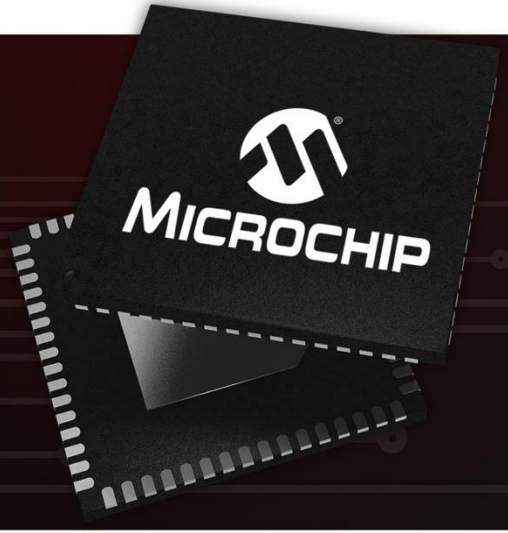
MICROCHIP



A Leading Provider of Microcontroller, Security, Mixed-Signal, Analog & Flash-IP Solutions

Phase Sync

Italo Tertuliano

Every Major Market We Address Is Developing New Services, & These Services Need More Precise Timing In More Places

Power Utilities

Financial Services

Data Center / Cloud Services

Communications

Transportation

Smart Cities

Position Navigation & Time Services
Connected Vehicles
Drones
etc

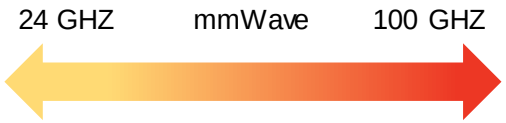
- 5G promises to deliver Real Time Low Latency Broadband connections for Machines and Humans
- LTE-TDD Millimeter Microwave Ultra Wideband Radio Technologies for Broadband Services Require Timing
- IP Video over 5G broadband Services will require Timing for IP Encoders and Decoders

5G evolution from Fixed to Mobile Wireless

5G Today	Fixed Wireless for broadband	Millimeter Microwave LTE TDD Technology
5G Future	Mobility	Ultra Wide Band Hand Sets
5G Timing	LTE TDD requires +/- 1.5 microseconds absolute time	LTE advanced features can add additional timing requirements

Fixed Wireless Broadband will be widely deployed by many players

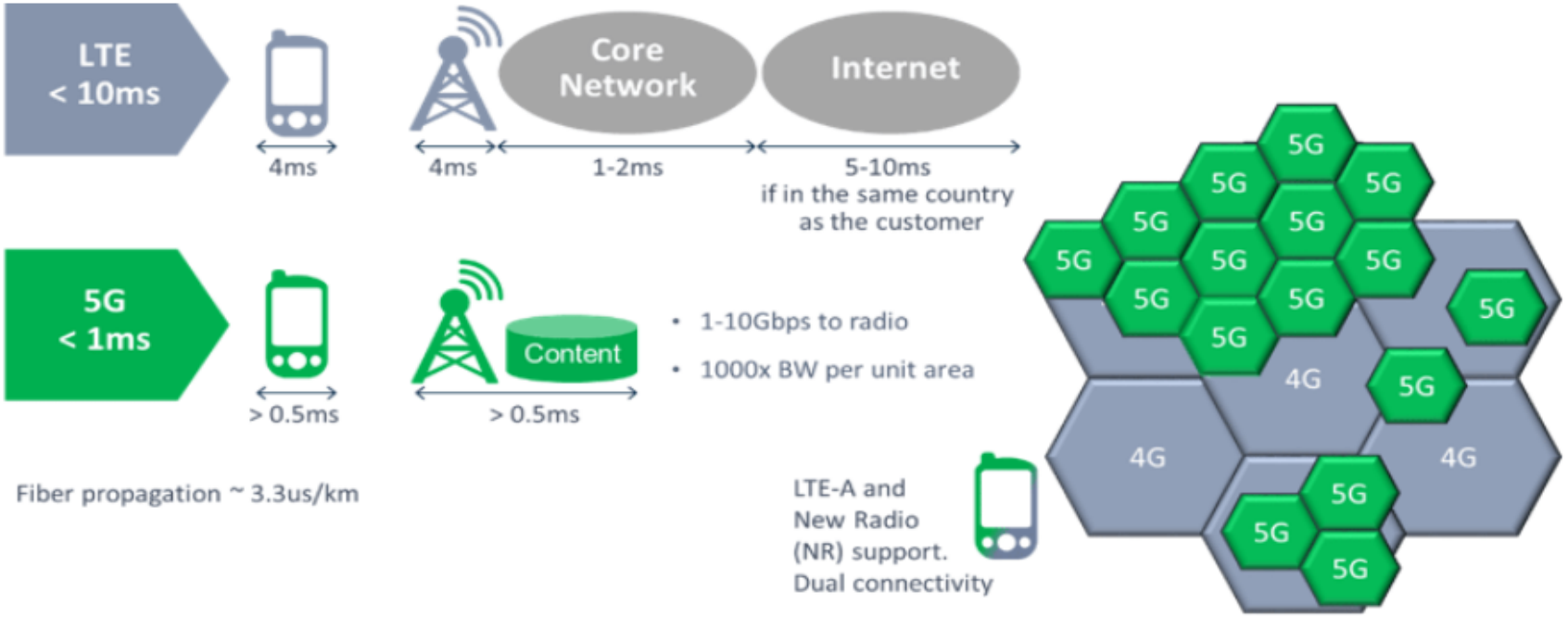
Wireless Telecom Operators
Cable Operators
Wireline Telecom Operators
Power Utilities



5G Issues to be handled

- Co-Channel Interference
- Ultra Low Latency
- More Capacity
- Security
- Phase services
- Industry Standard

4G and 5G Latency Difference and Co-Channel Interference



Sync Network vs GPS at Radio

	Sync Network Grandmaster	GPS at eNB/gNB
Needs network engineering	**Yes**	No
CAPEX	**Average**	$800-$1000 per site?: receptor, cable, antenna, arrestor, accessories, conduit, instalation services
Appliable for 5G (Midhaul/BBU sync)	**Yes**	No, does not meet minimum requirements (800ns – 1000 ns) 5G requires 130ns (Grandmasters 40ns / PRTC-B)
OPEX	**Low, dozens antennas**	Medium/High: hundred antennas
Redundancy/Holdover	**Yes, many days (Atomic Oscillators) and sync network to provide redundancy**	No, GPS can't provide redundancy neither holdover. Quarts oscillator can't hold phase for seconds
Services Impact	**Zero**	Affected radio MUST be removed from the cluster to avoid co-channel interference at 5G cluster
Transport Sync Routers, Switches, etc	**Yes**	No
Multivendor	**Yes**	No, require additional GPS for each vendor

Focus on Telecom

4G Mobile Backhaul & Basic LTE Services
5G Mobile Fronthaul & Advanced NR Services

Synchronism Types

Frequency Distribution: To ensure that two or more devices on the same network operating at the same Bit rate (speed)

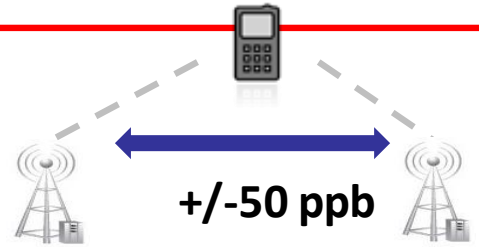
Time Synchronization: Ensure that the network elements are at the same time base (Time of Day traceable to UTC).

Phase Synchronization: To ensure that two or more of the same network equipment operating at the same speed and at the same time.

