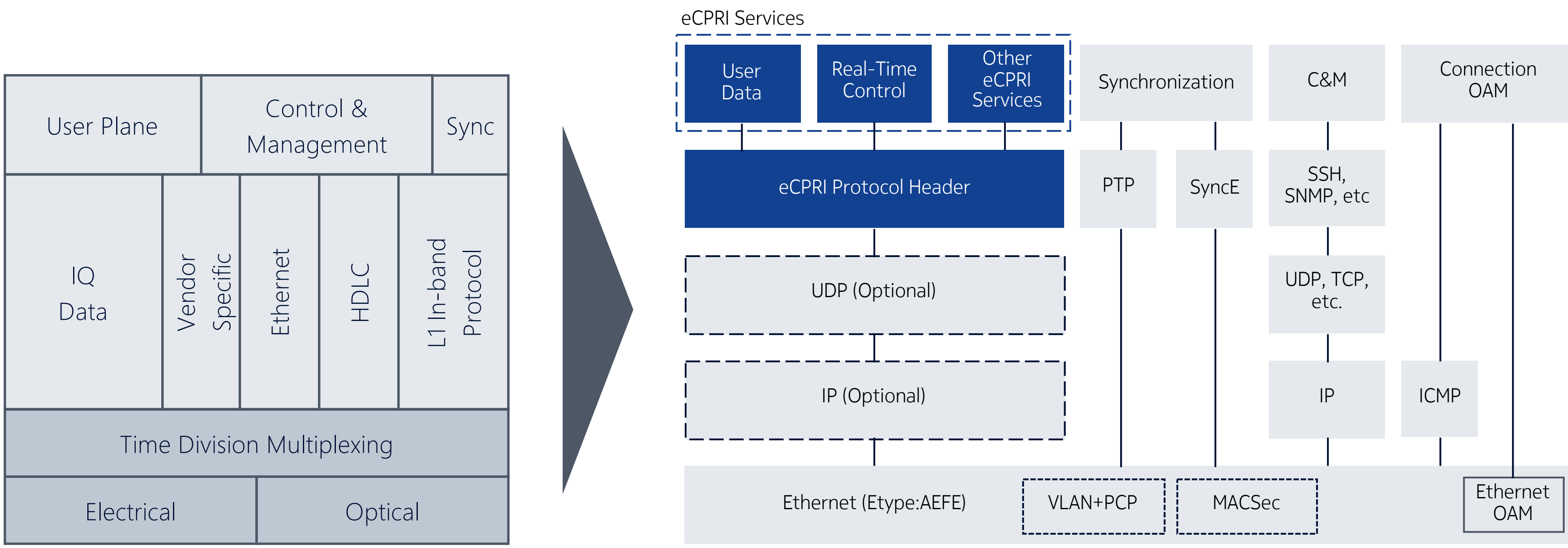


CU: Centralized Unit
DU: Distributed Unit
RU: Radio Unit

5G Fronthaul

Fronthaul Protocol Evolution

From CPRI to eCPRI



CPRI: Common Public Radio Interface

802.1CM: Time-Sensitive Networking (TSN) for Fronthaul

A set protocol and traffic requirements for Fronthaul bridges

	Profile A	Profile B*
IEEE 802.1AC MAC/802.3 MAC/PHY	✓	✓
IEEE 802.1Q VLANs / STP / RSTP	✓	✓
At least 3 queues (1 Strict Priority)	✓	✓
MEF 10.4 Ingress Rate Limiting	✓	✓
ITU-T G.8275.1 Telecom Profile	✓	✓
ITU-T G.8264 SyncE including ESMC	✓	✓
IEEE 802.3 Interspersing Express Traffic	X	✓
IEEE 802.1Q Frame Preemption	X	✓

* Profile B required when using frame sizes greater than 2000 octets for non-Fronthaul traffic

NOTE: this is a partial list, check full list on IEEE 802.1CM

Class	Traffic	Max One-Way Delay	Max One-Way Loss
High	User Plane (fast)	See table below	10^{-7}
Medium	User Plane (slow), C&M Plane (fast)	1ms	10^{-7}
Low	C&M plane (slow)	100ms	10^{-6}

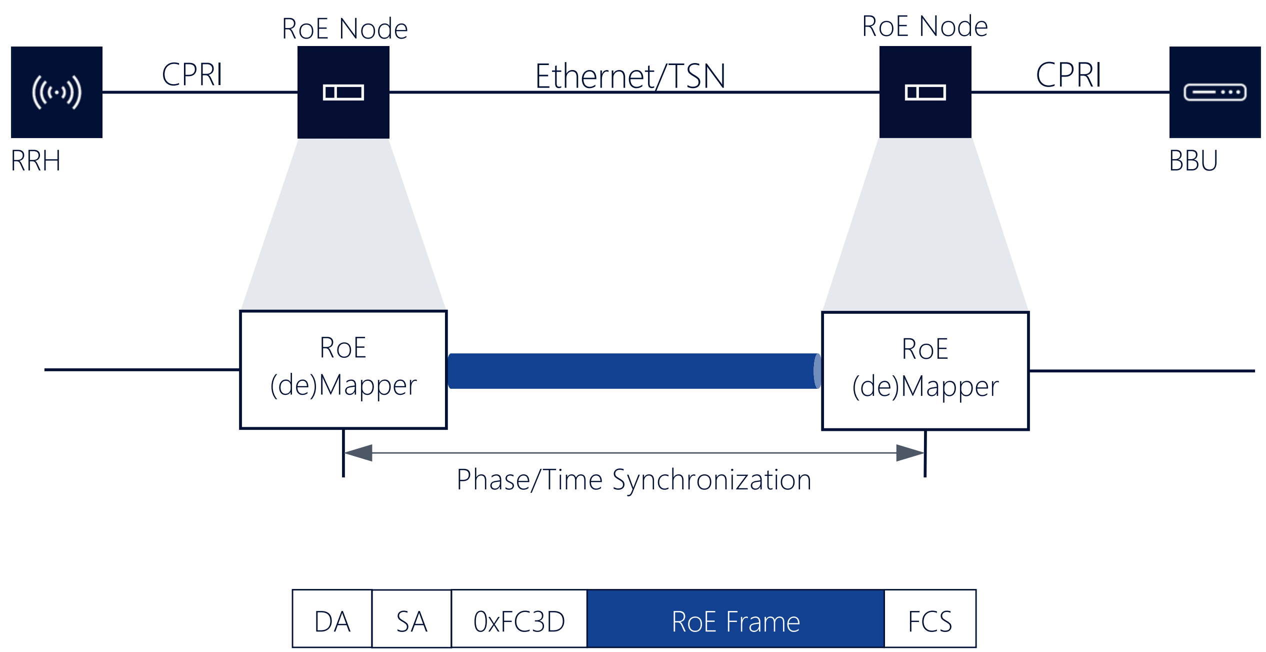
Latency Class	Max One-Way Delay	Max One-Way Loss
High25	25µs	Ultra low latency
High100	100µs	Full E-UTRA/NR
High200	200µs	Fiber links ~40km
High500	500µs	Large latency

