LightReading LIVE! WEBINAR

Why Time Matters: A Look at Precise Timing in Next-Gen 5G & Cable Networks

March 15, 2018

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Today's Presenters

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Agenda

- Towards commercial 5G deployment
- Implications for timing & synchronization
- Next-gen timing solutions for 5G NR and Cable DOCSIS 3.1

Global "5G" Activity (selected examples)

NAM

- Verizon: Interop tests, trials 5xFWA markets in 2018 @ 28GHz
- Sprint: Mid-band 5G 2.5GHz, 2018
- Bell
- TELUS
- T-Mobile: 600MHZ 5G Mid-band interest
- U.S. Cellular: 28GHz Trials
- AT&T: 12 markets in 2018 NSA Advocate

EMEA

- BT: NSA & Mid-Band Advocate
- Vodafone: 5G trial program 2018
- Orange: 2018 5G Deployment!
- Telia
- TIM: C-Band; 2 cities 2019
- zain: 5G @ 2GHz
- T-Mobile
- Telefónica: Automotive Tie-up (SEAT)
- elisa: 400MHZ of C-Band
- 3: 120MHZ of 3.5GHz

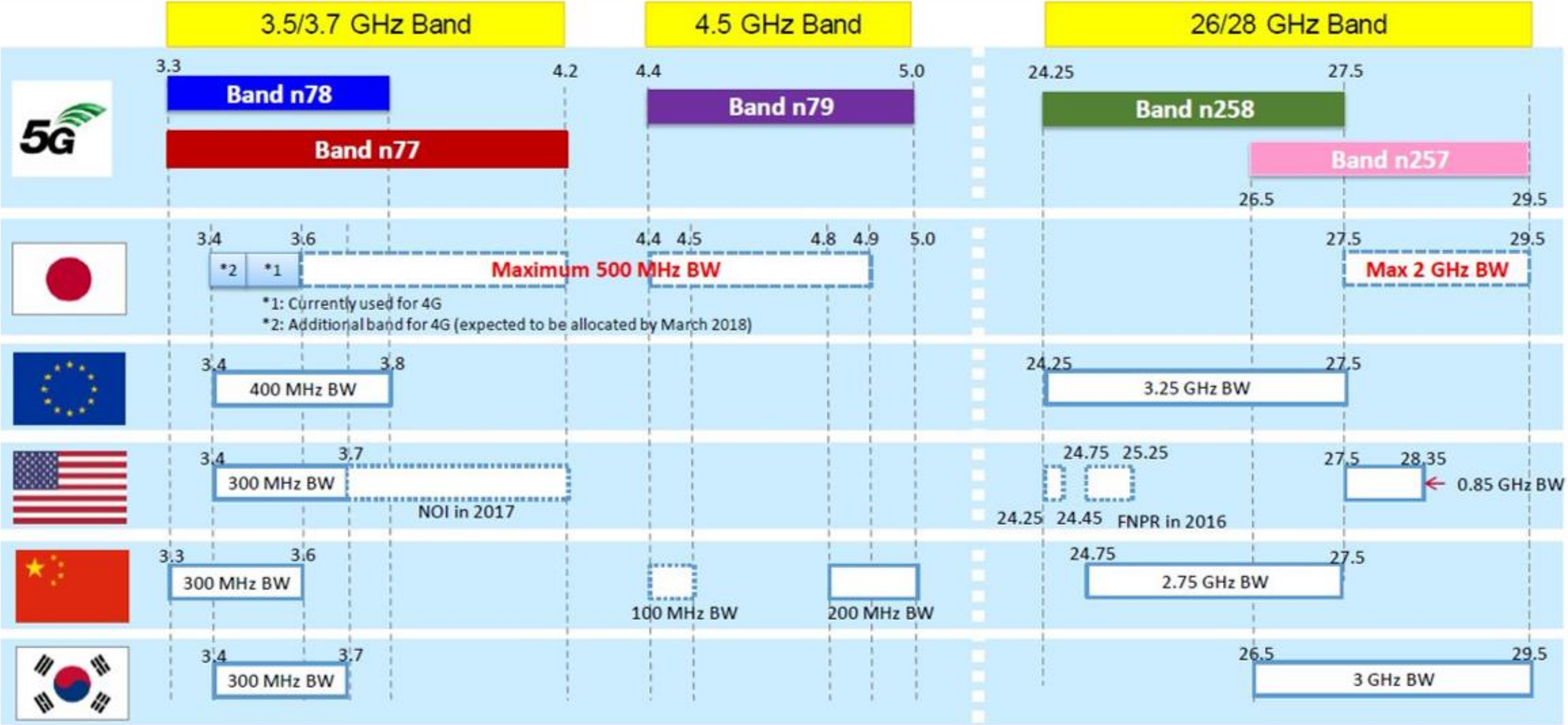
ASIA

- NTT docomo: 4.5-4.9GHz nationwide deployment plan; 2020 Summer Olympics Flagship
- KDDI: 5G network share in Japan
- SK
- Telstra
- SoftBank
- 中国电信 CHINA TELECOM
- 中国移动通信 CHINA MOBILE: Large scale trials in 2018 C-Band leader
- kt: 28GHz mobile @ 2018 Winter Olympics

Timeline to 5G @Scale

2017	2018	2019	2020	2021	2022
5G PoCs & Field Trials	End-to-end 5G Trials	City-level 5G	Commercial Launch @ Scale	National Coverage →	