Mobile Network Frequency or Phase Requirements are Based on Radio Service Inter Cell Alignment Specifications

FDD: frequency alignment

2G:GSM, 3G:WCDMA, 4G:LTE



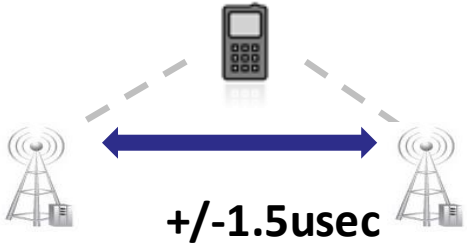
SyncE was designed for this application. RAN vendors pushing BC as SyncE not stable enough to support first 5G NR Frequency recovery

FDD/TDD: Absolute phase alignment

4G: LTE, 4.5G LTE-A

5G NR Basic Service :

+/-1.5usec Time Error from UTC

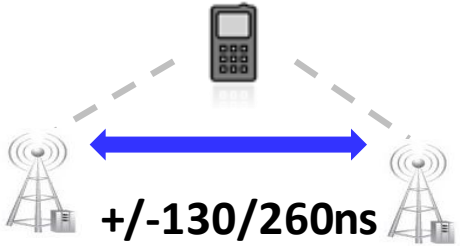


Ethernet / TDD require distributed PTP based Timing Architectures

5G NR Relative phase alignment

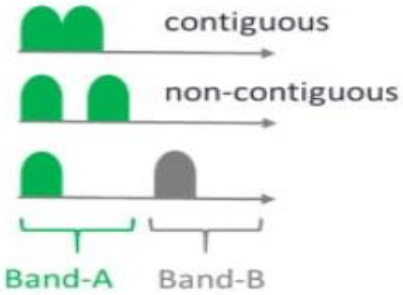
+/- range 130 to 260 nanoseconds

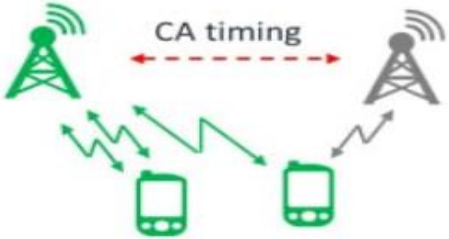
Radio to Radio



Advanced 5G services at the network edge will be mostly PTP based, especially for small 5G Radio Units

Mobile Network Frequency or Phase Requirements are Based on Radio Service Inter Cell Alignment Specifications





LTE-A timing/sync

TDD	+/- 1 to 5 µs
eICIC	+/- 1 µs
CoMP	+/- 200 ns to 1.5 µs

5G timing/sync

TDD	+/- 1.5 µs
CA	+/- 260 ns (Intra/Inter-band non-contiguous)
CA	+/- 130 ns (Intra-band contiguous)
MIMO	+/- 65 ns

3GPP Time Error Limits for LTE-TDD / LTE-A & Basic 5G Services

Absolute (1.5us)

Application	eNB Phase	Problems if Non Compliant
LTE (TDD)	**±1.5us**	Spectrum inefficiency, Packet collision
LTE-A function		
eICIC	**±1.5us**	Interference and crosstalk
CoMP	**±1.5us**	Poor signal quality
MBSFN	**±1.5us**	Video broadcast degradation
		3GPP TS 36.101/104

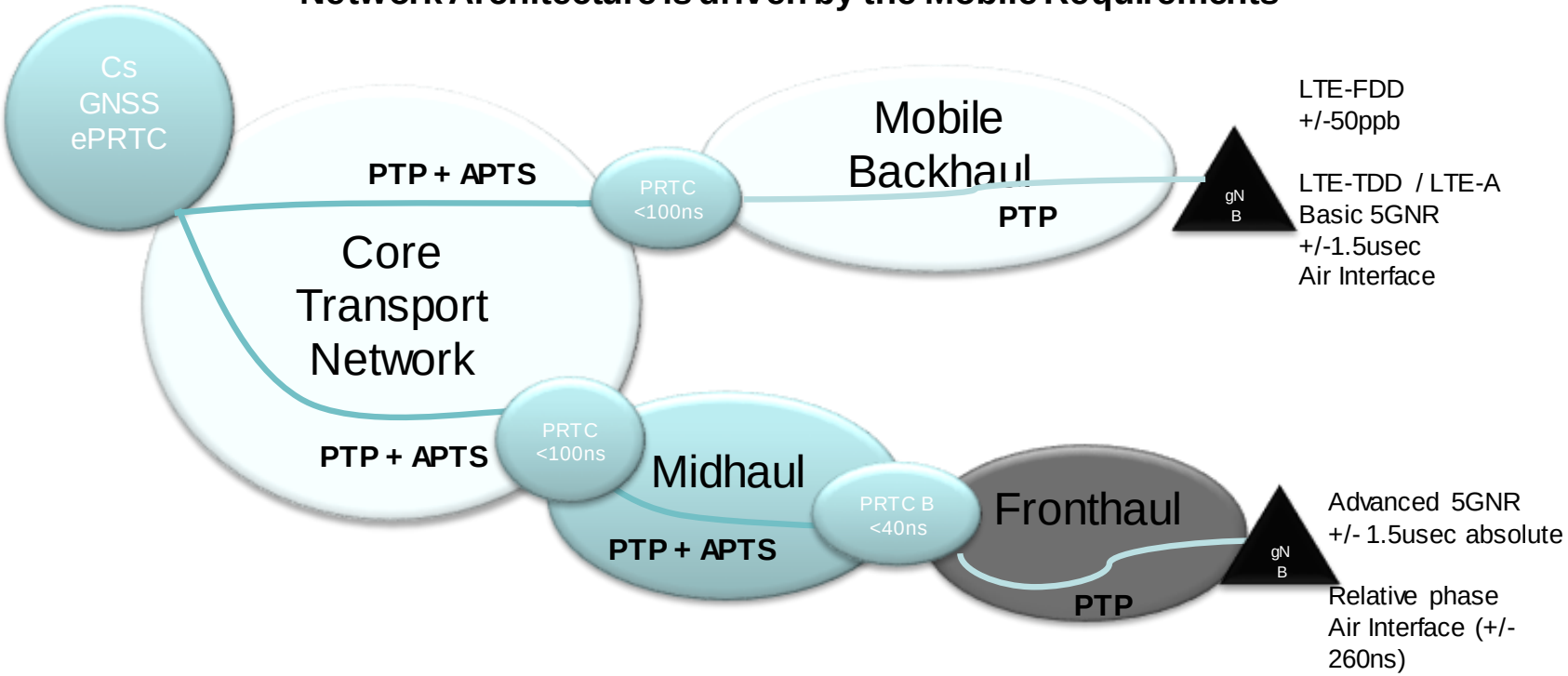
Intra-site & relative

TABLE II: MORE STRINGENT REQUIREMENT SET BY 3GPP FOR FUTURE NETWORKS.

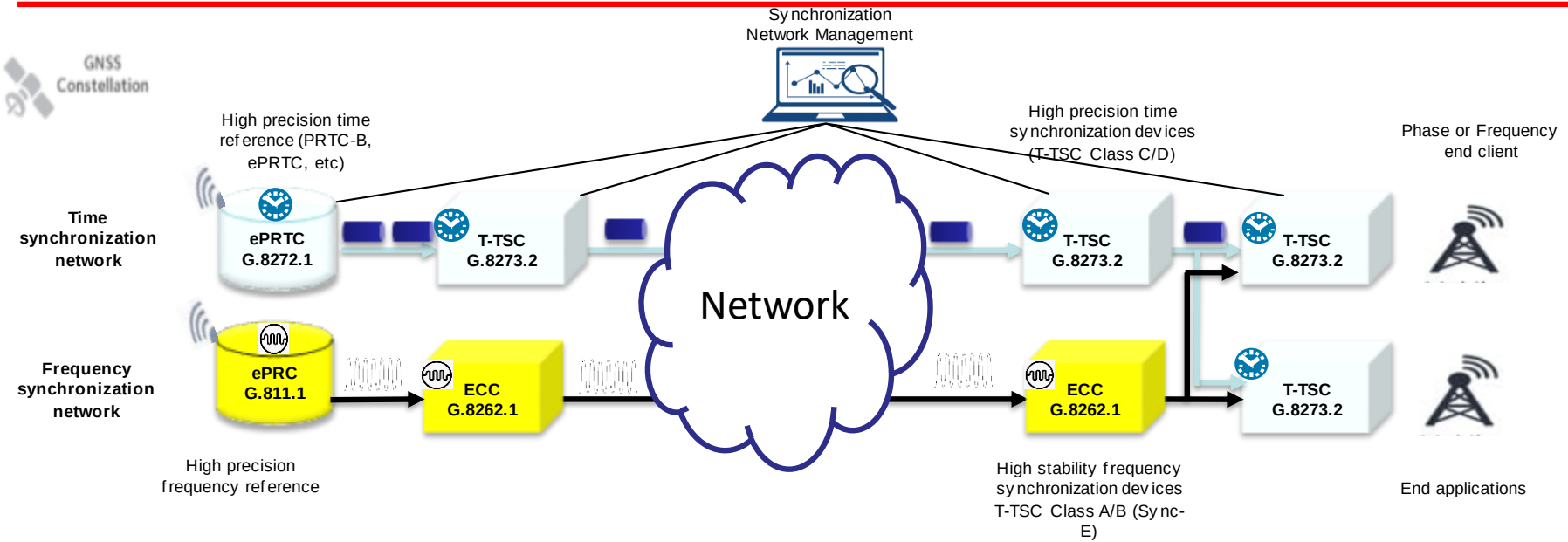
Typical applications (for information)	Time error requirements (Note 1)	Specification
Intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity, and inter-band carrier aggregation with or without MIMO or TX diversity	±260 ns	3GPP 36.104 V13.1.0 section 6.5.3.1
Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity	±130 ns	3GPP 36.104 V13.1.0 section 6.5.3.1
MIMO or TX diversity transmissions, at each carrier frequency	±65 ns	3GPP 36.104 V13.1.0 section 6.5.3.1

