Synchronization Distribution Architectures for LTE Networks

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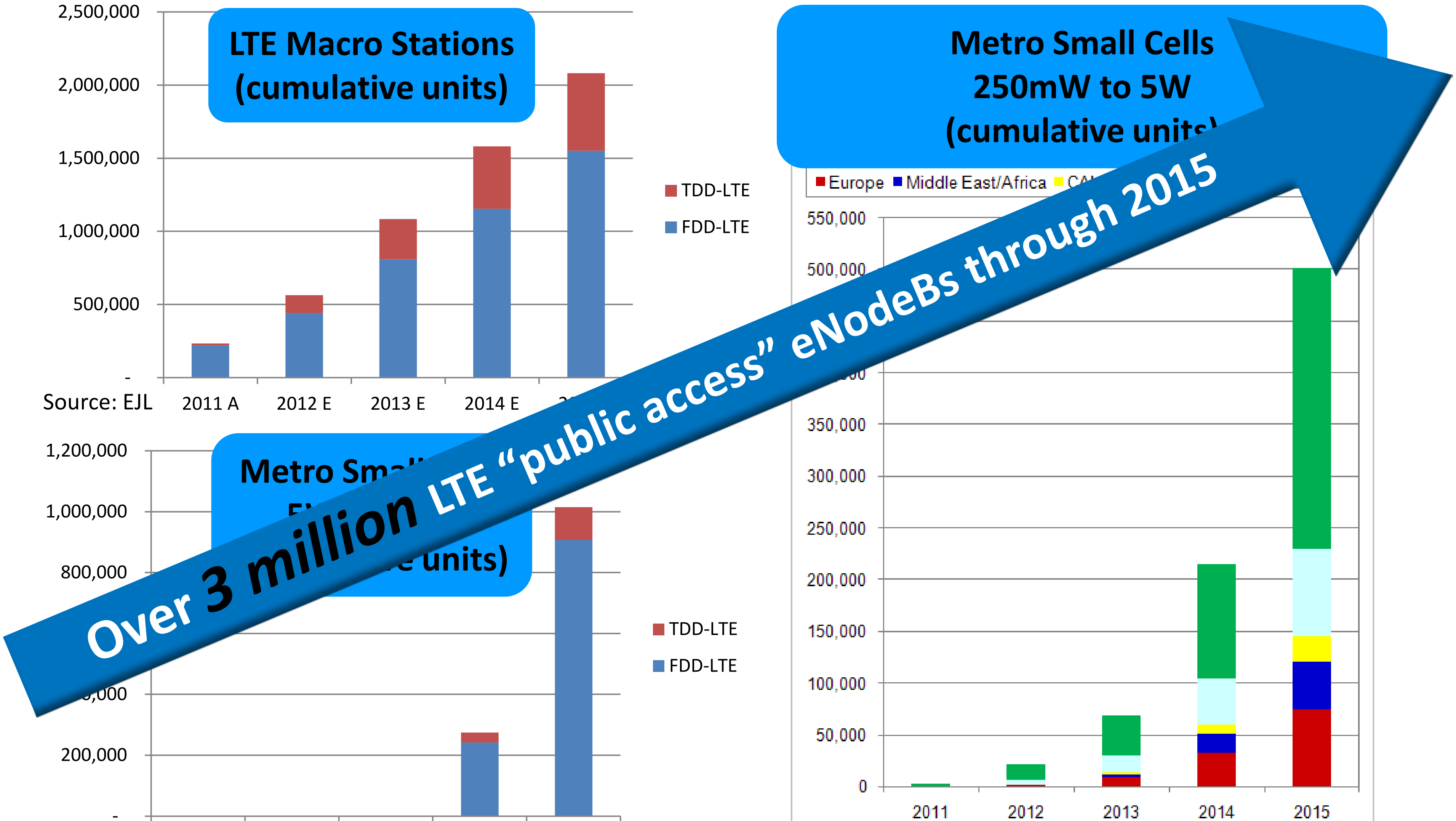
November, 2012

Agenda

- The Basic Question
- Synchronization, Standards and Requirements
- Synchronization Distribution Architectures for LTE

LTE Base Stations



Source: EJL

Source: Heavy Reading

The Basic Question

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How should I synchronize my LTE networks?