Mid- & High-Band 5G Spectrum is TDD



Source: NTT DOCOMO

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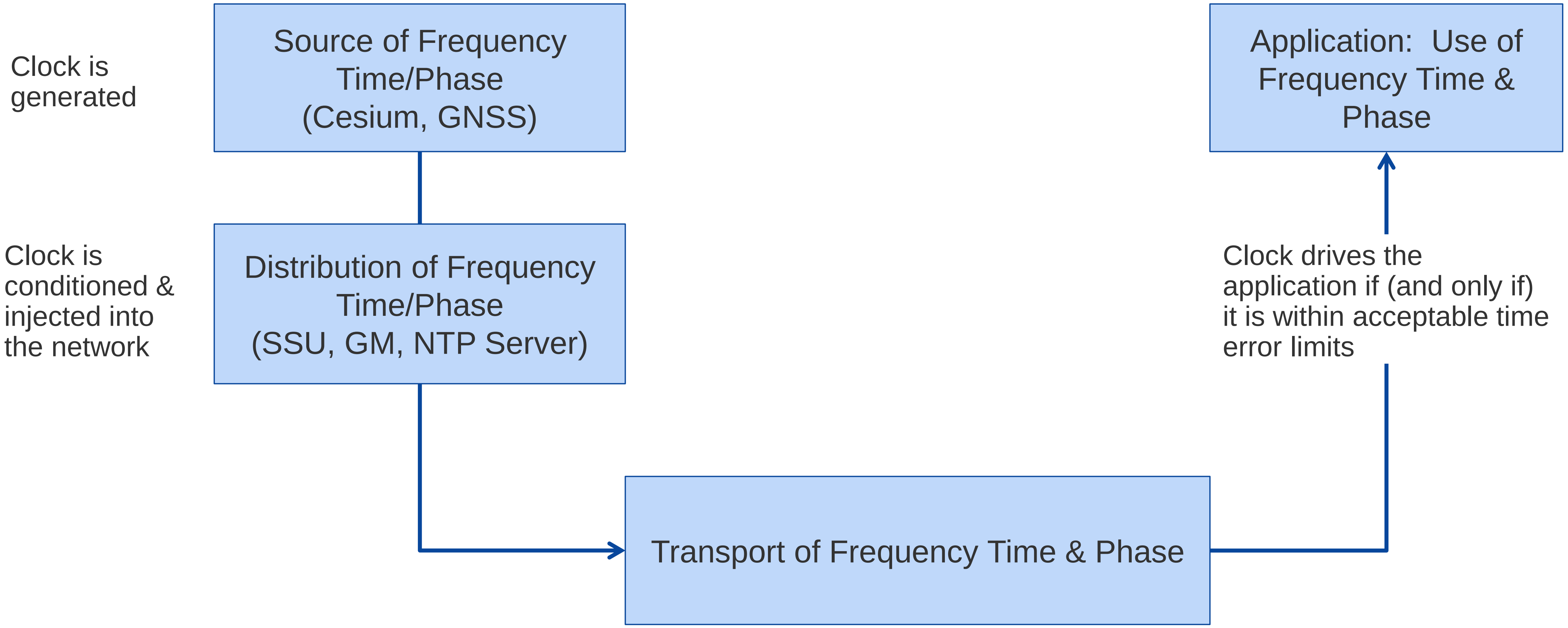
LightReading Networking the Communications Industry

Timing: A Simple Model



The Transport Network Introduces Error
(jitter, PDV, noise, asymmetry)

Technology Choices for Service Providers

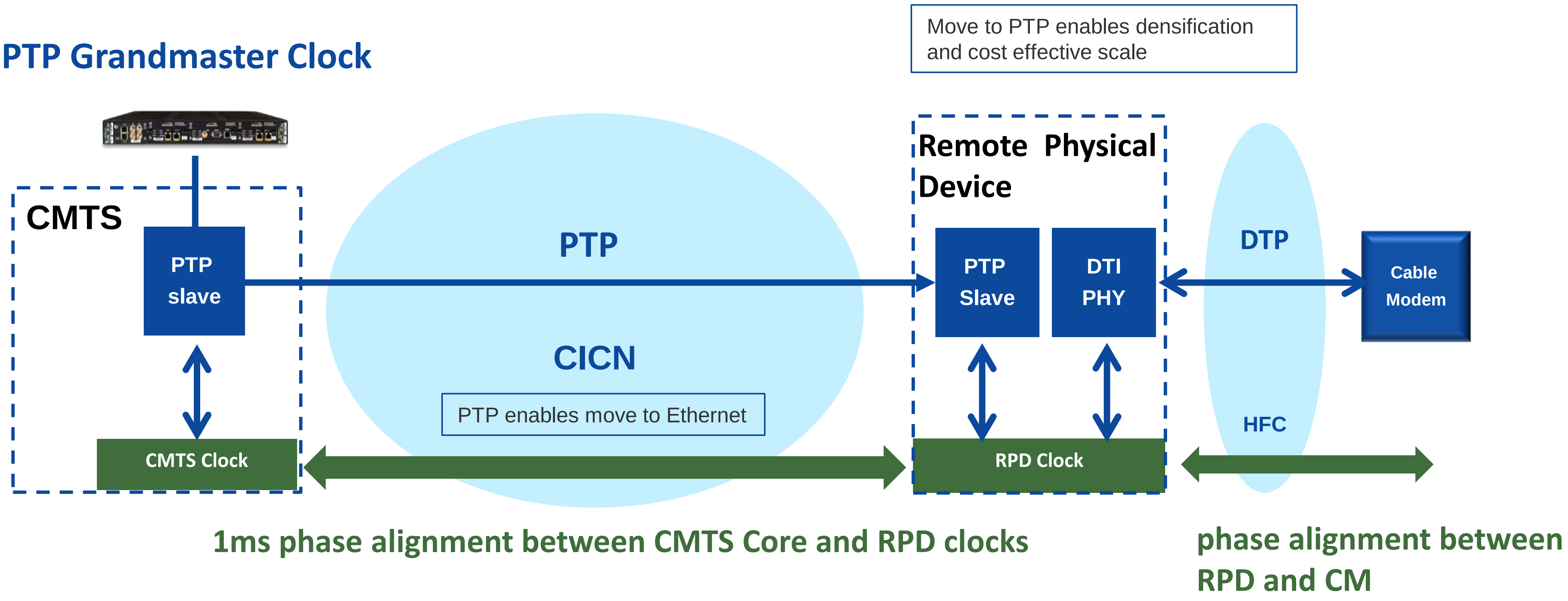
Transport challenges due to ever increasing bandwidth needs
Increasingly reliable mobile services everywhere (IoT, vehicles, devices)