Existing Radios Still Use CPRI Interfaces

Hybrid CPRI+eCPRI networks deployments

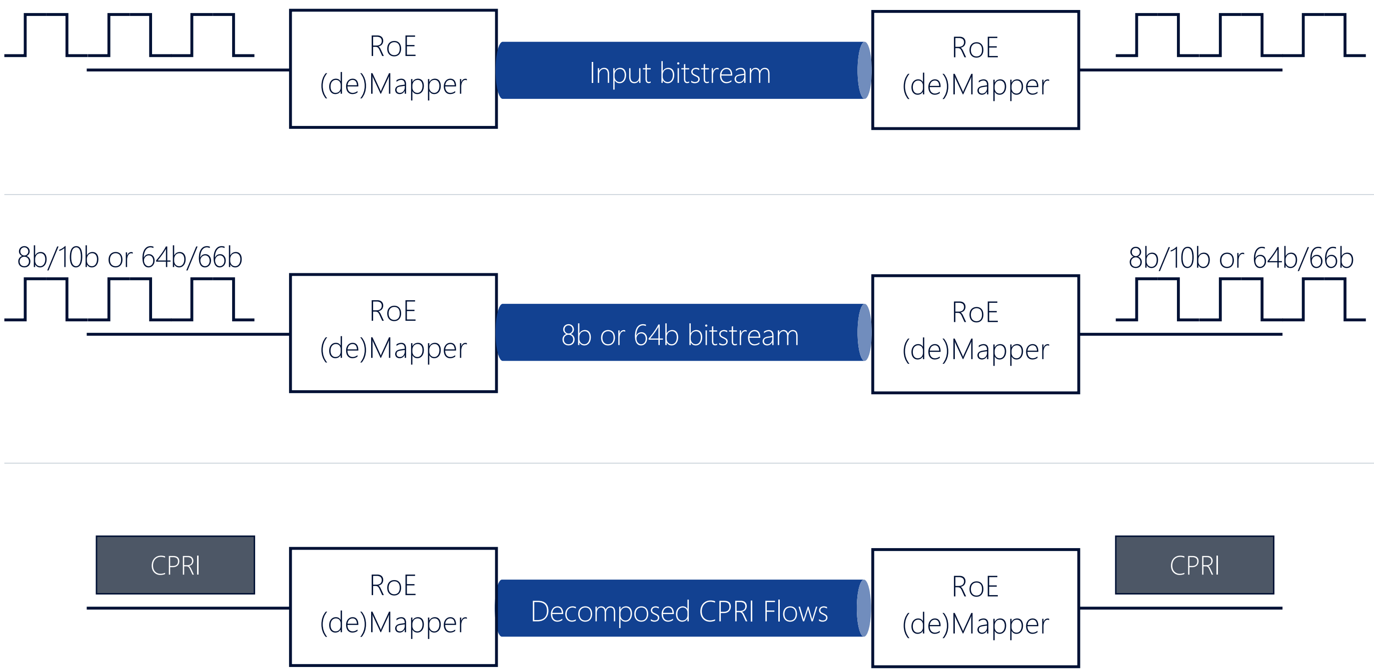
IEEE 1914.3 Radio over Ethernet (RoE)

Transporting CPRI over Ethernet networks



Radio over Ethernet Mapper Types

Flexible mapping for different deployment scenarios



Structure Agnostic Tunneling mode:
- CBR bitstream
- Any protocol
- High interoperability

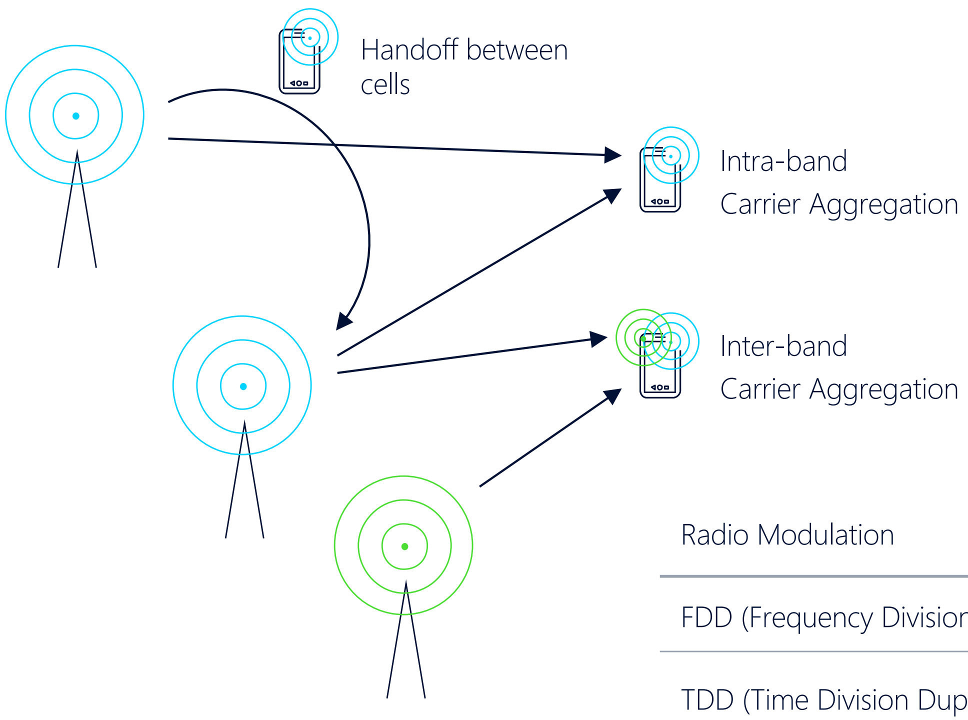
Structure Agnostic Line-Coding-aware mode:
- CBR bitstream
- Needs protocol awareness
- High interoperability
- Some BW savings

Structure-Aware mode:
- CPRI protocol only
- Removes unused bits
- RAN vendor dependent
- Large BW savings

5G Synchronization

Synchronization in Mobile Networks

Why do we need it?



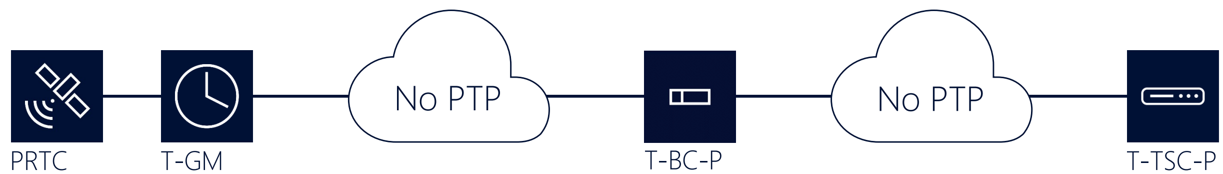
Radio Modulation	Synchronization Requirement	Typical Technologies
FDD (Frequency Division Duplex)	Frequency	GNSS, SONET, SyncE, PTP
TDD (Time Division Duplex)	Frequency + Time/Phase	GNSS, PTP

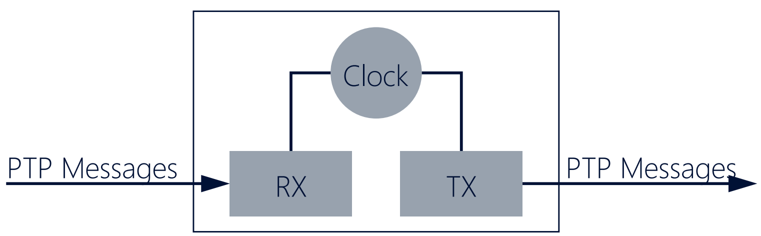
Network Timing Distribution Concepts

Full and partial timing support for IEEE1588v2 / PTP

FTS: Full Timing Support
Telecom Profile: ITU G.8275.1
Encapsulation: Ethernet

PTS: Partial Timing Support
Telecom Profile: ITU G.8275.2
Encapsulation: IP/UDP





PTP Boundary Clock

T-GM: Telecom grandmaster
T-BC: Telecom boundary clock
T-TSC: Telecom slave clock
T-BC-P: Partial-support telecom boundary clock
T-TSC-P: Partial-support telecom slave clock
PRTC: Primary reference time clock

Note on inclusive language:
At the time of this session, the IEEE is still working on defining inclusive language for IEEE1588/PTP through the P1588g PAR.