The answer is driven by service delivery network fundamentals:

- Selection of LTE technology (LTE-FDD, LTE-TDD, LTE-Advanced) drives the synchronization requirements
- Mobile network equipment selection and cell site locations (particularly for small cells) define what can and cannot be done
- Backhaul network technologies, topology and performance drive decisions for sync equipment selection and deployment locations

Synchronization, Standards and Requirements

Frequency, Phase and Time Synchronization

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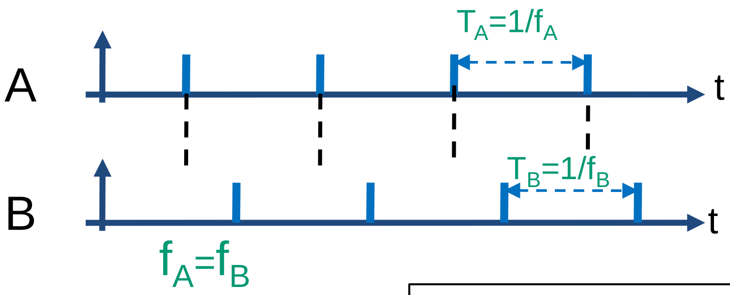
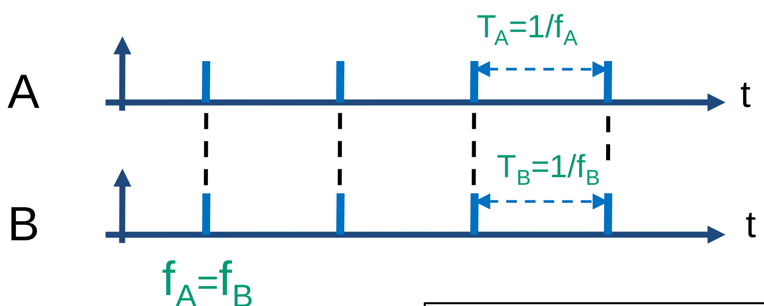
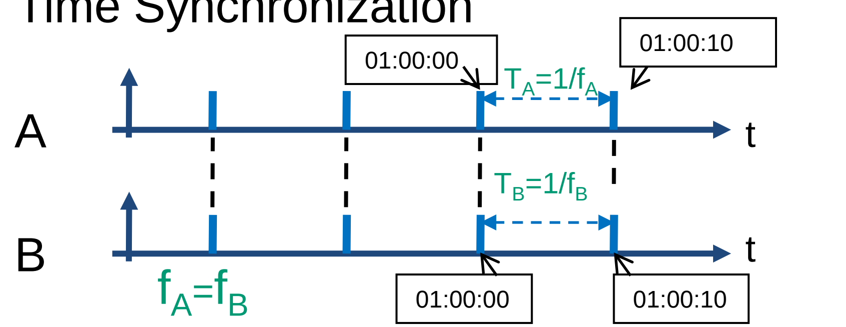
Frequency Synchronization



Phase Synchronization



Time Synchronization



Why is Synchronization Required?

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Application	Why You Need to Comply	Impact of Non-compliance
LTE -FDD	Call Initiation	Call Interference Dropped calls
LTE -TDD	Time slot alignment	Packet loss/collisions Spectral efficiency
LTE-A MBSFN	Proper time alignment of video signal decoding from multiple BTSs	Video broadcast interruption
LTE-A MIMO/COMP	Coordination of signals to/from multiple base stations	Poor signal quality at edge of cells, LBS accuracy
LTE-A eICIC	Interference coordination	Spectral inefficiency & Service degradation

Needs and Impacts are cumulative: "plus all of the above"

Structure of ITU-T Recommendations

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Definitions / Terminology

- **G.8260:** Definitions and Terminology for Synchronization in Packet Networks

Frequency

Basic Aspects

- **G.8261:** Timing and Synchronization Aspects in Packet Networks (Frequency)