4G & 5G Synchronization Architecture: High Precision Core Clocks for Holdover, Distributed PRTC for Phase at the Network Edge

Network Architecture is driven by the Mobile Requirements



4.5G & 5G Synchronization Architecture: High Precision Core Clocks and new transport elements class



ePRTC – Enhanced Primary Reference Time Clock
ePRC – Enhanced Primary Reference Clock
T-TSC – Telecom Time Slave Clock
T-BC – Telecom Boundary Clock
EEC – Synchronous Ethernet Equipment Clock
cTE – Constant Time Error

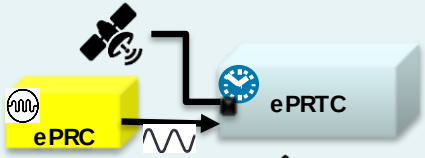
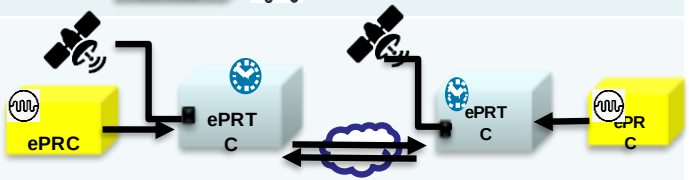
cTE (ns)	Class A	Class B	Class C
T-TSC	50	20	10
T-BC	50	20	10

*Class D for future study

MaxTE (ns)	Class A	Class B	Class C
T-TSC	100	70	30
T-BC	100	70	30

*Class D for future study (goal 5ns)

New Standard Clocks for 5G and so on

PRTC Type	Performance	Device Configuration
PRTC A (G.8272)	**Maximum time error 100ns**	
PRTC B (G.8272)	**Maximum time error 40ns** Error reduction of GNSS signal reception by multi-band receiver	
Enhanced PRTC (ePRTC) (G.8272.1)	**Maximum time error 30ns** Time synchronization is maintained when GNSS reception is impossible by frequency reference device ePRC (within 100ns over 14 days)	
Coherent network PRTC (cnPRTC) (G.8275 et al.) under discussion	**Maximum time error ?** Reliability improved by mutual monitoring and comparison through the network High precision achieved by mutual synchronization	

Holdover
Time Error Budget based on G.8271.1

ITU-T G.8271.1/Y.1366.1

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

(10/2017)

Network limits for time synchronization in packet networks

Table V.1 – Example of time error allocation

Budget component	Failure scenario (a) *(T-GM rearrangement)*	Failure scenario (b) *(Short GNSS interruption)*	Failure scenario (c) *(Long holdover periods, e.g., 1 day)*
PRTC (ce_{ref})	100 ns	100 ns	100 ns

V.3 Failure scenarios

There are three main failure scenarios considered here.

a) Failures in the synchronization network that cause the end application clock to enter holdover for a short period. This is denoted TE_{REA} (rearrangement TE), which is provided by end application, and is normally considered to be less than 250 ns.

– As an example, this might be triggered by a loss of PRTC traceability of one of the redundant T-GMs in the network. The loss of traceability is indicated by the clockClass field carried in the Announce messages indicating a degraded quality level, and triggers the BMCA to run. If the clockClass is set to a value that is unacceptable to the end application, then the clock will enter holdover for a short period (e.g., 1 min) prior to synchronizing to another T-GM.

b) Failures in the synchronization network that do not cause the end application clock to enter holdover. This is denoted TE_{HO} (holdover TE), which is provided by PRTC, and is normally considered to be less than 400 ns.

– As an example, this might be related to a short interruption of the GNSS signal (e.g., 5 min), causing the PRTC to go into holdover for a short period. During this period, either a PRC-traceable synchronous Ethernet signal or a stable internal oscillator might be used as a back-up to the PRTC. In this case, the clockClass field continues to indicate an acceptable quality level so that the end application clock stays locked to the PTP reference.

c) Long interruption to the GNSS signal, with no alternative UTC-traceable T-GM available. The long-term holdover condition is handled as a special case where the 1.5 µs limit is exceeded. This is assumed to be a particularly rare event.

The TE due to the holdover in this case, provided by PRTC, is assumed to be, in the worst case, 2 400 ns.

Comparison Rubidium vs. High Quality OCXO (Qz) Time/Phase Holdover

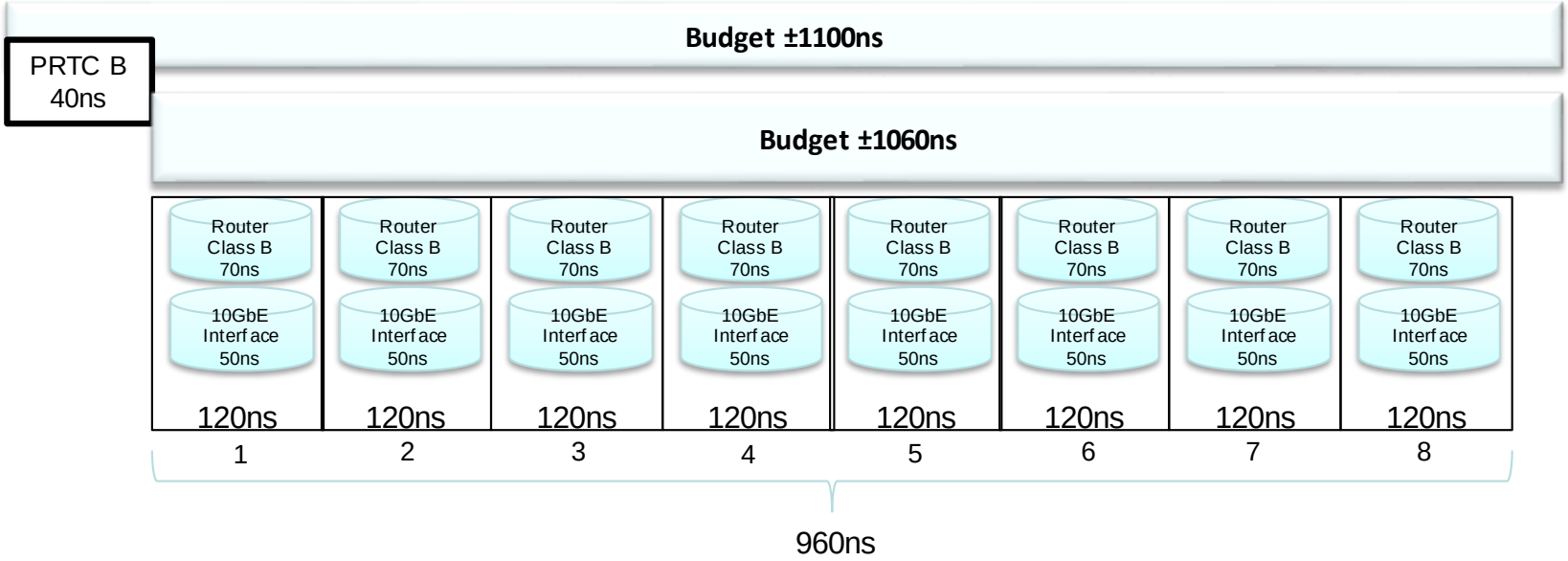
Oscillator Type	200 ηs	400 ηs	1100 ηs	1500 ηs	5000 ηs	10000 ηs
OCXO ++ (other vendors) (zero temp variation & Phase/Freq Error ZERO)	---	15 hours	1.3 days	2 days	4 days	6 days
Rubidium (Microsemi) (no restrictions on initial phase and freq error, regular temp variation of ±5˚C)	1 day	1.8 days	3.5 days	4.3 days	8.5 days	12.5 days