Timing Accuracy Limits

Time error (TE) contribution by each element in the network

T-BC/T-TSC TE Limits
(G.8273.2)

Class	Constant TE (ns)	Max. TE (ns)	dTE_L MTIE (ns)
A	±50	100	40
B	±20	70	40
C	±10	30	10

Note: there are other requirements that need to be considered to fully comply with clock classes

PRTC+T-GM TE Limits
(G.8272/G.8272.1)

Class	Constant TE (ns)
PRTC-A	±100
PRTC-B	±40
ePRTC	±30

Other sources of time error:

- Link asymmetry
- Temperature variation
- Component variation

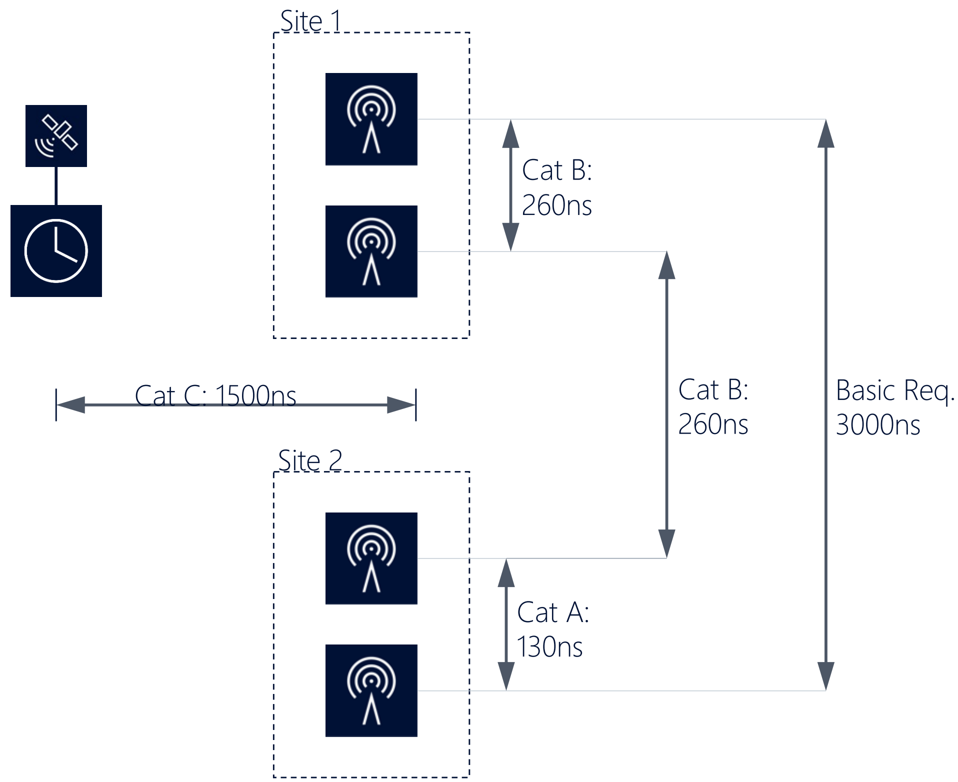
5G Timing Accuracy Requirements

Radio features drive network timing error limits

Category	Max TE	Radio Features
A	130ns**	NR (FR2) intra-band contiguous carrier aggregation, with or without MIMO or TX diversity
B	260ns**	NR intra-band contiguous (FR1 only) and Intra-band non-contiguous (FR2 only) carrier aggregation, with or without MIMO or TX diversity
C	1500ns*	Basic NR TDD New radio (NR) intra-band non-contiguous (FR1 only) and inter-band carrier aggregation, with or without MIMO or TX diversity

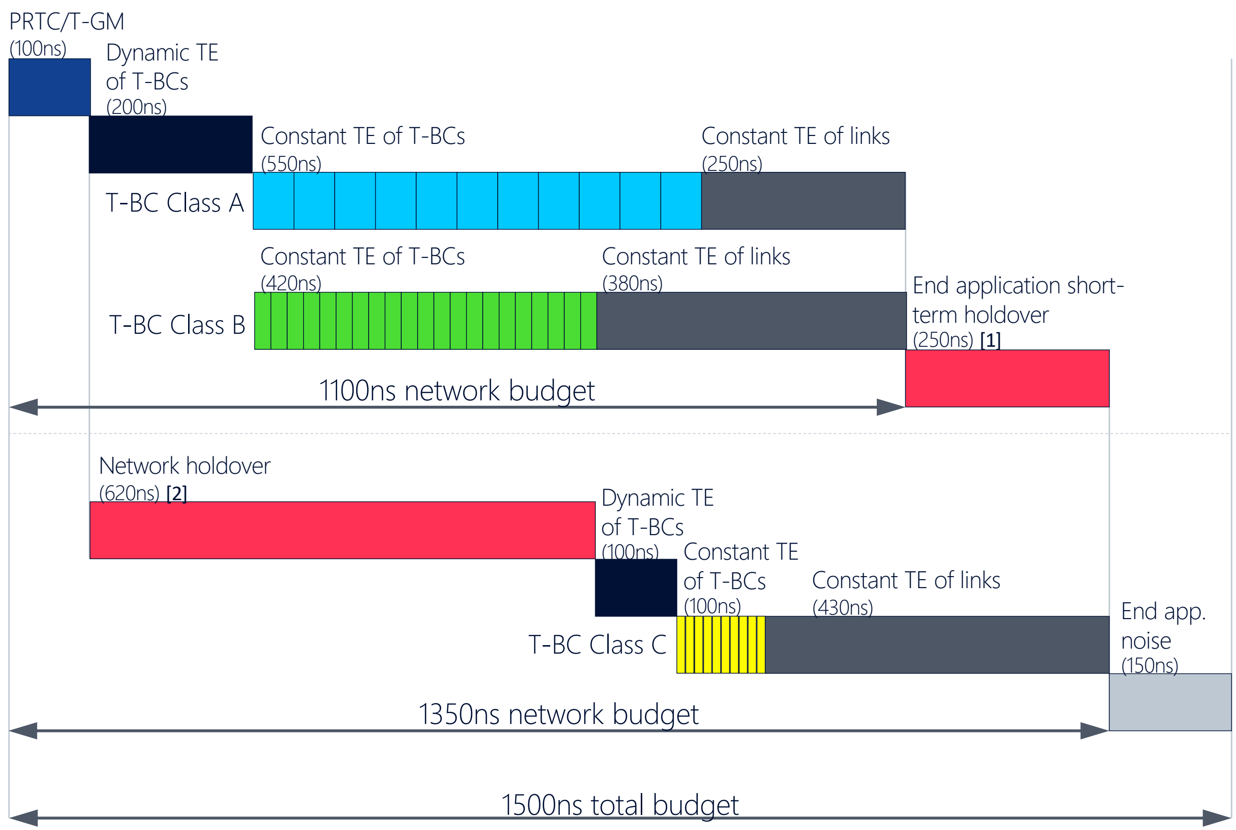
* Absolute value: from the antenna to the timing source

** Relative value: between any 2 antennas



Backhaul Time Error Budget Examples

Cat C requirements as described on ITU G.8271.1



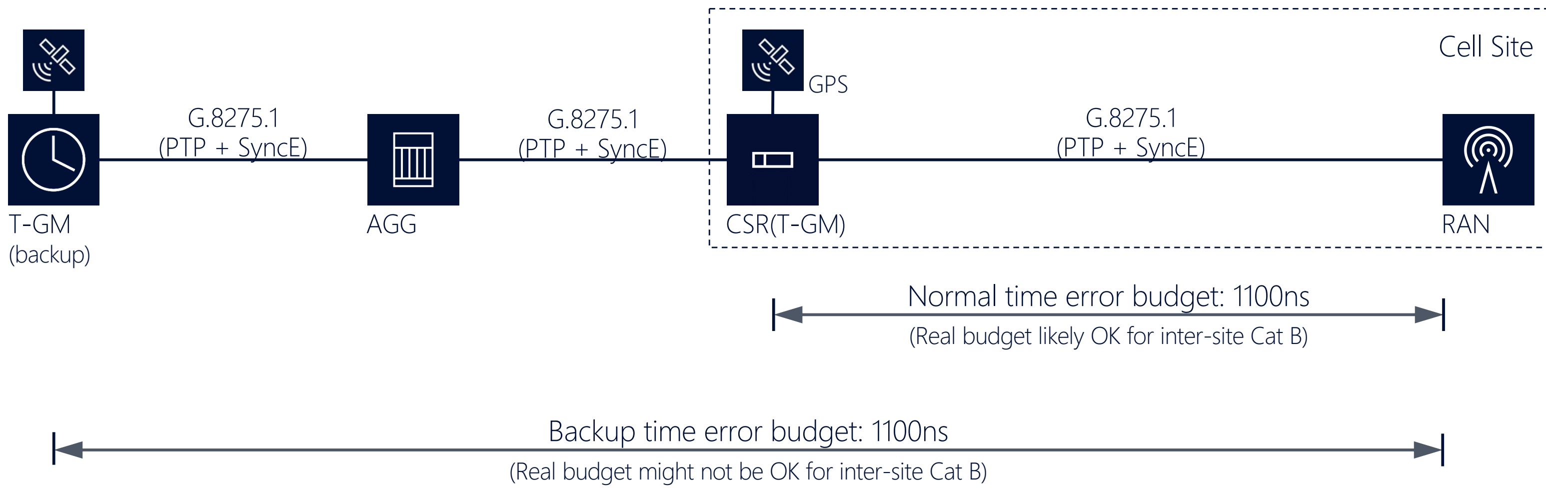
Notes:

[1] Considers loss of PRTC reference and T-GM re-selection by the application (RAN)

[2] Considers long loss of PRTC reference and enhanced SyncE and T-BC Class C to the application (RAN)

Typical Backhaul Deployment Architecture

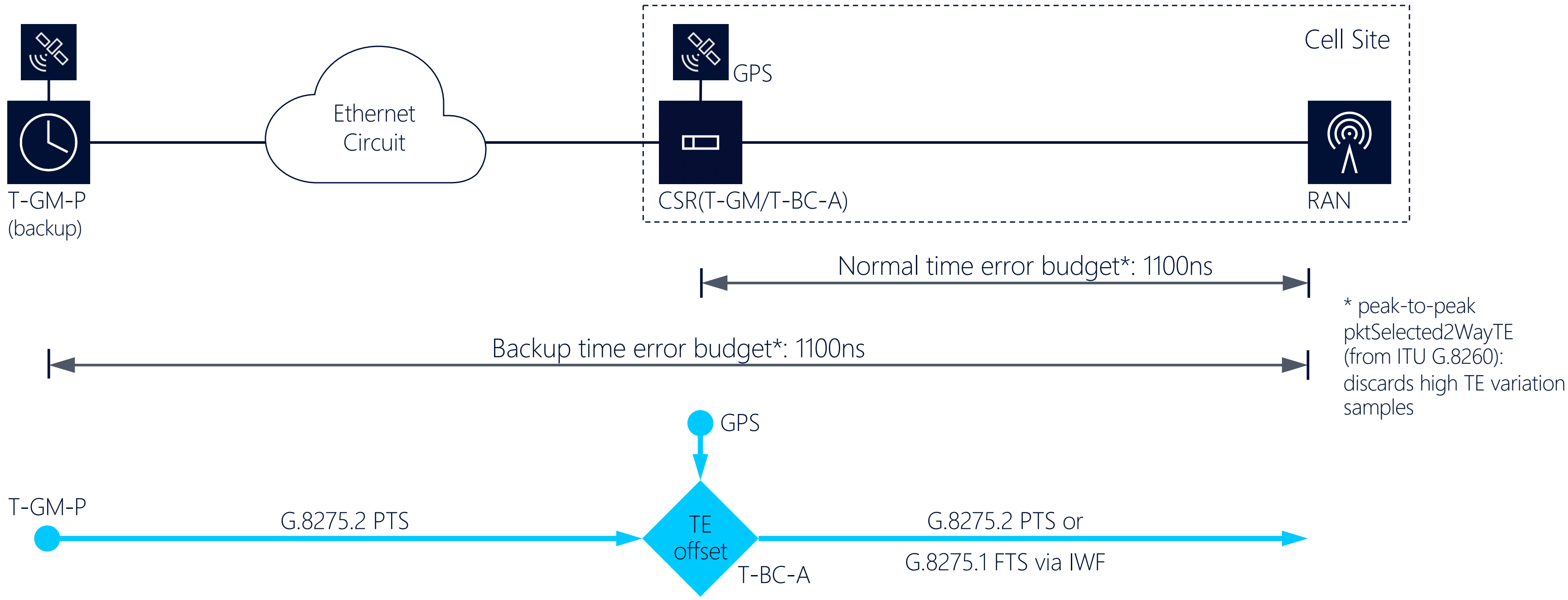
FTS – Full Timing Support via G.8275.1



Backup used if the operator owns the fiber infrastructure

Backhaul Timing Redundancy via PTS Network

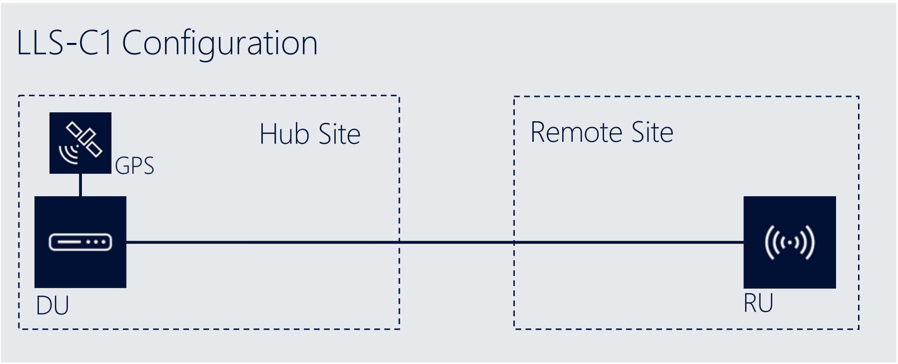
APTS – Assisted Partial Timing Support

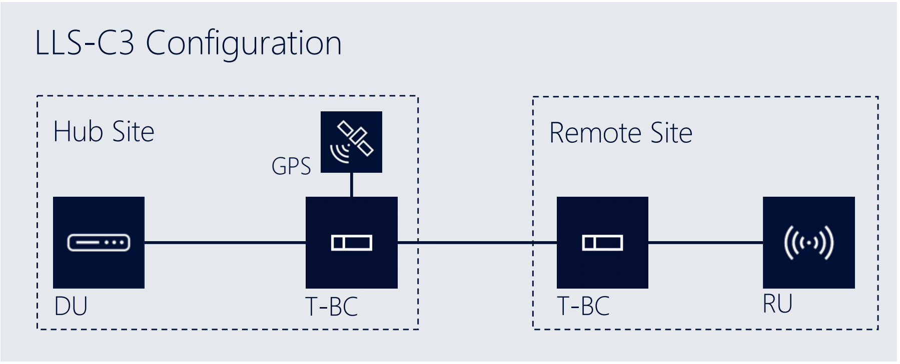


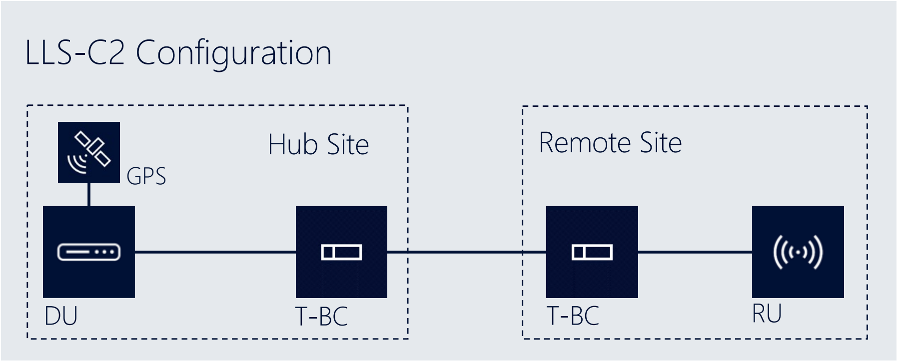
Note: PTS networks need to be carefully planned as their PDV and delay asymmetry can vary with the number of hops, traffic profile, queueing characteristics, reroute events, etc.