Network Requirements

- **G.8261.1:** PDV Network Limits Applicable to Packet-Based Methods (Frequency)
- G.8261.2: Reserved for future use

Clocks

- **G.8262:** Timing Characteristics of a Synchronous Ethernet Equipment Slave Clock (EEC)
- **G.8263:** Timing Characteristics of Packet-Based Equipment Clocks (PEC)

Methods

- **G.8264:** Distribution of Timing Information through Packet Networks
- **G.8265:** Architecture and Requirements for Packet-Based Frequency Delivery

Profiles

- **G.8265.1:** Precision Time Protocol Telecom Profile for Frequency Synchronization
- G.8265.2 PTP Telecom Profile for Frequency #2

Time/Phase

Basic Aspects

- **G.8271:** Time and Phase Synchronization Aspects in Packet Networks

Network Requirements

- **G.8271.1:** Network Requirements for Time/Phase (Jul13)
- G.8271.2: Reserved for future use

Clocks

- **G.8272:** PRTC (Primary Reference Time Clock) Performance
- **G.8273:** Packet-Based Equipment Clocks for Time/Phase: Framework (Jul13)
  - **G.8273.1:** Telecom Grandmaster (T-GM) (Jul13)
  - **G.8273.2:** Telecom Boundary Clock (T-BC) (Jul 13)
  - G.8273.3: Telecom Transparent Clock (T-TC)
  - G.8273.4: Telecom Time Slave Clock (T-TSC)

Methods

- G.8274: Reserved for future use
- **G.8275:** Architecture and Requirements for Packet-Based Time and Phase Delivery (Jul 13)

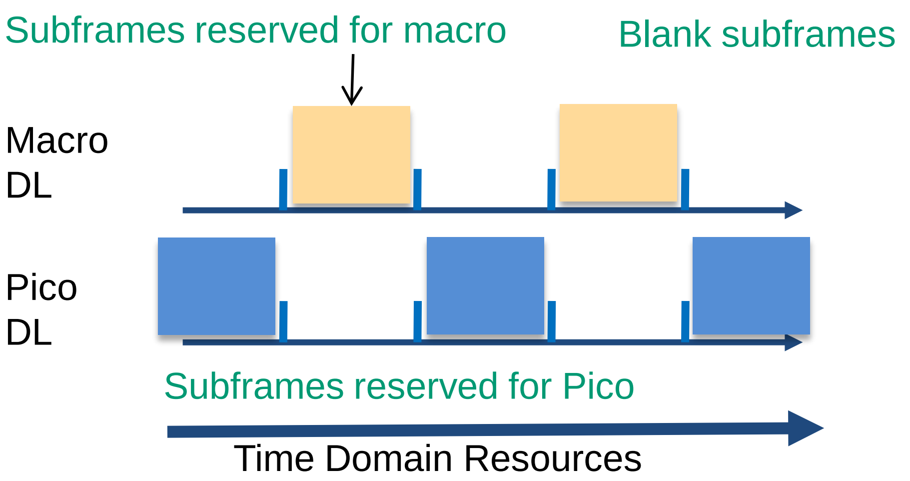
Profiles

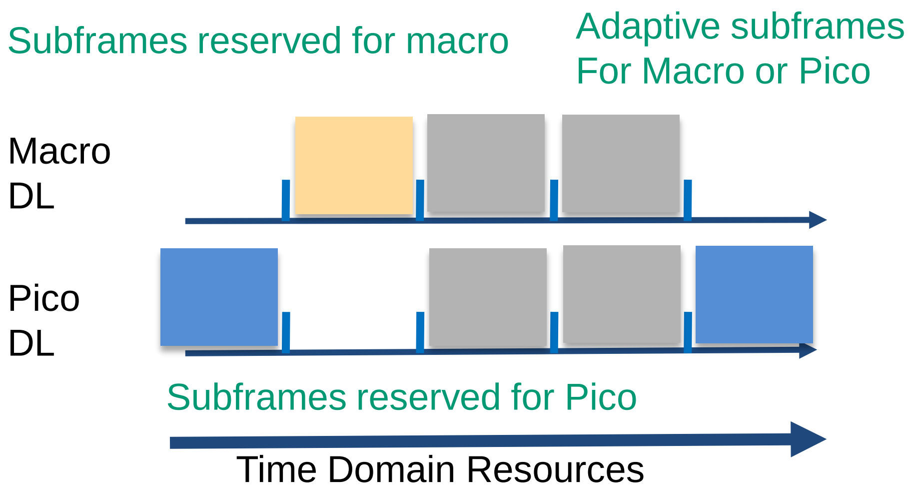
- **G.8275.1:** PTP Profile for Time and Phase Synchronization *(full timing support)* (Jul 13)
- **G.8275.2:** PTP Profile for Time and Phase Synchronization *(partial timing support)* (New!)