Densification (Mobile, Cable):
cost implications of distributed access points, implementing interference control, how to get timing to the edge, how to get signals indoors, how to guarantee availability

Spectrum Diversity: Licensed, Unlicensed, CBRS, etc.,

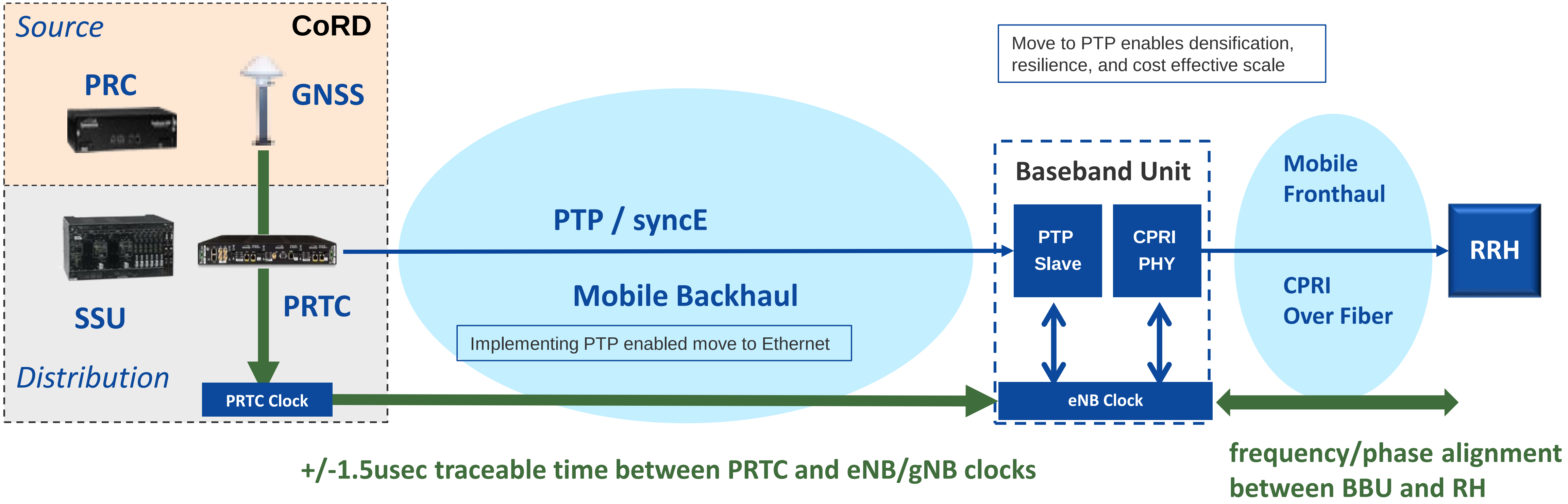
New Architectures:
Virtualized functions: vRPD, vRAN
Convergence: Central Office Re-architected as Data Center (CORD)
Split architectures: eCPRI, Remote PHY (DOCSIS 3.1)

Sync Architecture for Cable DOCSIS 3.1: Scaling with PTP



- CMTS Cable Modem Termination System
- CICN Converged Interconnect Core Network
- RPD Remote Physical Device
- HFC Hybrid Fiber-Coaxial access network
- DTP DOCSIS Timing Protocol
- DTI DOCSIS Timing Interface
- PTP Precision Timing Protocol