Mobile Architectures and Sync Deployment

How Hops Matter in a Transport Network

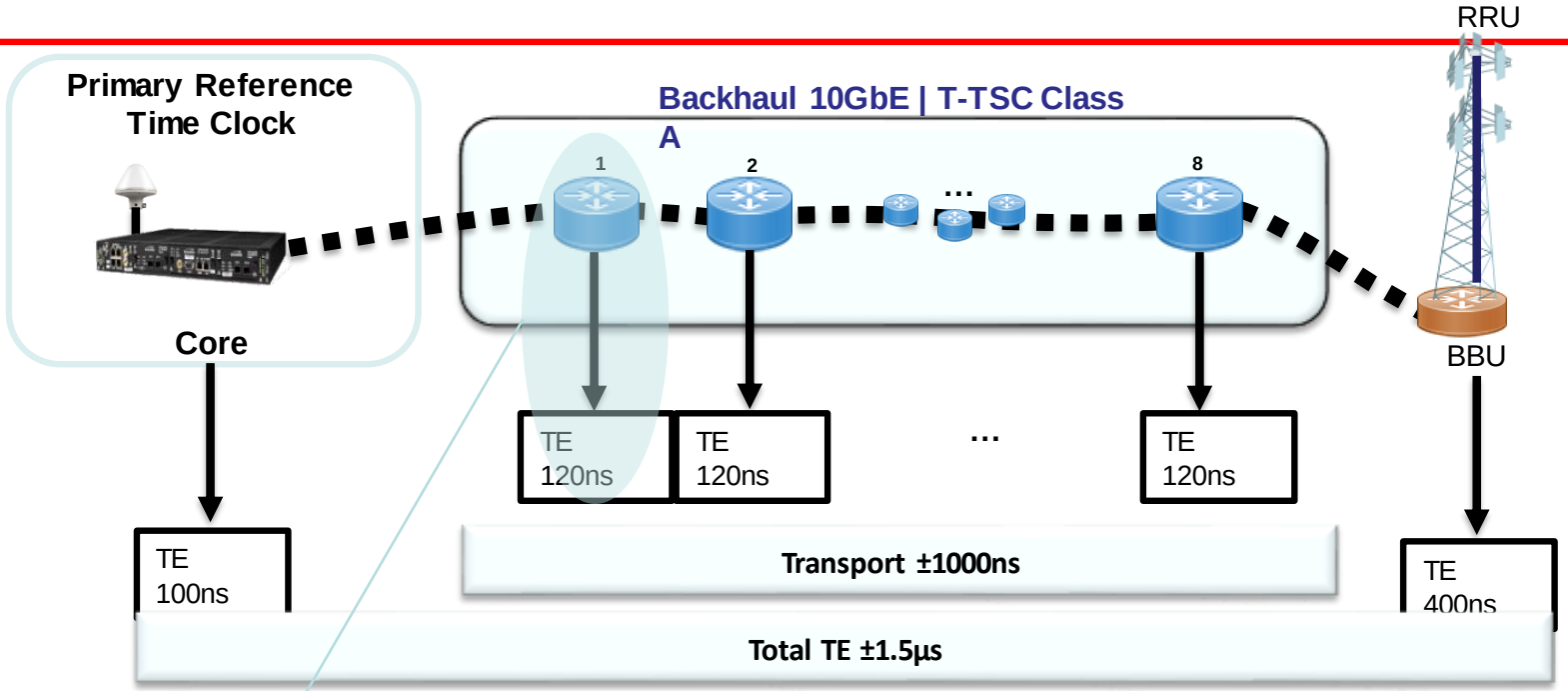
Phase Services T-TSC Class B (10Gb)

RRU



How Hops Matter in a Transport Network

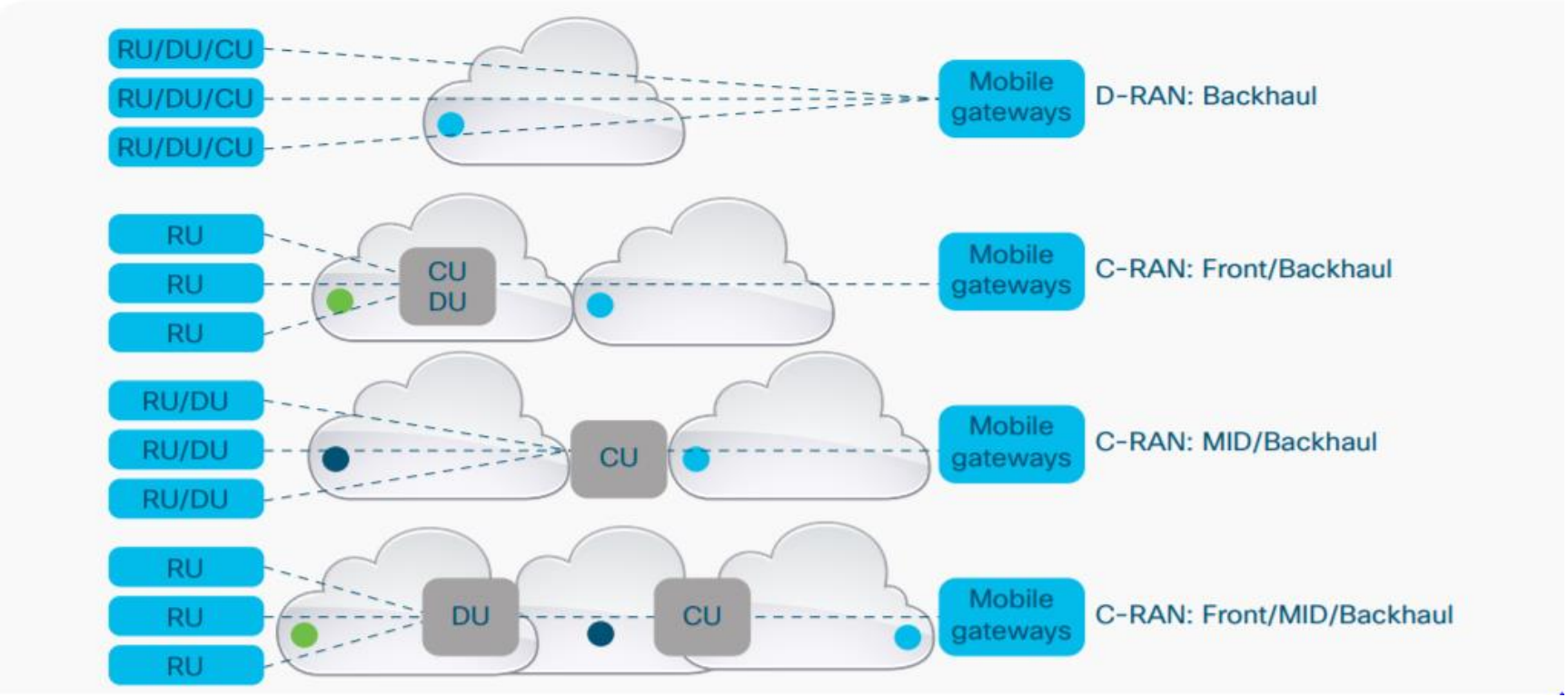
Phase Services T-TSC Class B (10Gb)