Legend: agreed | ongoing | options

Inter-Cell Interference Coordination

eICIC = enhanced Inter-cell Interference Coordination





- R8 ICIC defines a limited one dimensional frequency based interference management for macro nodes
- R10 eICIC introduces control in the HetNet on the three dimensions of power, phase, and frequency
- LTE-A can also use modified X2 adaptive resource partitioning in a TDD environment also (requires precise time & phase synchronization)

LTE Synchronization Requirements

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Application	Frequency Network / Air	Phase	Note
LTE – FDD	16 ppb / 50 ppb	NA	-
LTE – TDD	16 ppb / 50 ppb	± 1.5 µs	≤3 km cell radius
		± 5 µs	>3km cell radius
LTE MBMS (LTE-FDD & LTE-TDD)	16 ppb / 50 ppb	± 10 µs	inter-cell time difference
LTE- Advanced	16 ppb / 50 ppb	± 1.5 to 5 µs	see table below for detail

Frequency requirements for earlier generations are same as above. GSM, UMTS, W-CDMA do not have a phase requirement. CDMA2000 phase requirement is ±3 to 10 µs. TD-SCDMA phase requirement is ±1.5 µs.

Small cell/femtocells (UMTS, LTE-FDD) require frequency performance of 100-250 ppb for the air interface.

LTE-Advanced	Type of Coordination	Phase
eICIC	enhanced Inter-cell Interference Coordination	± 1.5 to 5µs
CoMP Moderate to tight	UL coordinated scheduling	± 5 µs
	DL coordinated scheduling	± 5 µs
CoMP Very tight	DL coordinated beamforming	± 1.5 µs
	DL non-coherent joint transmission	± 5 µs
	UL joint processing	± 1.5 µs
	UL selection combining	± 1.5 µs
	UL joint reception	± 1.5 µs

Note: Inter-cell coordination. Times are requirement for distributed time accuracy.

LTE-A covers multiple techniques rather than a single technology.

Not all features will deployed everywhere, leading to differences in real world requirements.

Figures are still in discussion by members of the 3GPP.

Poll Questions

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Synchronization Distribution Architecture for LTE Networks

3 Guidelines

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1. Use an independent source for sync
   – Best in class solutions
   – Efficient operation in a multi-vendor network

2. Protect your sync for service assurance
   – GNSS, PTP & Stable frequency source
   – High performance holdover

3. Deploy PTP Grandmaster where the network needs it for accuracy
   – Backhaul supports accuracy: allows deployment closer to the core
   – Noisy, high PDV network: requires deployment “at or near the edge”

4 Basic Network Scenarios

1. LTE frequency, managed Ethernet backhaul
   – Consistent, known backhaul performance

2. LTE frequency, high PDV, noisy backhaul
   – Diverse transport technologies, 3rd Parties, many hops

3. LTE phase, retrofitted or new Ethernet backhaul
   – SyncE and Boundary Clocks in every network element

4. LTE phase, existing backhaul, possibly high PDV, noisy
   – No BC, probably no SyncE, diverse transport, 3rd party

Setting and Holding
Two aspects of synchronization

Frequency		Phase	
Deliver and set frequency	Hold frequency	Deliver and set phase	Hold phase