Sync Architecture for Mobile: PTP, GNSS, SyncE

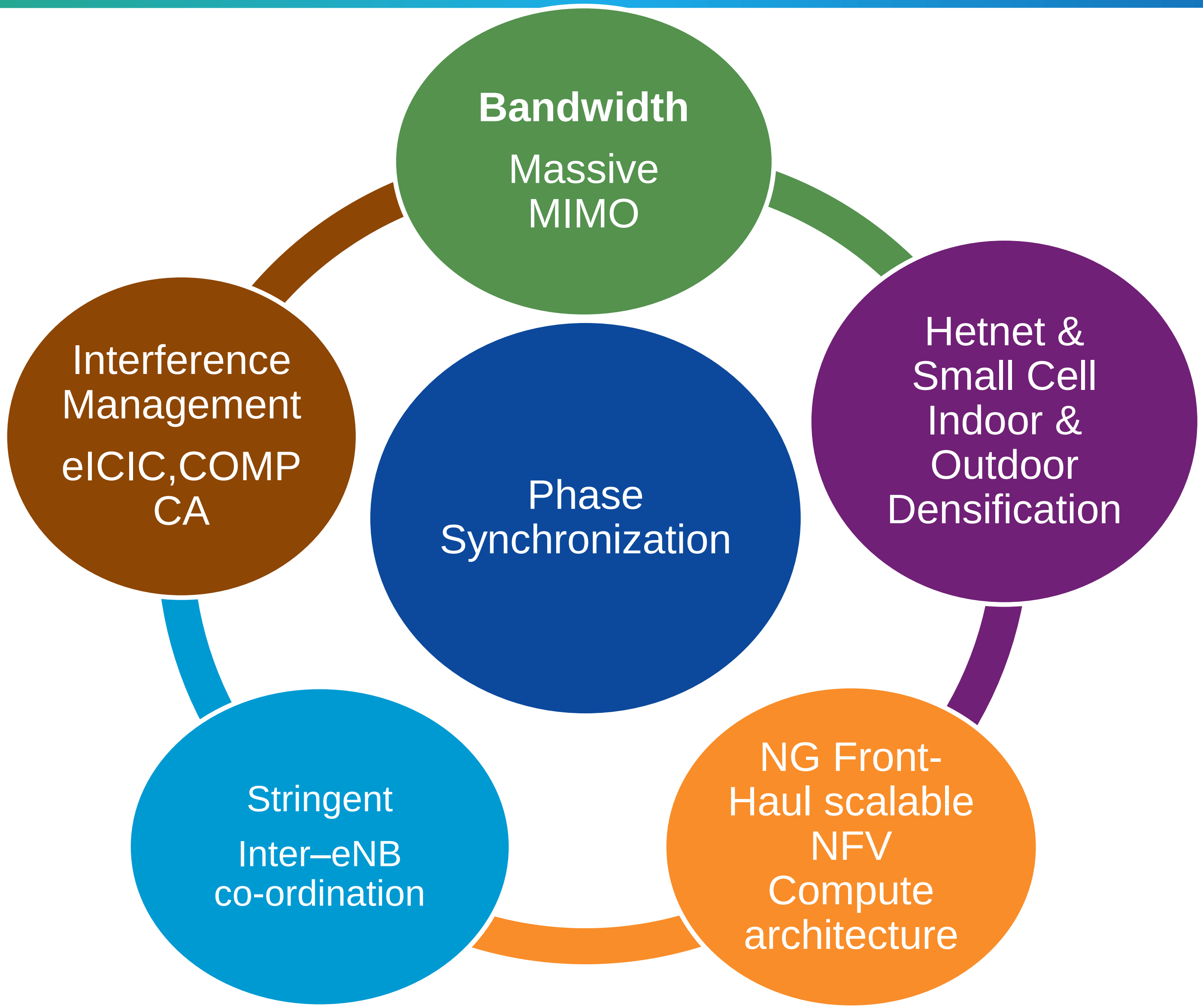


- CoRD — Central Office Re-invented as Data Center
- PRTC — Primary Reference Time Clock
- SSU — Synchronization Service Unit
- PRC — Primary Reference Clock
- GNSS — Global Navigation Satellite System
- BBU — BaseBand Unit
- RRH — Remote Radio Head
- CPRI — Common Public Radio Interface