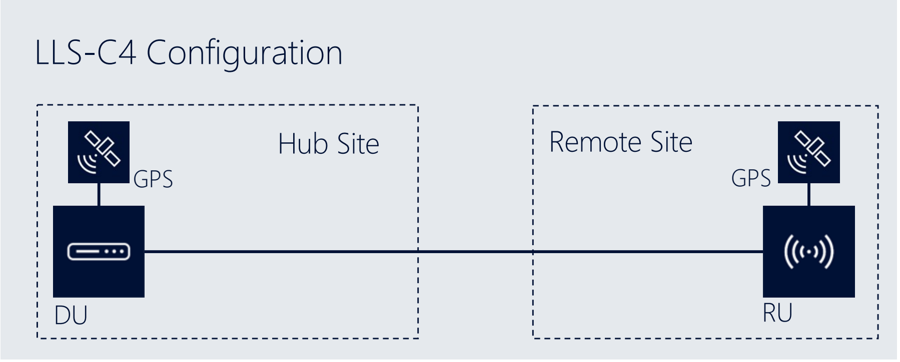
Fronthaul Synchronization Topologies

According to the O-RAN WG4 CUS Specification



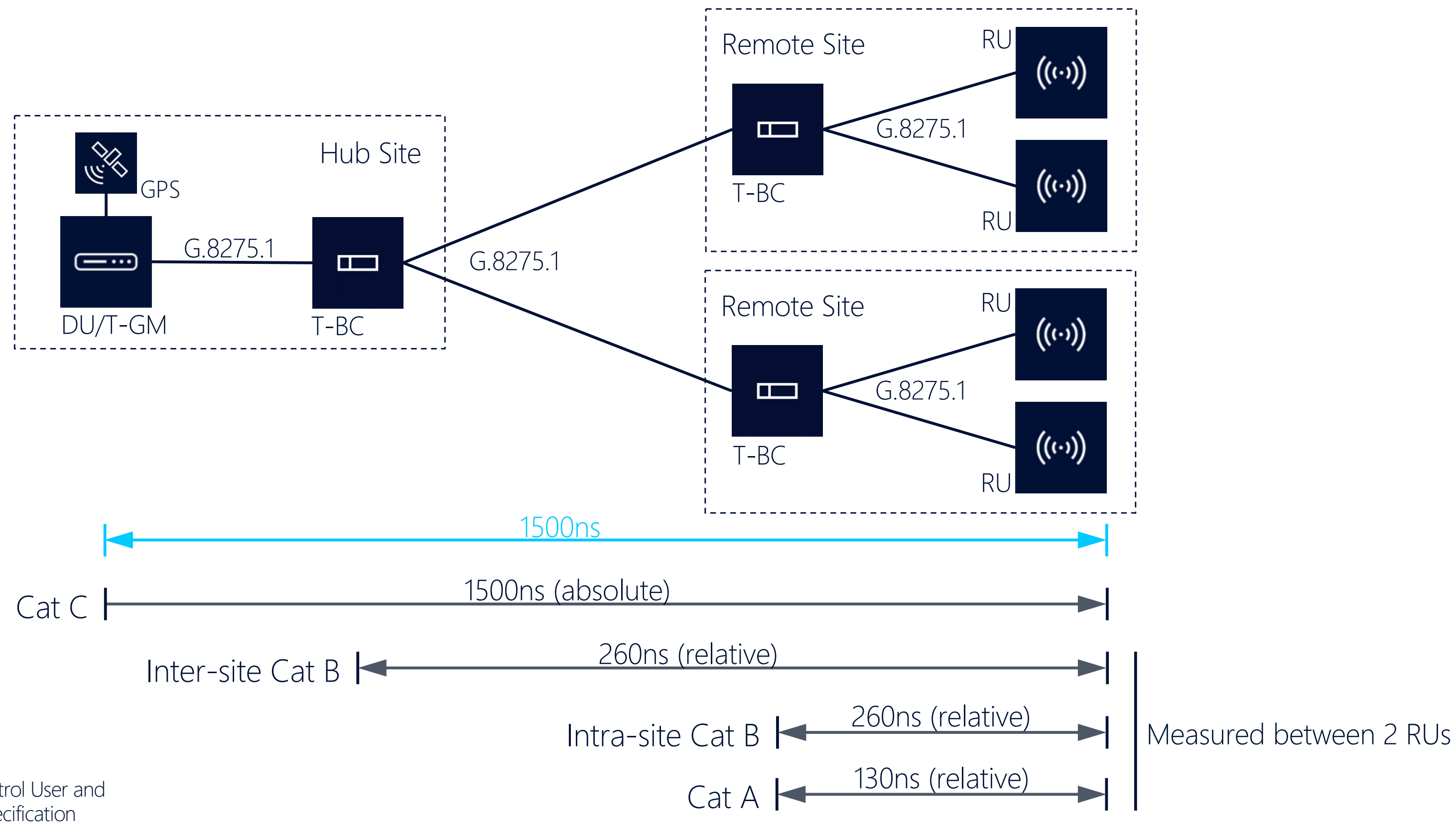






Fronthaul Deployment Example

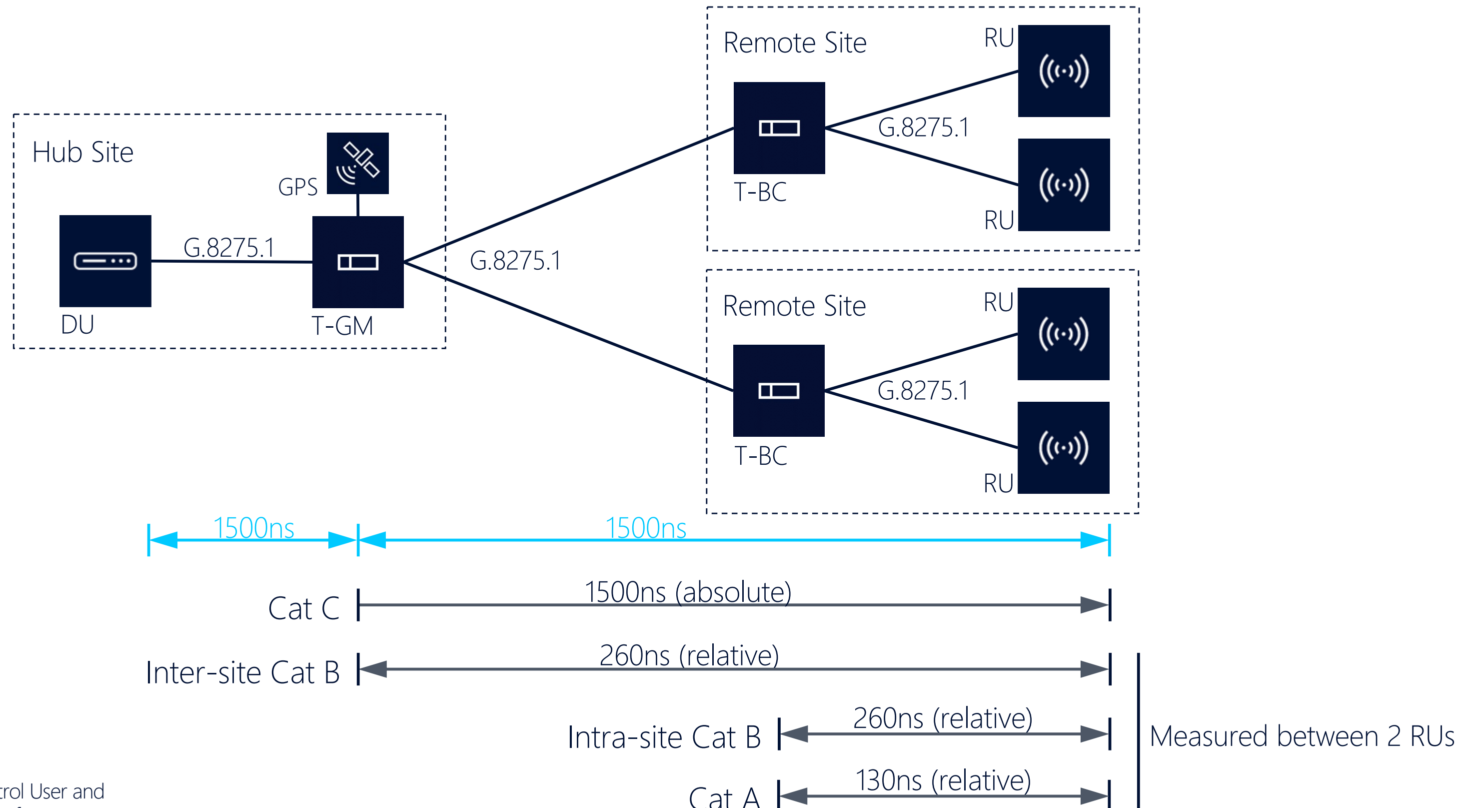
Fronthaul network time error budgets (O-RAN LLS-C2)



Source: O-RAN WG4 Control User and Synchronization Plane Specification

Fronthaul Deployment Example

Fronthaul network time error budgets (O-RAN LLS-C3)