1. LTE Frequency: G.8265.1 Basic Architecture

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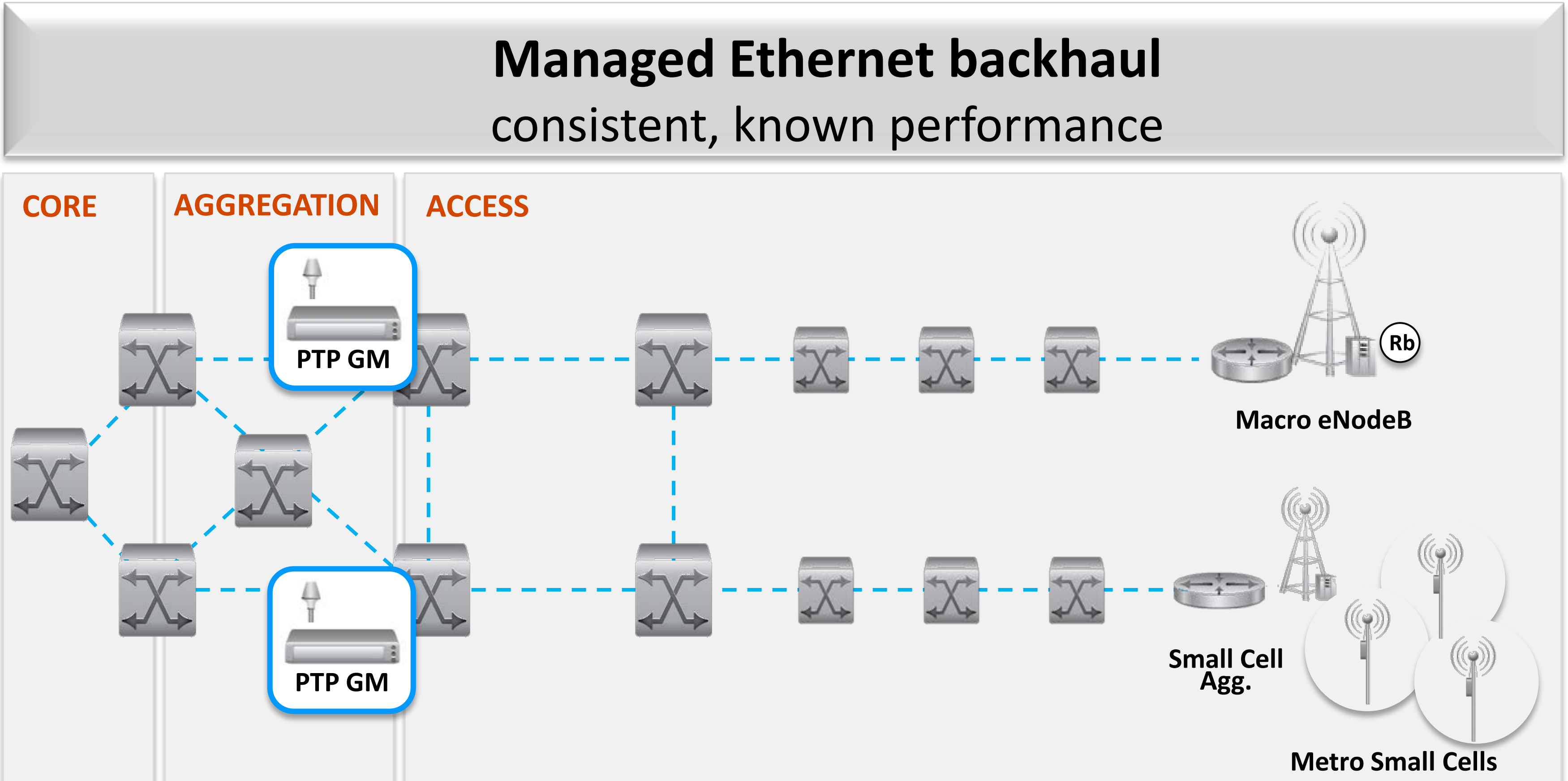

- Set frequency with PTP (GNSS primary source)
- Hold frequency with high quality oscillator