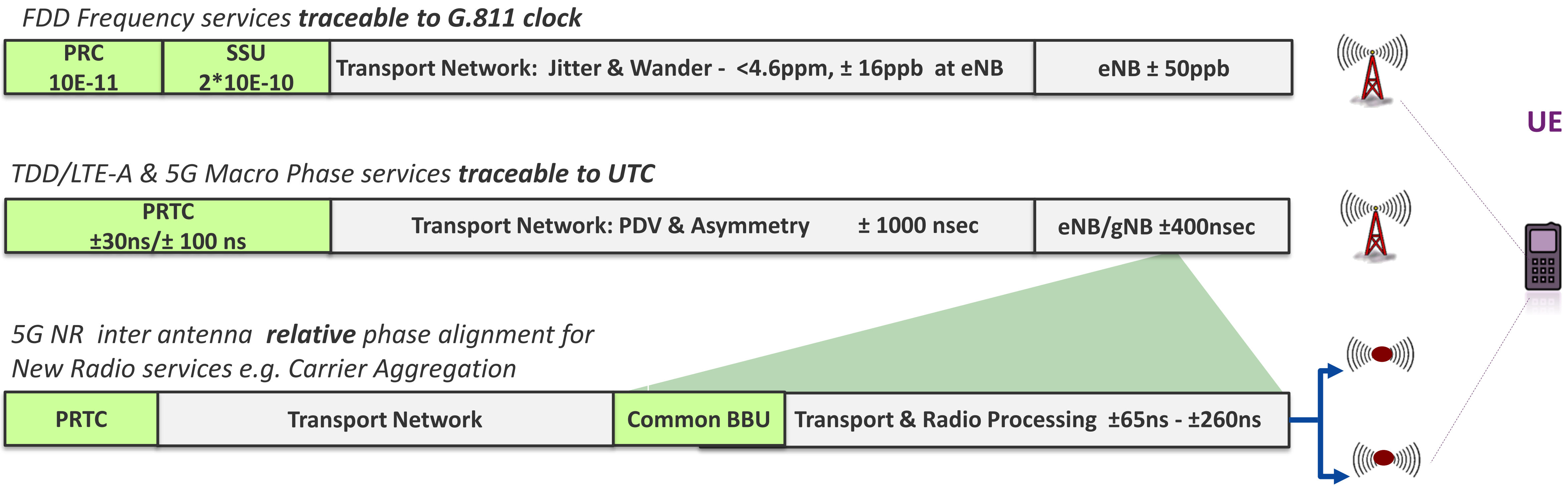
Why Sync Matters

- Cable
  - Video over HFC with TDMA requires phase alignment between RPD and Modem
  - Poor timing means poor performance, inefficient resource (bandwidth) usage,
    - DOCSIS 3.0 timing implementation limited scale
    - PTP in the Backhaul enables shift to ethernet backhaul and scales more cost effectively at the edge
- Mobile
  - A fundamental function for mobile: no sync = no mobile services
  - Most new spectrum being made available is TDD
  - Good synchronization
    - Reduces interference between adjacent frequencies and adjacent operators
    - Enables coordinated radio resource management
    - Enables advanced network services such as CMP/MiMO, Carrier Aggregation for wideband 5G
- Major challenges to sync delivery
  - Need to align UL / DL ratios (phase required)
  - May need multi RF support (e.g. LTE, LTE-A, LTE-AA, 5G NR etc)
  - Enabling seamless roaming – especially with cross-border operators (mainly Europe)
  - How to deliver/guarantee sync across disparate transport networks, 3rd party backhaul

For Mobile, Network Services Drive Synchronization Requirements



Typical Error Budgets For Mobile Services



- LTE-FDD — eNB are frequency aligned at +/-50ppb of the reference clock
- LTE-TDD / LTE-A — eNB are phase aligned within +/-1.5usec Time Error with respect to UTC
- 5G NR Macro — gNB are phase aligned at +/-1.5usec Time Error with respect to UTC

Antenna locked to common BBU have relative phase alignment from +/- 65ns to +/- 260ns depending on the network services

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LTE / LTE-A & 5G NR Timing Requirements

LTE, LTE-TDD, LTE-A	Inter eNB alignment
FDD	50ppb
TDD	±1.5usec
Basic LTE-A services eICIC, CoMP MIMO,	±1.5usec
5G NR macro layer as above	**antenna alignment**
Inter-band contiguous, Intra-band non-contiguous Carrier Aggregation	±260nsec
Intra-band contiguous Carrier Aggregation	±130nsec
MiMO with Transmit diversity	±65nsec

Value Add	Non Compliance
Higher bandwidth	Service degradation
Spectrum efficiency	Crosstalk & random noise
More connections	Dropped calls
Faster handoff	Packet loss/collision
Interference control	Poor signal quality
Resource management	

(3GPP TS 36.101/104.)

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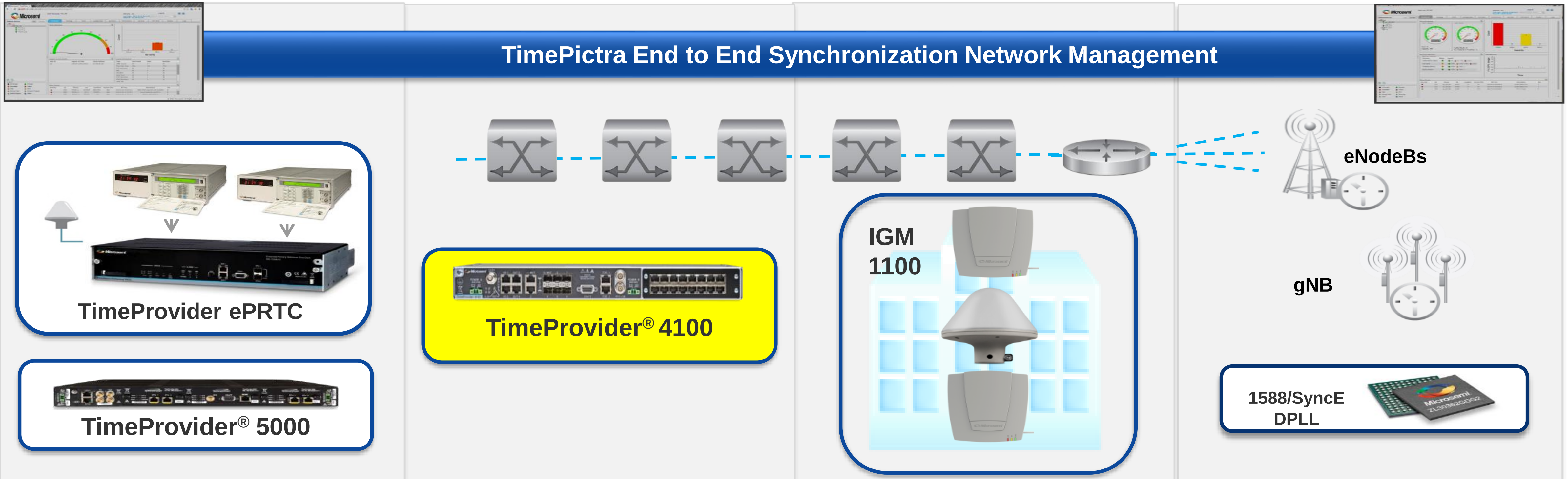
Requirements Evolution



Core Clocks

- Frequency focus
- Complements Aggregation & Edge GMs via PTP & APTS

CORE

Requirements
- Enhanced Fan-out
- Phase
- Monitoring
- IPv6 (PTP & Mgt)