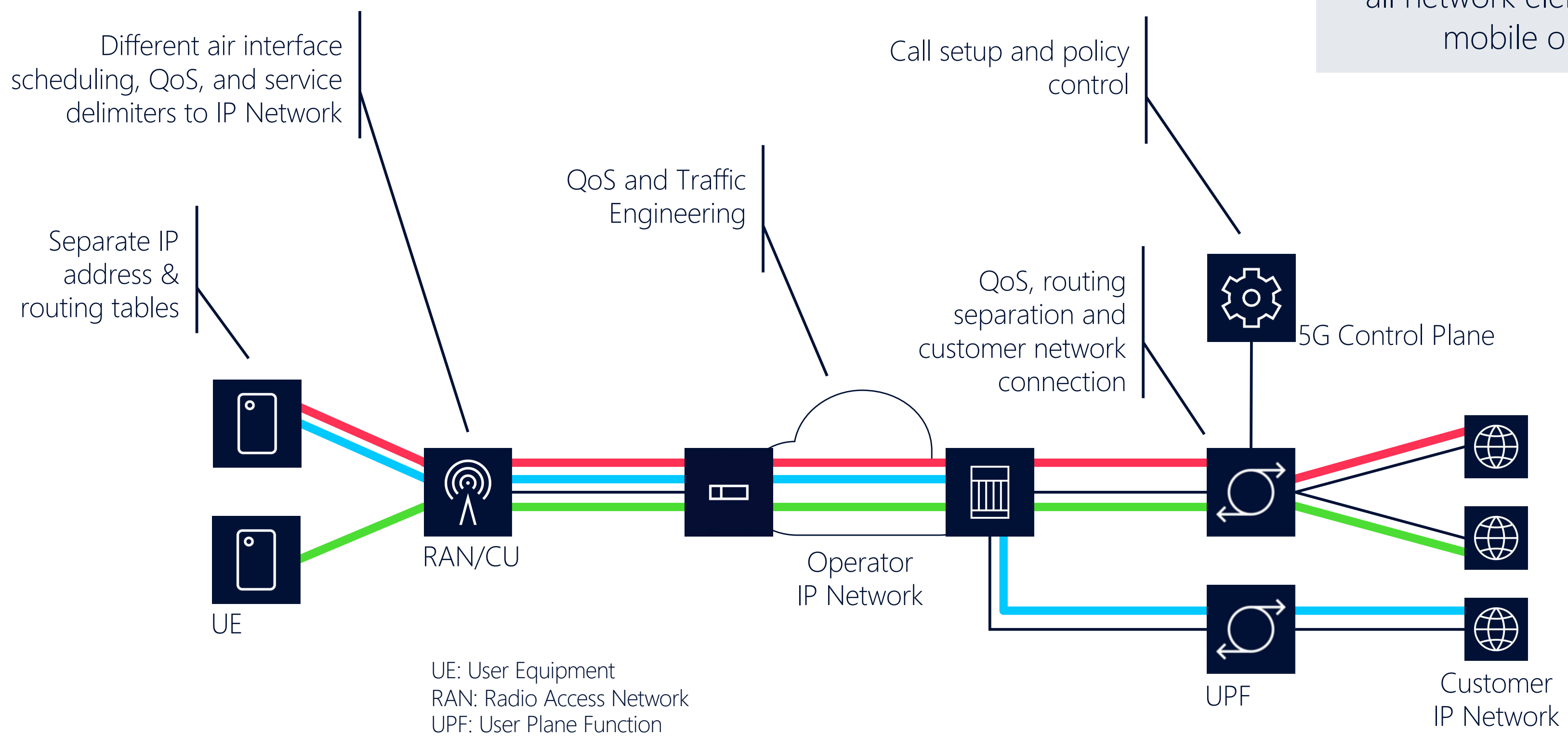
Source: O-RAN WG4 Control User and Synchronization Plane Specification