2. LTE Frequency: G.8265.1 Overlay Architecture

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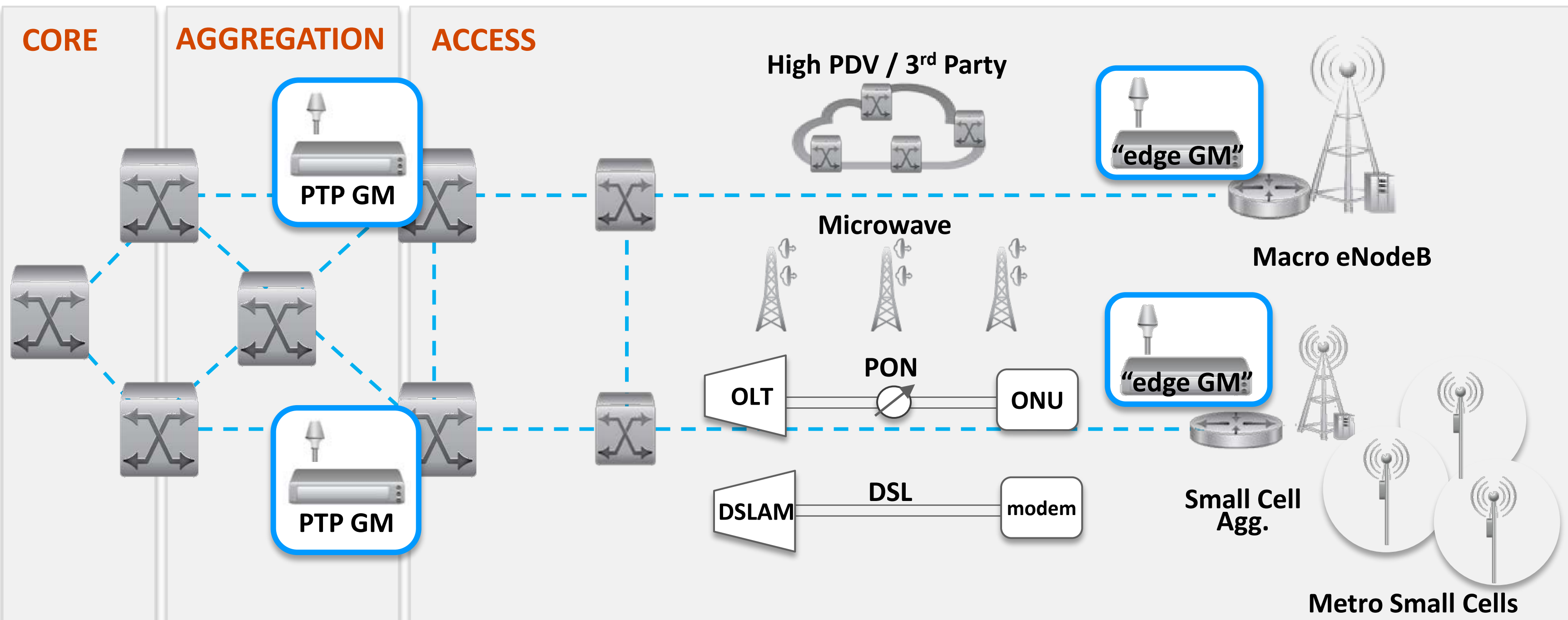
Uncertain performance, noisy backhaul

Multiple technologies, many hops/paths, high packet delay variation, 3rd party access vendors, etc.