AGGREGATION

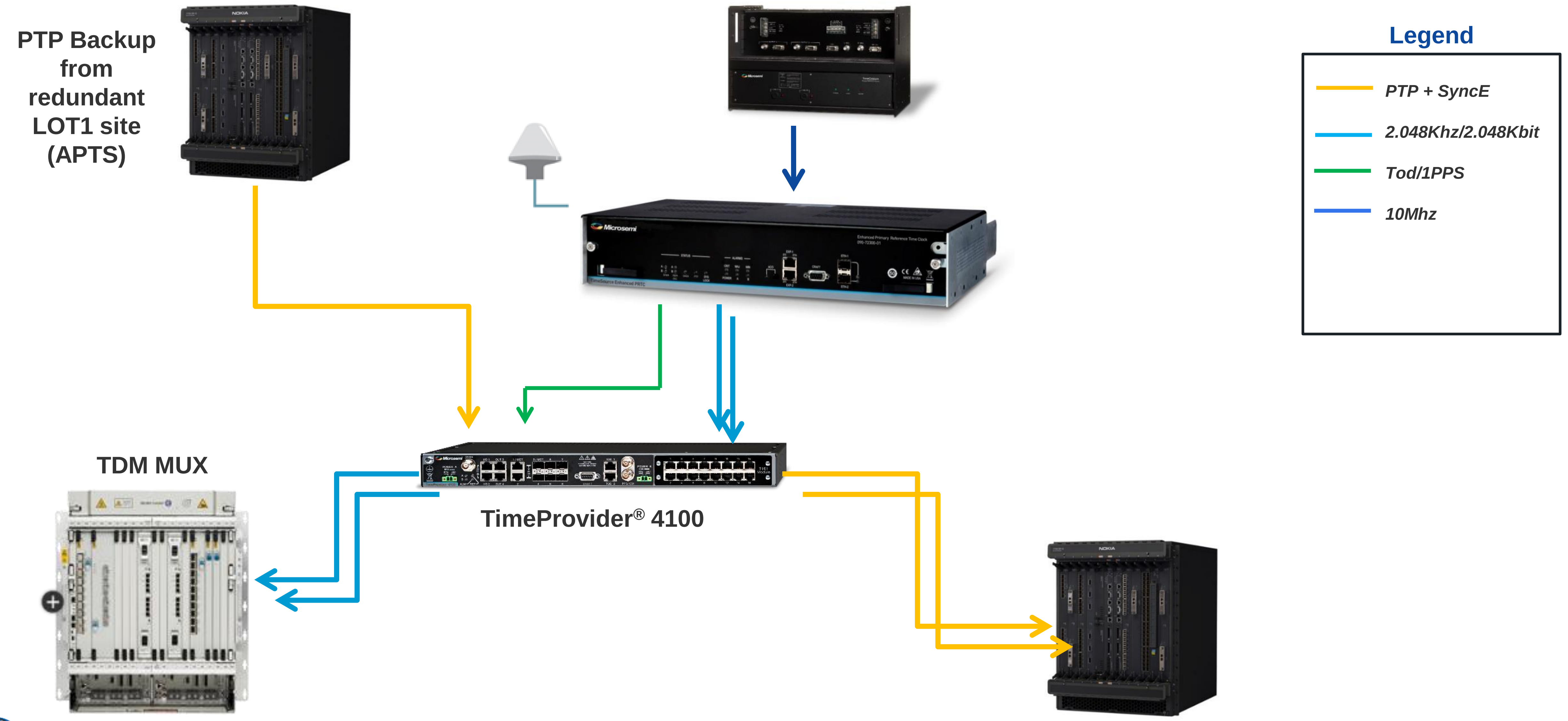
Indoor /Outdoor mini-GM Clocks
- 4-32 Clients
- Integrated Antenna
- PTP, Sync-E