5G Network Slicing

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

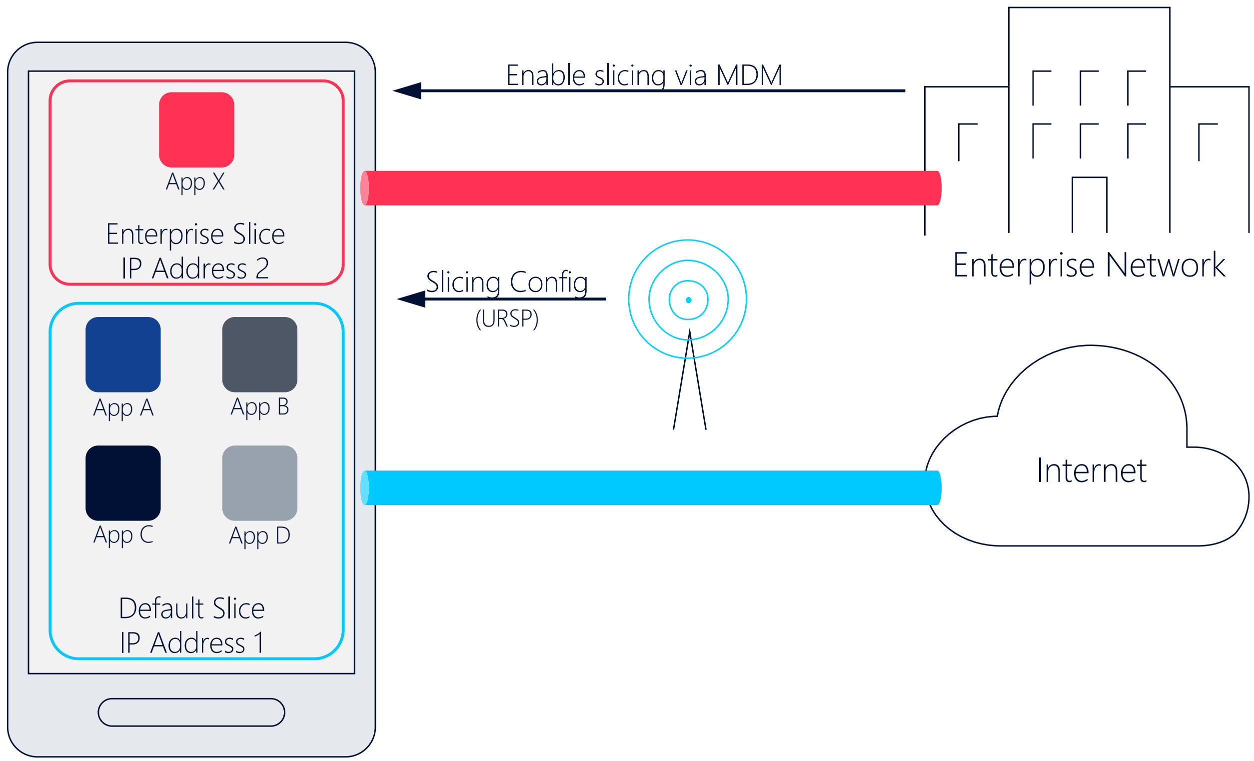
Using 5G Network Slicing

Protected Enterprise app use case

URSP Slicing Selection

Precedence 1
- App: "App X ID"
- Slice ID: SST:1/SD:2
- DNN: Enterprise

Precedence 2
- App: match-all
- Slice ID: SST:1/SD:1
- DNN: Internet

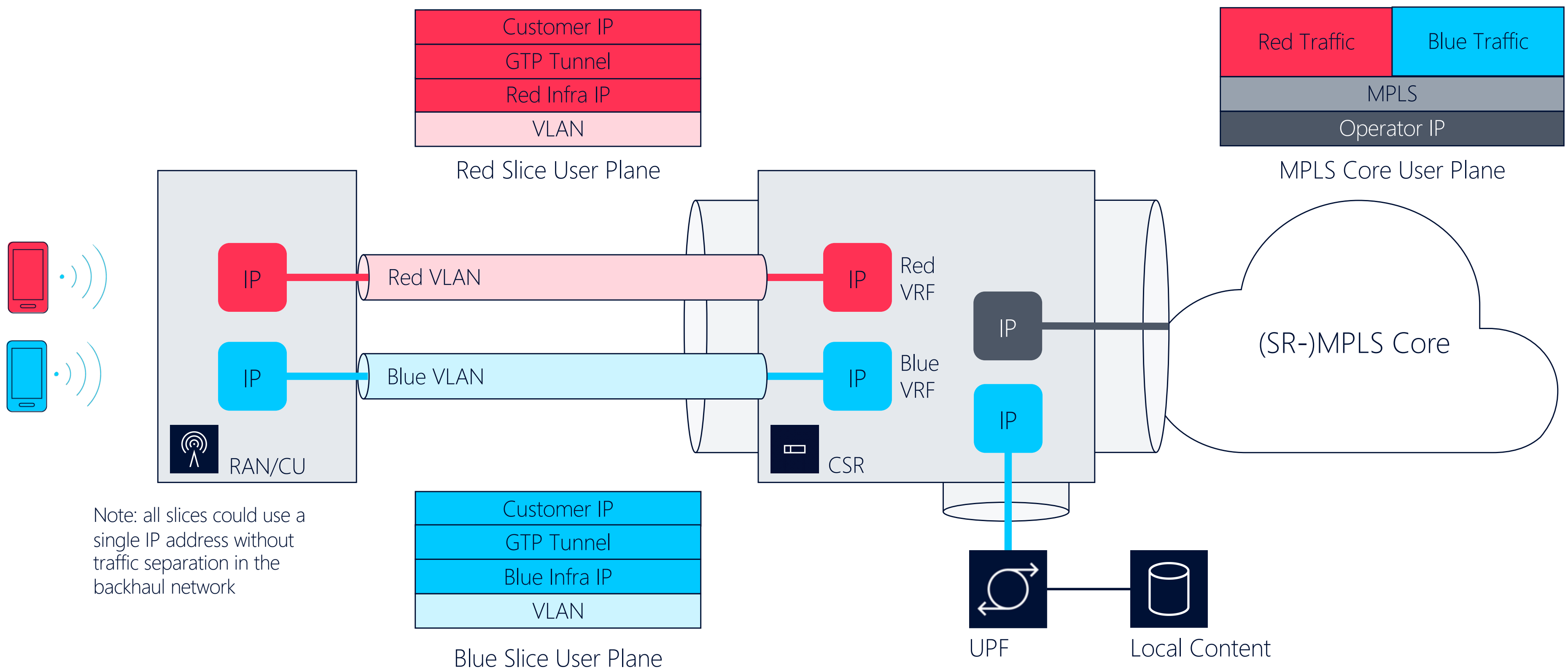


URSP: UE Route Selection Policy

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

Building 5G Network Slicing

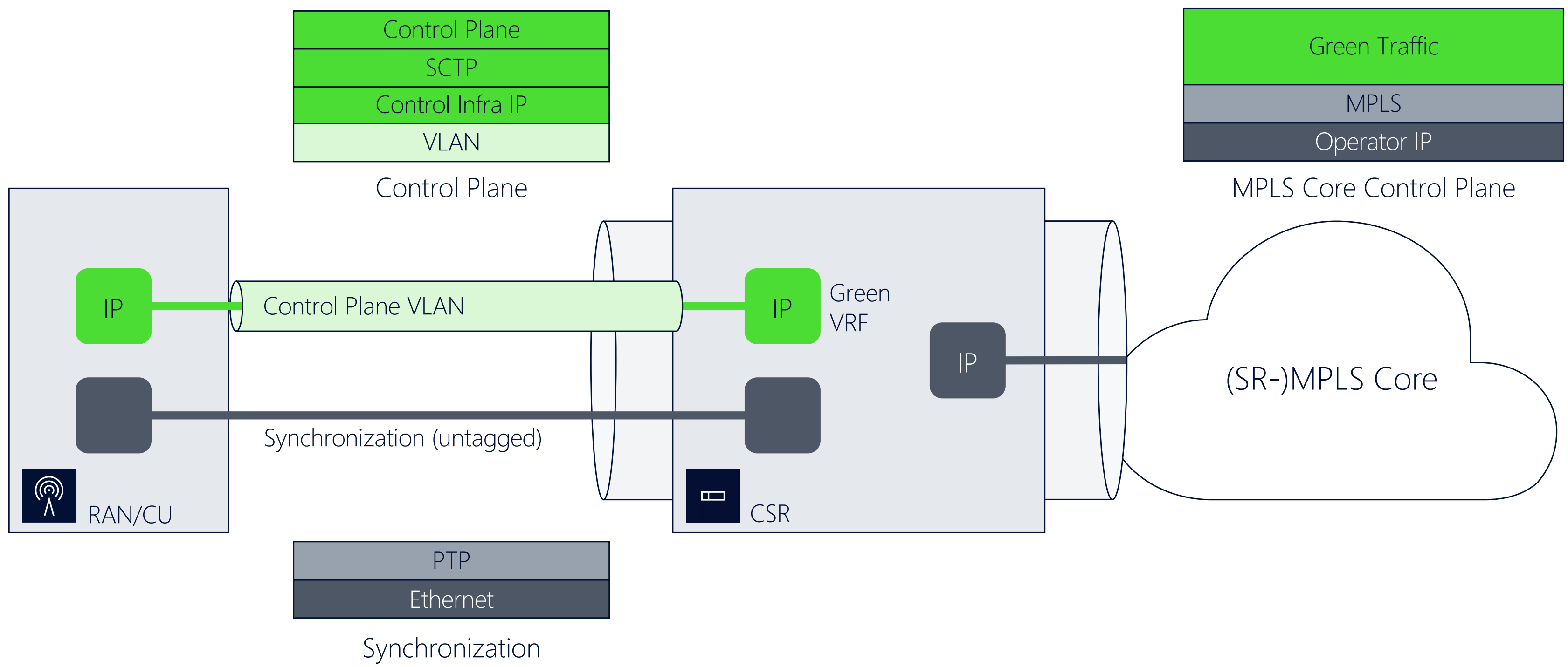
Ingress User Plane classification – MPLS example



Note: all slices could use a single IP address without traffic separation in the backhaul network