- Set frequency with PTP or GNSS
- Hold frequency with PTP or GNSS

- G.8265.1 profile

3. LTE Phase: G.8275.1 Architecture (pre-standard)

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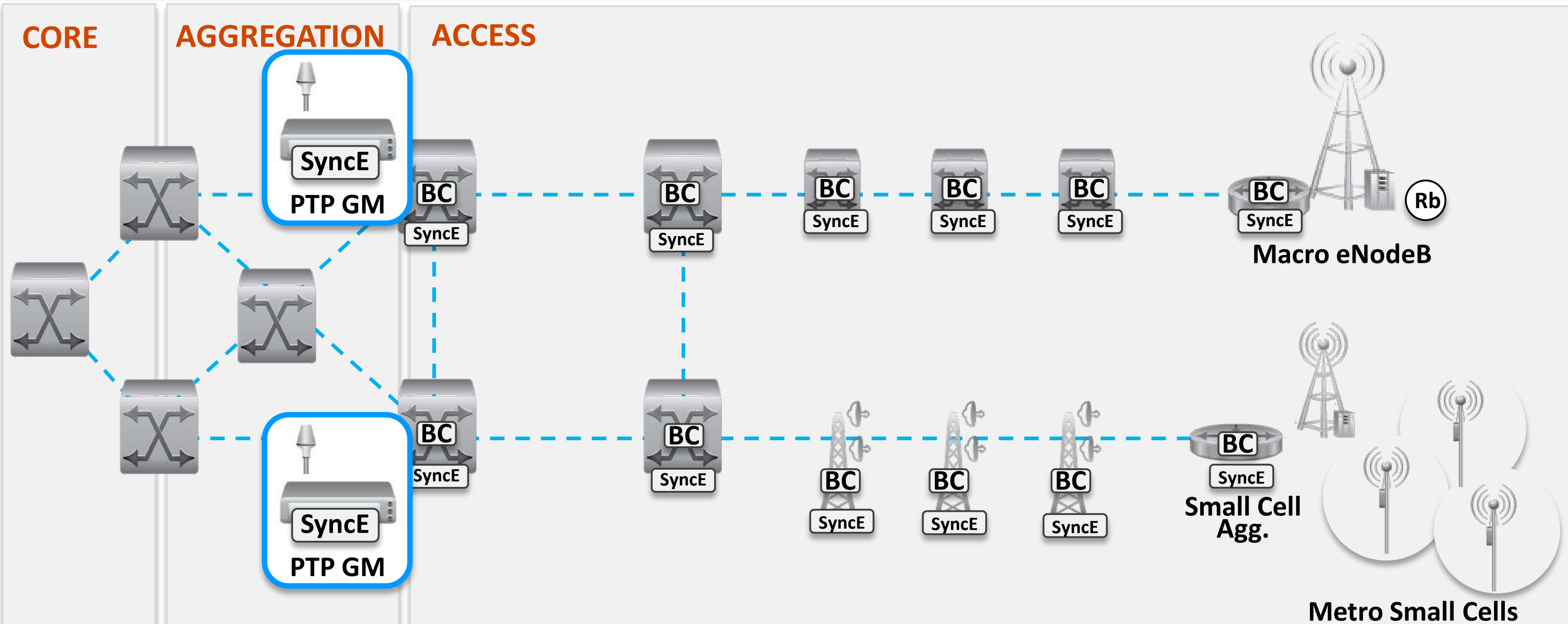
Retrofit existing equip. or build new network

Managed Ethernet, synchronous Ethernet, boundary clocks

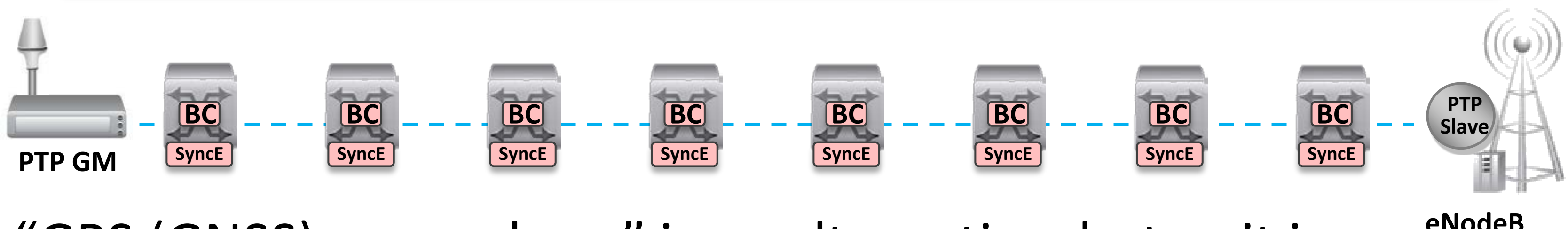


- Set time/phase with PTP (GNSS/GPS at primary source)
- Hold time/phase with rubidium