ACCESS

Embedded Clocks

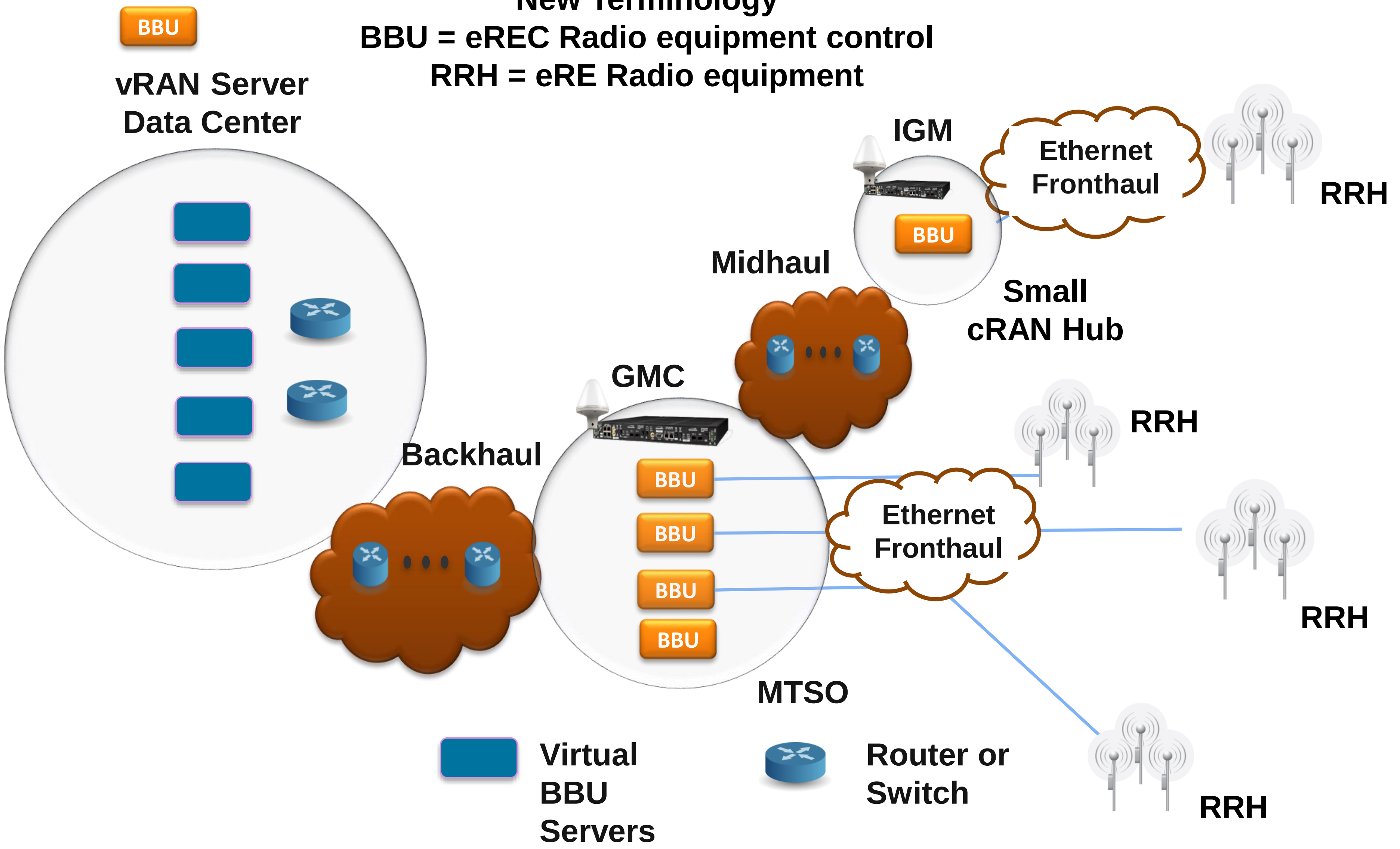
- PTP Slave Clocks
- PTP Boundary Clocks
- Sync-E

Typical Connectivity Needs for Deployments

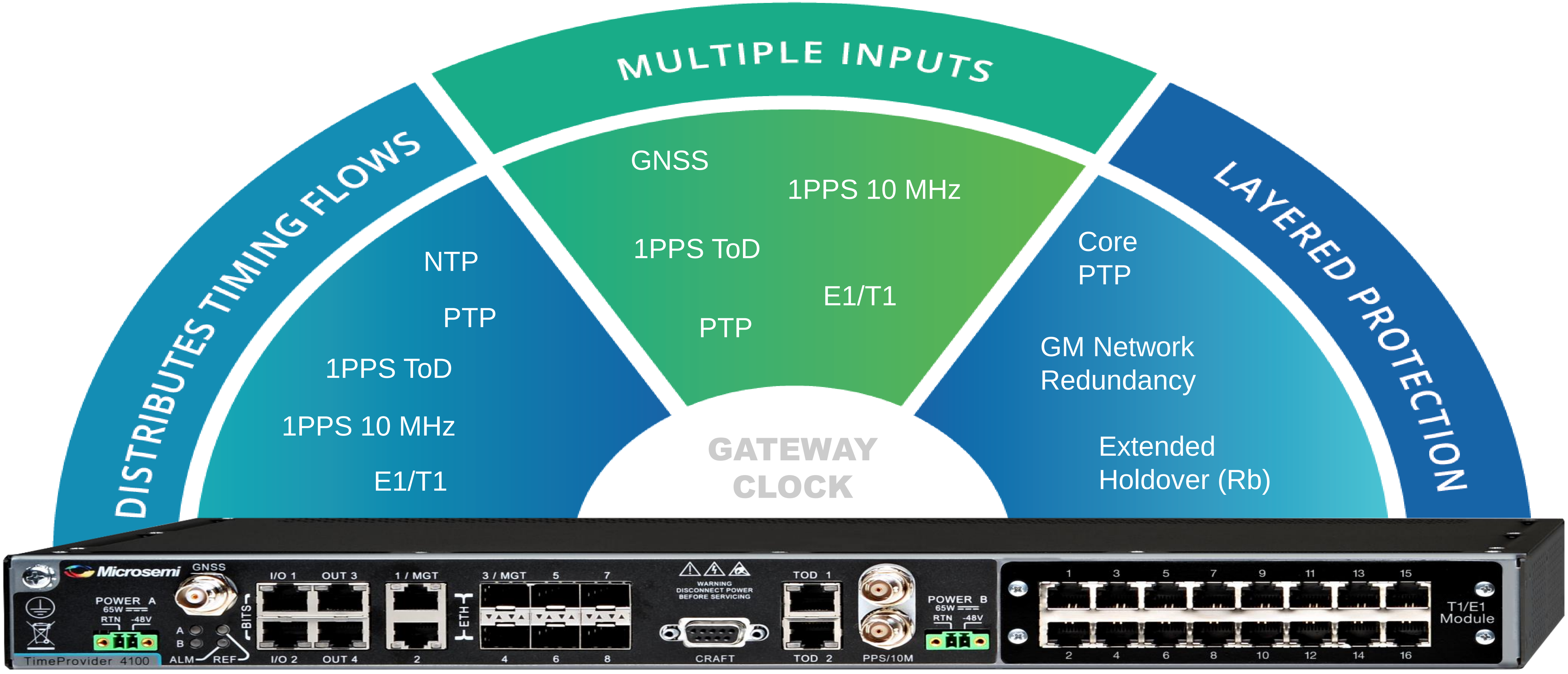


vRAN Future 5G (eCPRI) Timing Architecture

New Terminology
BBU = eREC Radio equipment control
RRH = eRE Radio equipment



TimeProvider 4100 – Gateway Clock



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Solution – Functions Required on Gateway Clock