Class A ~70ns + PDV ~15ns + Asymmetry ~20ns + Congestion ~15ns = ~ 120ns

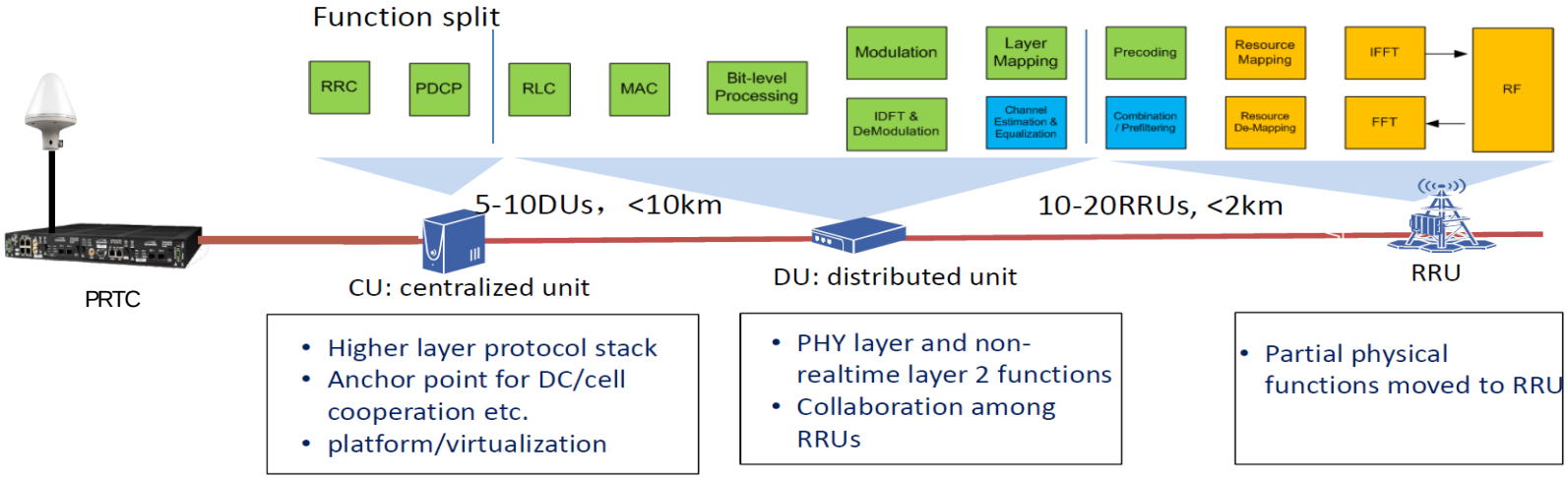
Transport Budget = 1000ns
Total Hops = ~8 (8x120=960)

5G Topologies

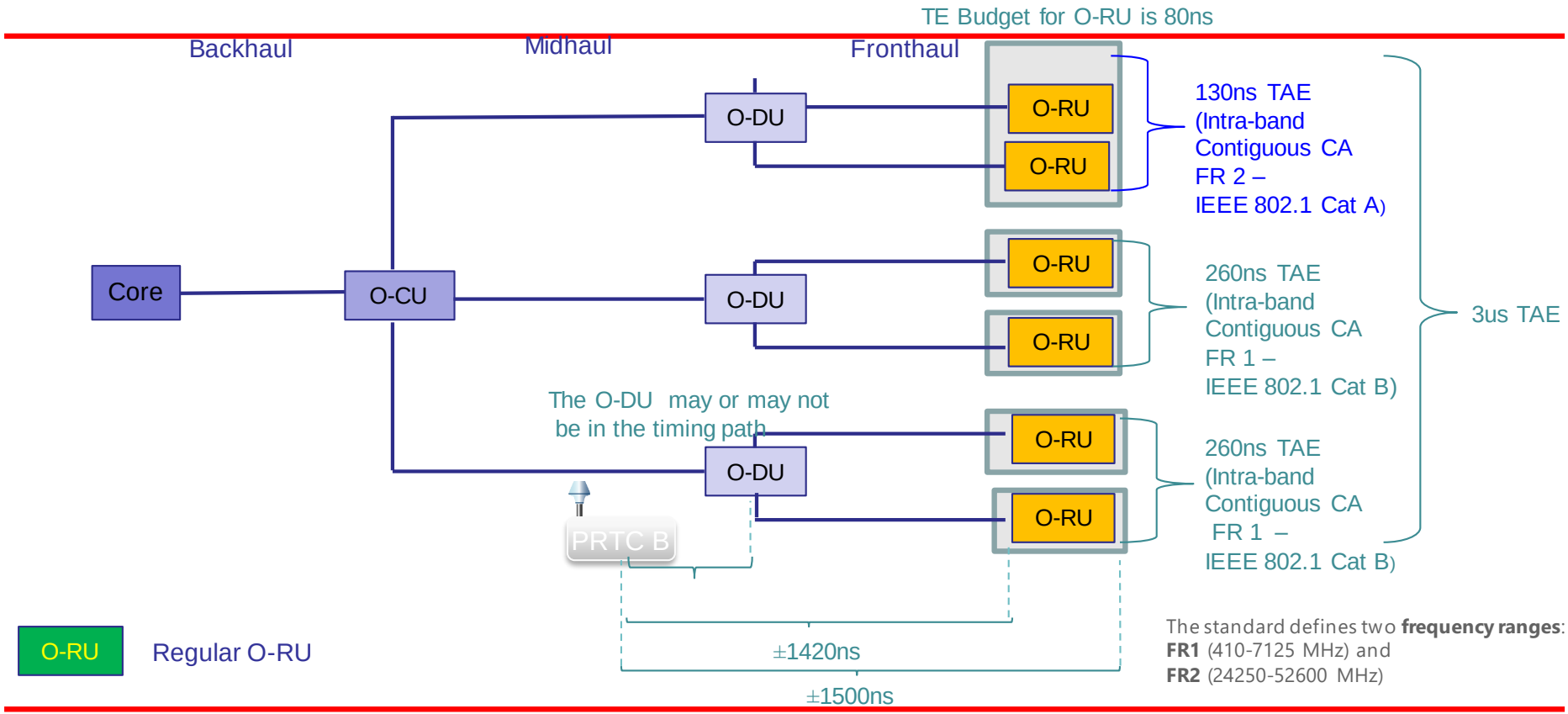


cRAN Architecture for 5G NR Advanced Services - Domain

- **5G C-RAN BBU will be divided into the functional entities of CU and DU.**
- **Accordingly, the fronthual domain will include two stages (IEEE 1914 NGFI):**
  - **Domain I between RRU and DU**
  - **Domain II between DU and CU**