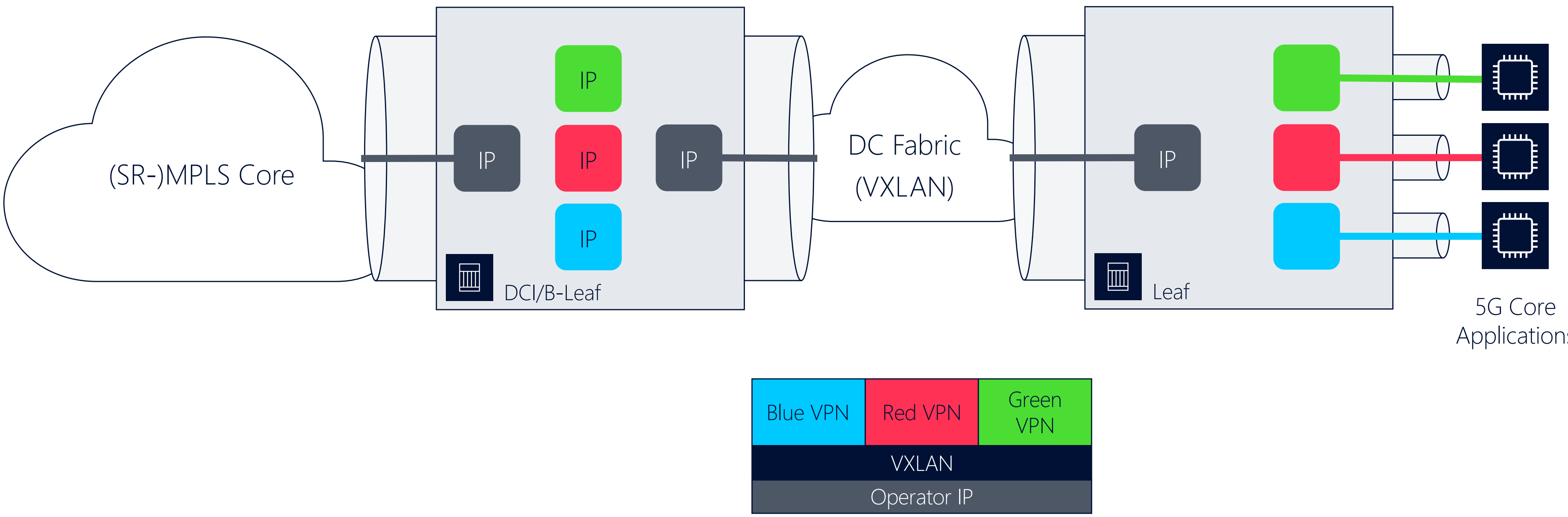
Building 5G Network Slicing

Synchronization and Control planes – MPLS example



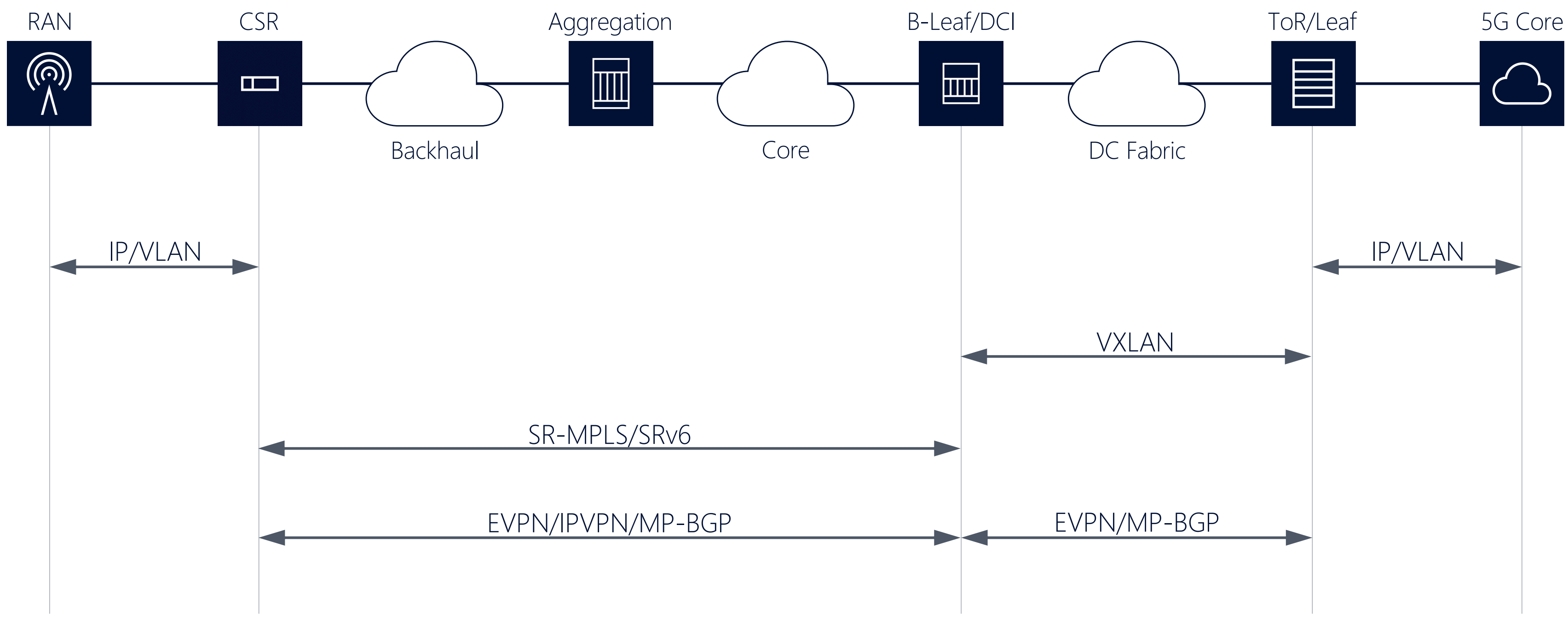
Building 5G Network Slicing

Interconnection to the 5G Core in the Data Center



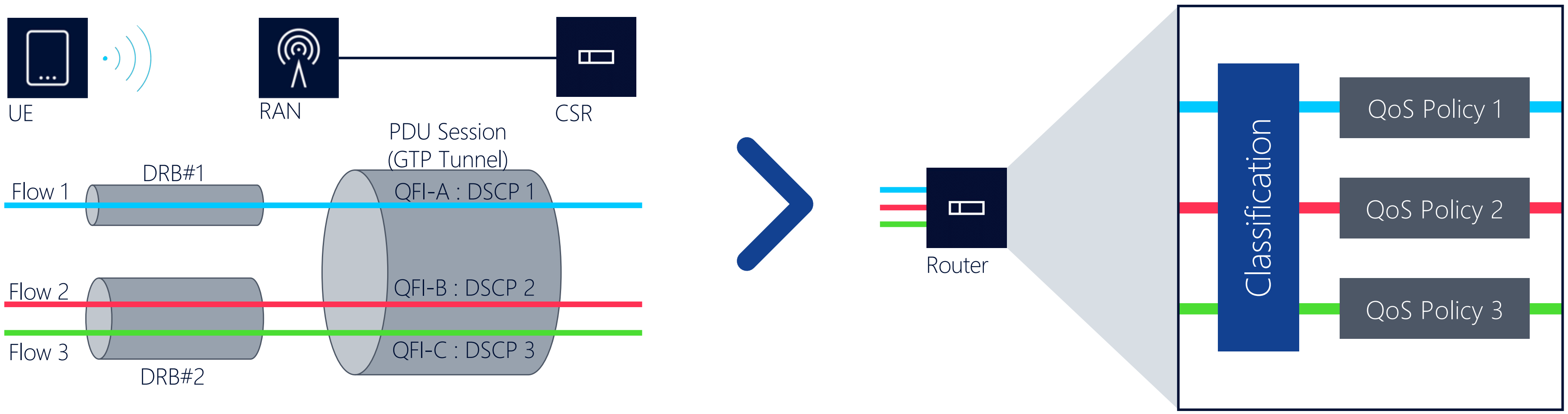
End-to-End 5G Slicing Architecture

Flexible design for any service



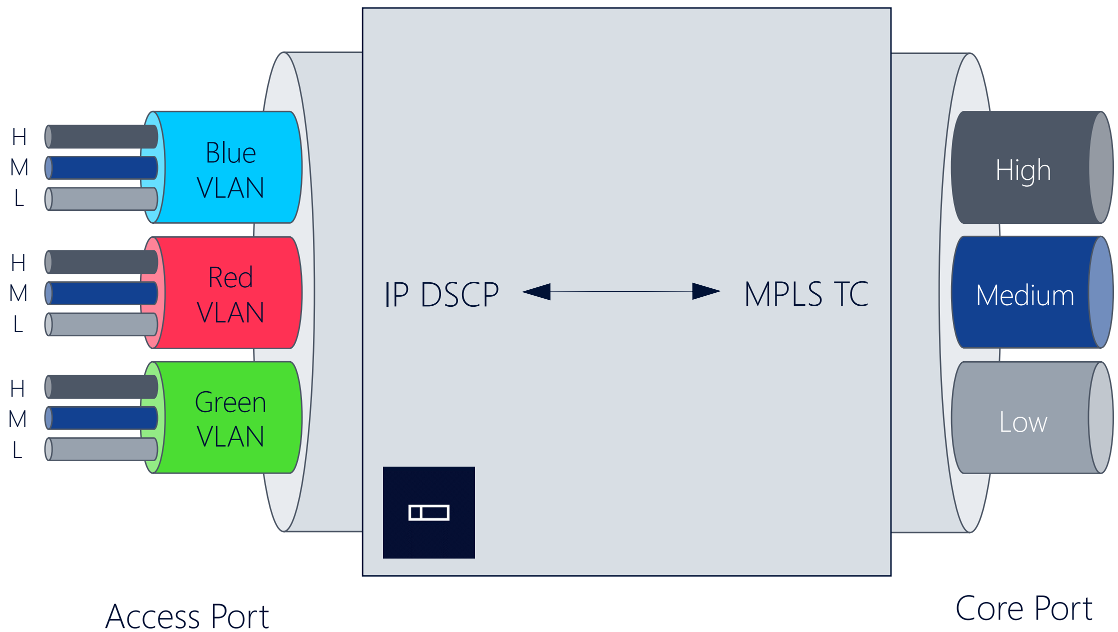
5G Flow-Based QoS Capabilities

Granular control of traffic flows



High-Level QoS Model for Network Slicing

Hierarchical queueing in the access, flat queueing in the Core



Thank You!

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