Innovative hardware architectures & advanced algorithms to provide high MTBF

Resilience

Scalability Performance

PRTC 100ns
Dense PTP clients
Hardware Timestamping
Smart AI

Oscillators
GNSS Back Up
Redundancy

Monitoring

Extensive Ethernet Fan-Out

Multiple 1GE, 10GE ports & beyond

SSU Function

Legacy Sync Ports
E1/T1
SyncE

Extensive PTP & NTP Functions

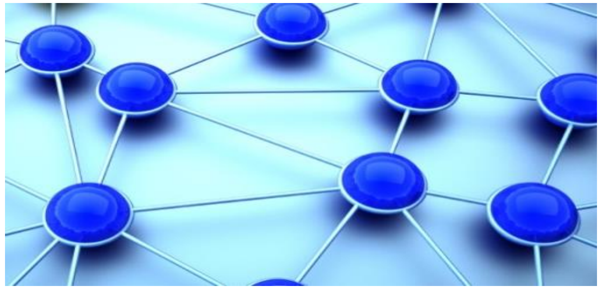
Feature	Description
PRTC	Meets ITU 100ns specification
PTP	
PTP GM - Frequency	Ethernet Default, Default (IPv4 only), Telecom-2008, ITU-G.8265.1
PTP GM - Phase	ITU-G.8275.1, ITU-G.8275.2
PTP Input (client) - Frequency	Telecom 2008, ITU-G.8265.1
PTP Input (client) - Phase	ITU-G.8275.1, ITU-G.8275.2
PTP Input (client)	BMCA and alternate BMCA support
PTP Profiles - Serving mix of clients	Multiple PTP profiles support for box
NTP Reflector	
NTPr Support	V4 and V6 NTP reflector - FPGA implementation, more secured, 20,000 tps

Reliability, Robustness

Maintain performance levels for a period of time until technicians can re-establish or fix the disruption

Oscillator Choice
(mini OCXO, OCXO, Rb)

UTC Traceability



System & Geographical
Redundancy

GNSS BackUp - PTP Input
APTS G.8273.1
AAC (Patented)

Edge Holdover
ePRTC at Core

Solution – Scalability & Performance

Flexible Packet services

Scale to several thousands of 1588 clients

PTPc, PTP GM, PTP probe

High performance NTP (hardware timestamp), security

Flexible Physical Layer Services

Rich SSU Function

SyncE, ESMC

E1/T1, SSM

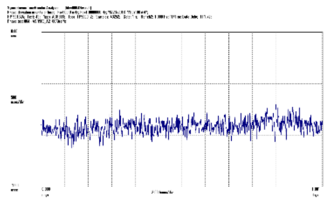
Complete GNSS Services

Multiple Constellations

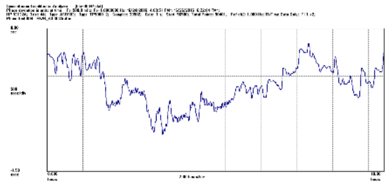
Multiple Bands (L1, L2, L5), PRTC-B

Multiple Antennas

Solution – Monitoring Example for Phase



Fo = 1.00000000000000 Hz N = 43252   Mean=-915.4258 nsec   Median=-916.1008 nsec
Ymin=-1.128100090340 usec   Ymax=-694.8010055056 nsec   Ymax-Ymin=433.2990848344 nsec
Minimum: -1.140000 usec   Mean: -915.4633 nsec
Maximum: -690.0000 nsec   Standard Deviation: 61.54 nsec



Fo = 1.00000000000000 Hz N = 33982   Mean=-600.4868 nsec   Median=-595.1006 nsec
Ymin=-1.115800339168 usec   Ymax=-153.4006405670 nsec   Ymax-Ymin=962.3996986008 nsec
Minimum: -1.125000 usec   Mean: -600.4639 nsecMaximum: -150.0000 nsec   Standard Deviation: 214.9 nsec

PTP	1PPS
Time Error - TE	1PPS Input to 4100 & TE
Daily path offset average value	Daily path offset average value
Constant Time Error - cTE	cTE
Maximum Time Error - Max|TE|	Max|TE|
Time Error threshold alarm	TE threshold alarm

Summary: Cable DOCSIS 3.1 and 5G Mobile Network Timing

- New architectures with stringent phase requirements at the network edge
- **Cable**
  - PTP leverages the packet core, enables flexible massive scale while maintaining phase control
  - Allows Cable OPCO to engage in IoT, Connected Vehicles, Smart Home, Smart City, and advanced Mobile services
- **Mobile**
  - Phase based architectures/standards defined in 3GPP, ITU-T, IEEE, to complement existing frequency implementations
- **Synchronization & Timing Challenges**
  - Must deliver very high accuracy and high stability timing functions, plus scalability, resilience, high performance, management and monitoring
  - Must provide flexibility, easy addition of features, simple integration into virtualized systems
- **Gateway Clock: the Best Solution**
  - A new category of telecom clock designed to cost effectively and seamlessly scale a rich feature set in the dynamic NG environment for both Cable and Mobile networks

Thank You!

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Q&A