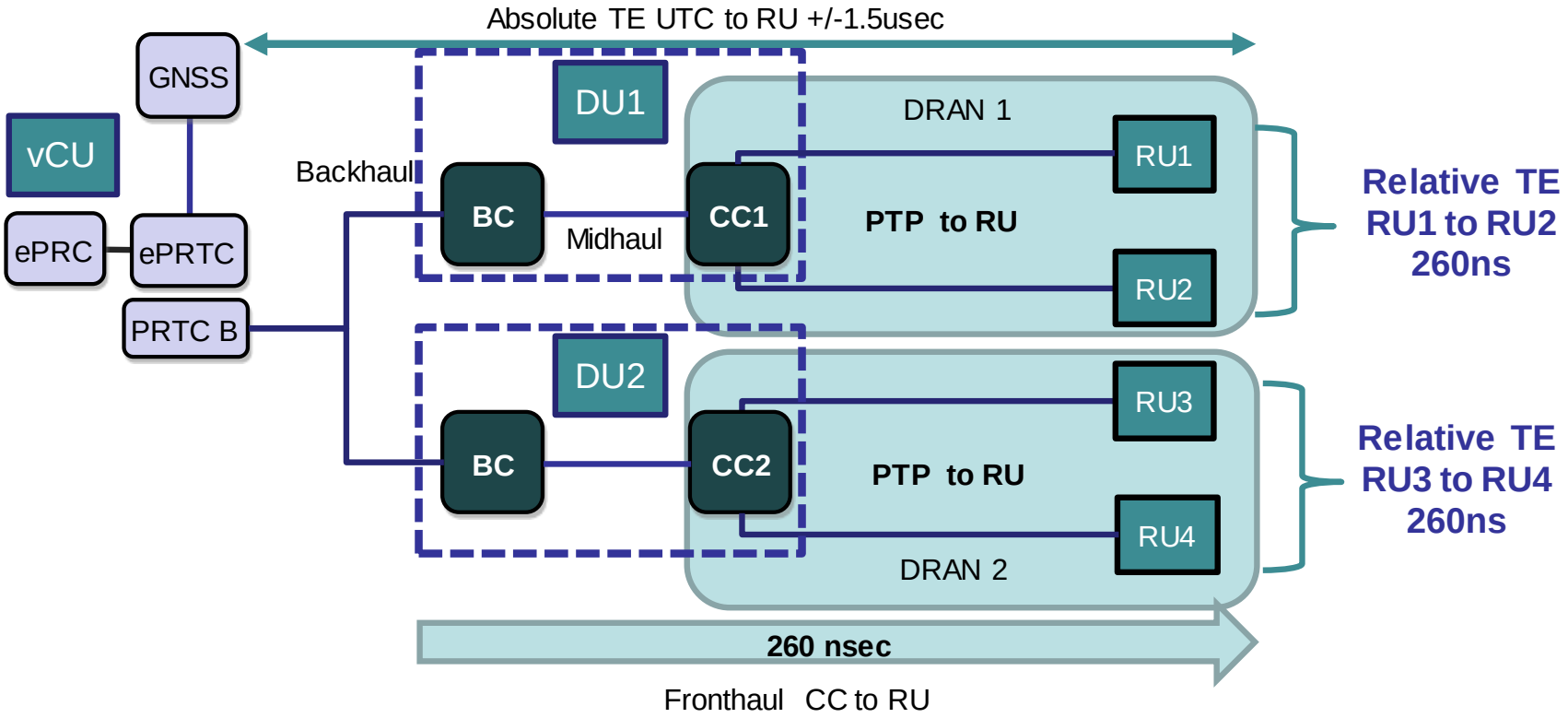


Timing Requirements

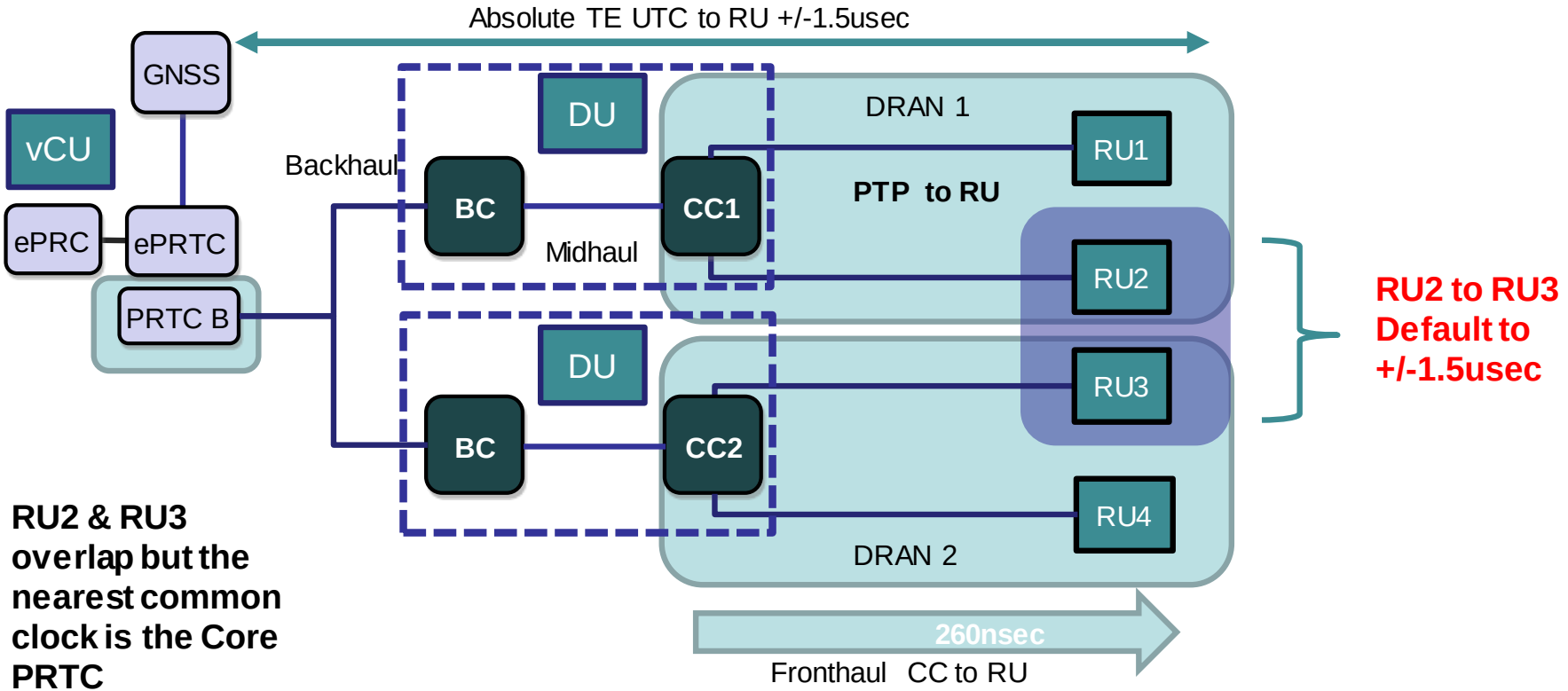


The standard defines two **frequency ranges**:
FR1 (410-7125 MHz) and
FR2 (24250-52600 MHz)

Relative Time Error RU to Common Upstream Clock



Relative Time Error Between RU & Common Upstream Clock



RU2 & RU3 overlap but the nearest common clock is the Core PRTC

Synchronization in new eCPRI – Separate Path

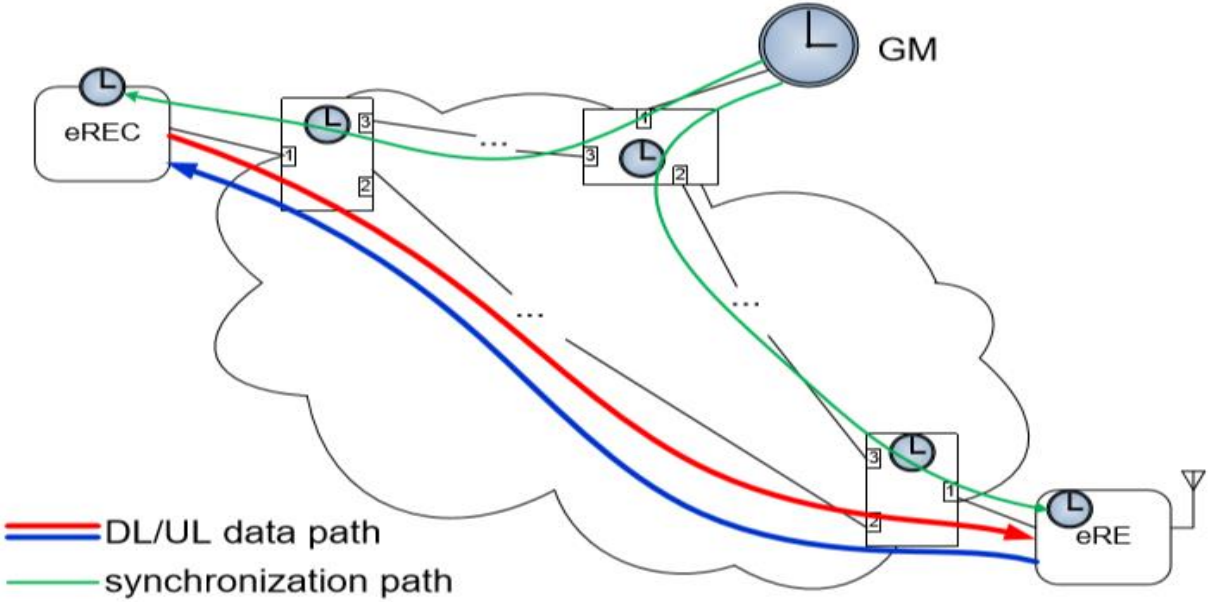


Figure 33: eCPRI topology example with synchronization via PTP

EPRTC

ePRTC System

ePRTC

Performance = 30nS
(time & phase)

Performance = 1 part in 10^{12}
(frequency)

ePRC
Enhanced
Primary Reference
Clock

ITU-T G.811.1 (Pub. 8/2017)

Performance = 40 ns
(phase)

PRTC B
Primary Reference
Time Clock class B

ITU-T G.8272 class B

ITU-T G.8272.1 (Pub. 2016)

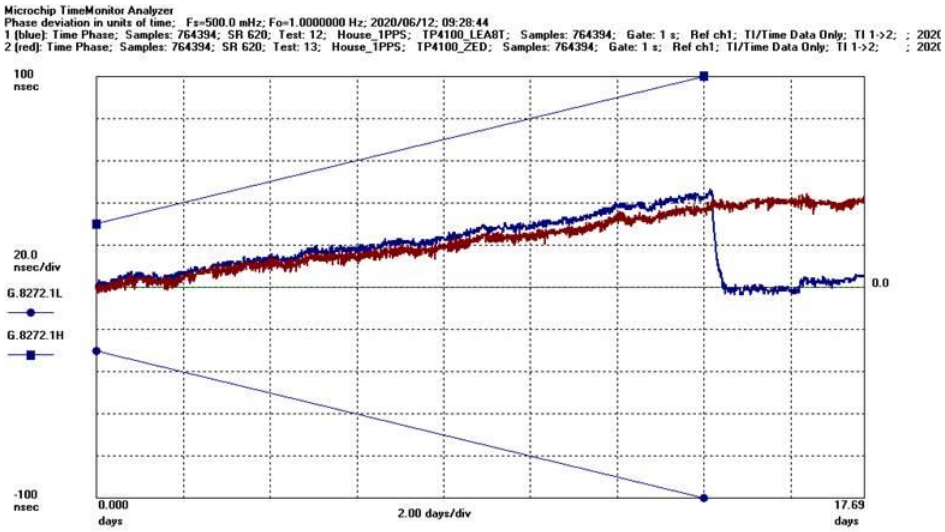
Support for
TimeCesium 4400/4500

Smart
GNSS antenna

TimeSource Enhanced PRTC

TP4100 ePRTC 14-day Holdover Tests

Holdover GNSS Outage Operation ITU Compliance (Calibrated)



- Performance of a timescale depends on underlying atomic clocks in holdover
- Final results show excellent holdover performance with margins in agreement with Holdover "Gas Gauge" Pre-Holdover dashboard prediction
- Maintained 25ns clock class for almost the entire duration of the outage
- 4 time better than 100 ns required

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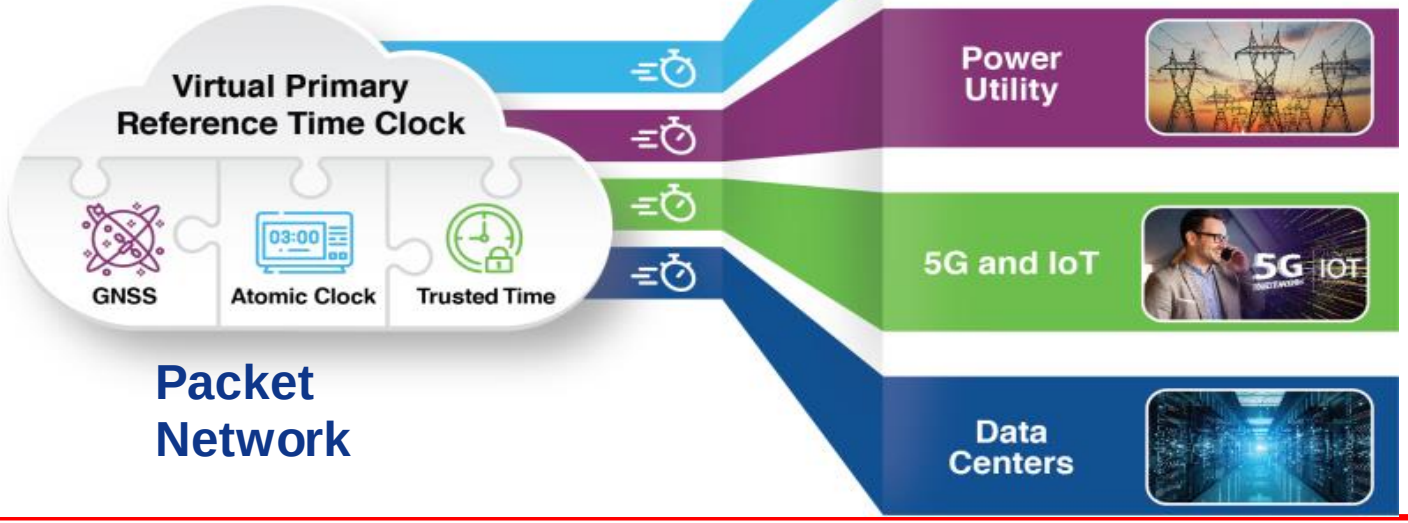
THE VIRTUAL PRTC

Virtual PRTC Timing Services Solution

vPRTC is a PTP based Network Time Service that delivers timing signals over the transport network with GNSS and atomic clock accuracy



Typical Timing Requirements

Rail: +-1 us
AV: 10 ns/10 us

To Substation +-250 ns
Target 1 us

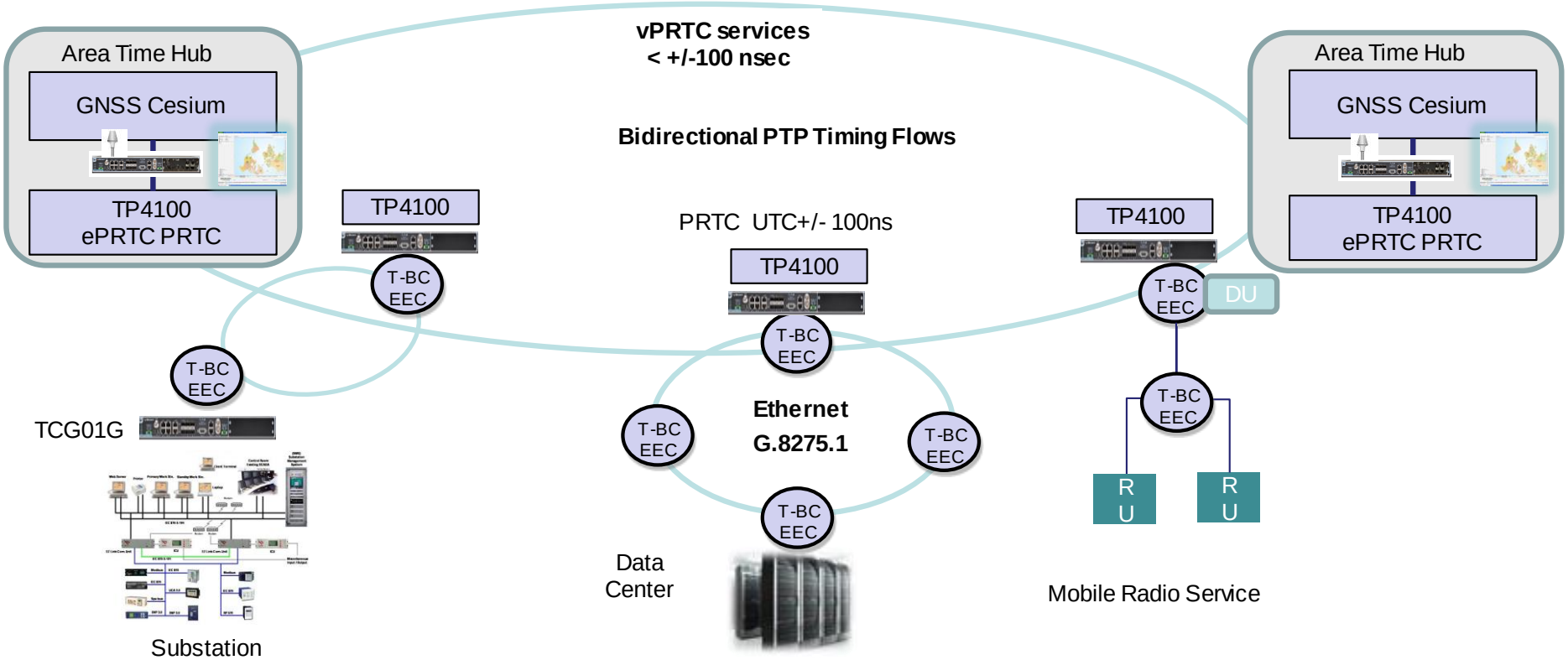
+/-1.5 us
& 260 ns

1 us

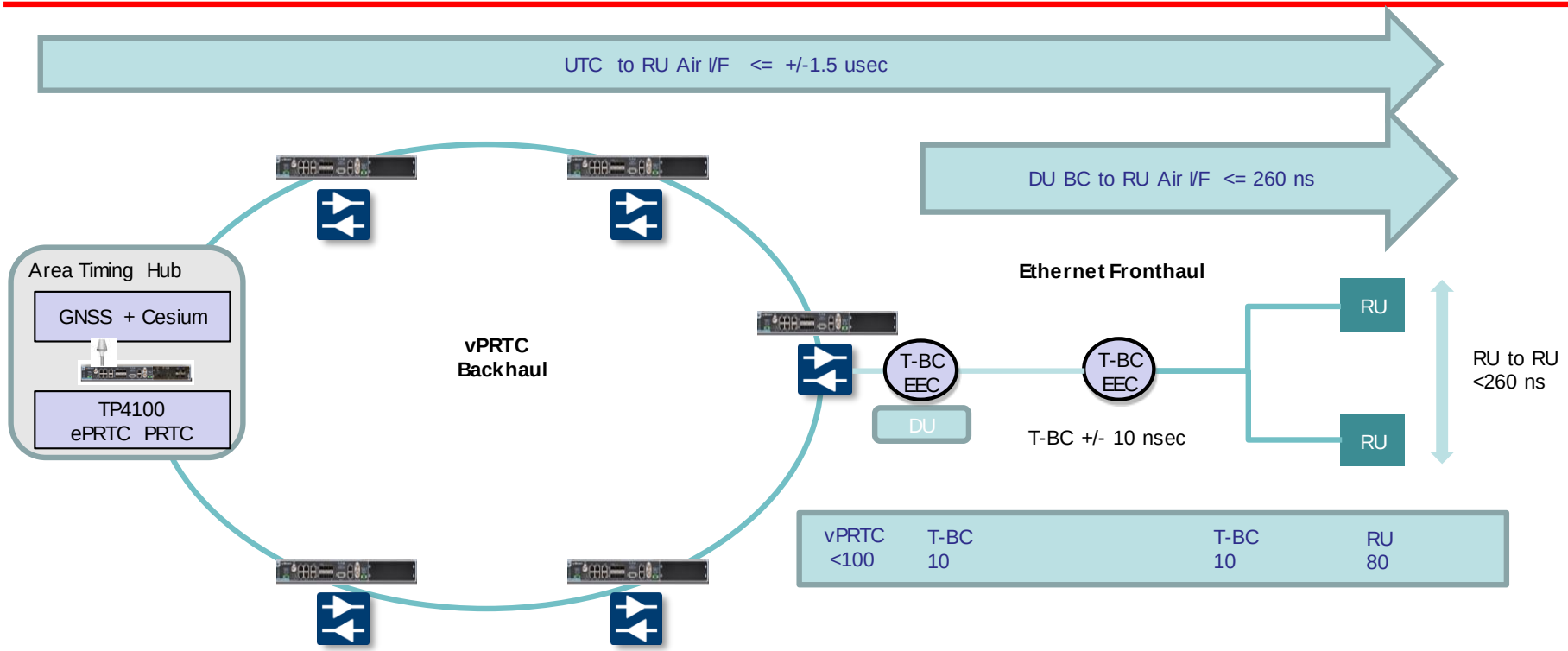
Source: Microchip

East West Model for vPRTC

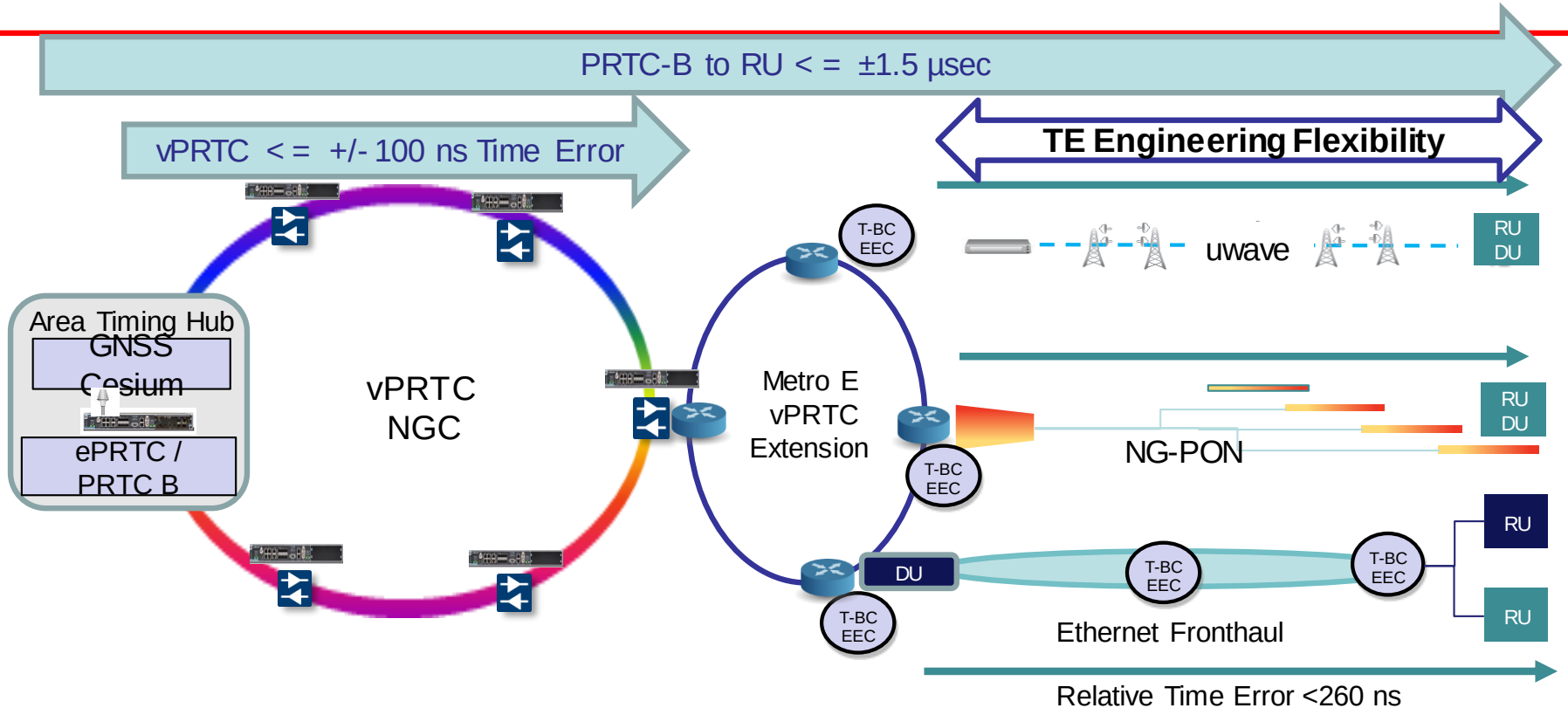
max|TE 3 ns per DWD



Transport to RU Over vPRTC and Ethernet Fronthaul



vPRTC Enables Flexible TE Engineering at the Access Edge



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