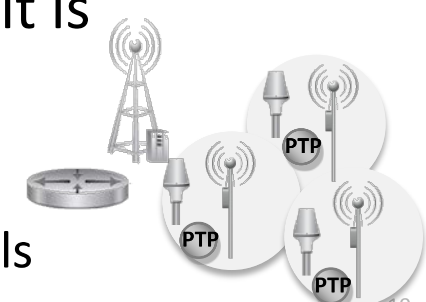
G.8275.1 Does Not Fit All Networks

- SyncE with Boundary Clocks is not always viable
  - Many networks are not suitable: diverse transport technologies, 3rd party backhaul, many Ethernet paths and asymmetry, PON, bonded DSL and VDSL2+, WiFi, weak PTP clients
  - Major retrofit cost to existing networks. Not feasible for many carriers
  - Manual hop-by-hop tuning required (example: at CMCC)

ITU direction (G.8275.1): Boundary Clock in every network element



- "GPS (GNSS) everywhere" is an alternative, but as it is today…
  - Vulnerable, needs backup
  - Not feasible for many deployments—particularly small cells



G.8275.2 Cost Effective Alternative Architecture

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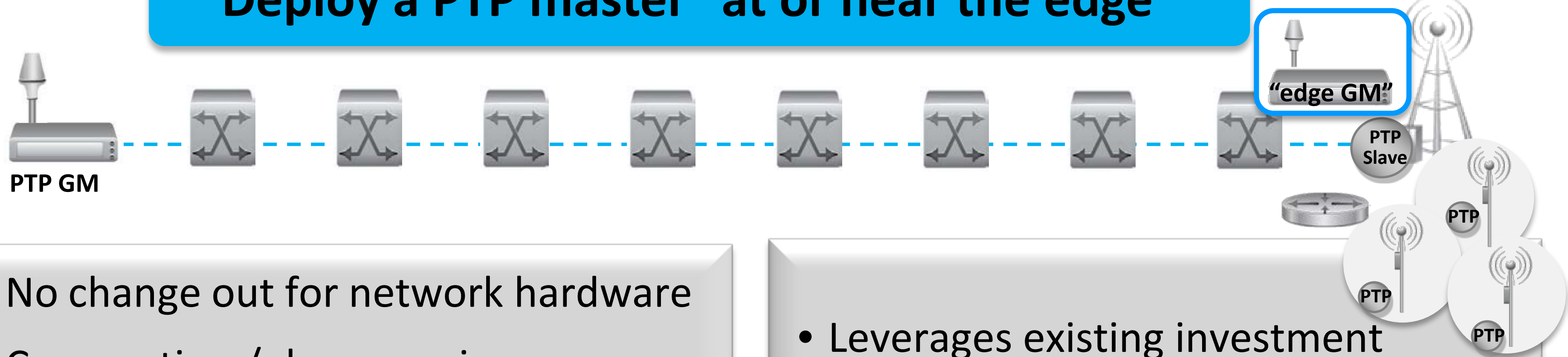
Deploy a PTP master "at or near the edge"



- No change out for network hardware
- Can run time/phase services over existing MPLS / CE network
  - Preserves MPLS value proposition
- No change to back office engineering and operations processes
  - Removes BC engineering
- Mitigates asymmetry as an issue
- Stand alone sync not dependent on embedded NE
  - Quality of BC design not an issue

- Leverages existing investment made in GPS at eNodeB sites
- Leverages any existing PTP deployments for FDD architectures
- Deploys highest quality PTP client
- Compliant to all existing FDD and TDD standards
  - compatible with G.8265.1 profile
- Simple and easy to deploy for all LTE architectures

4a. LTE Phase: G.8275.2 Hybrid GPS/PTP Arch. (pre-standard)

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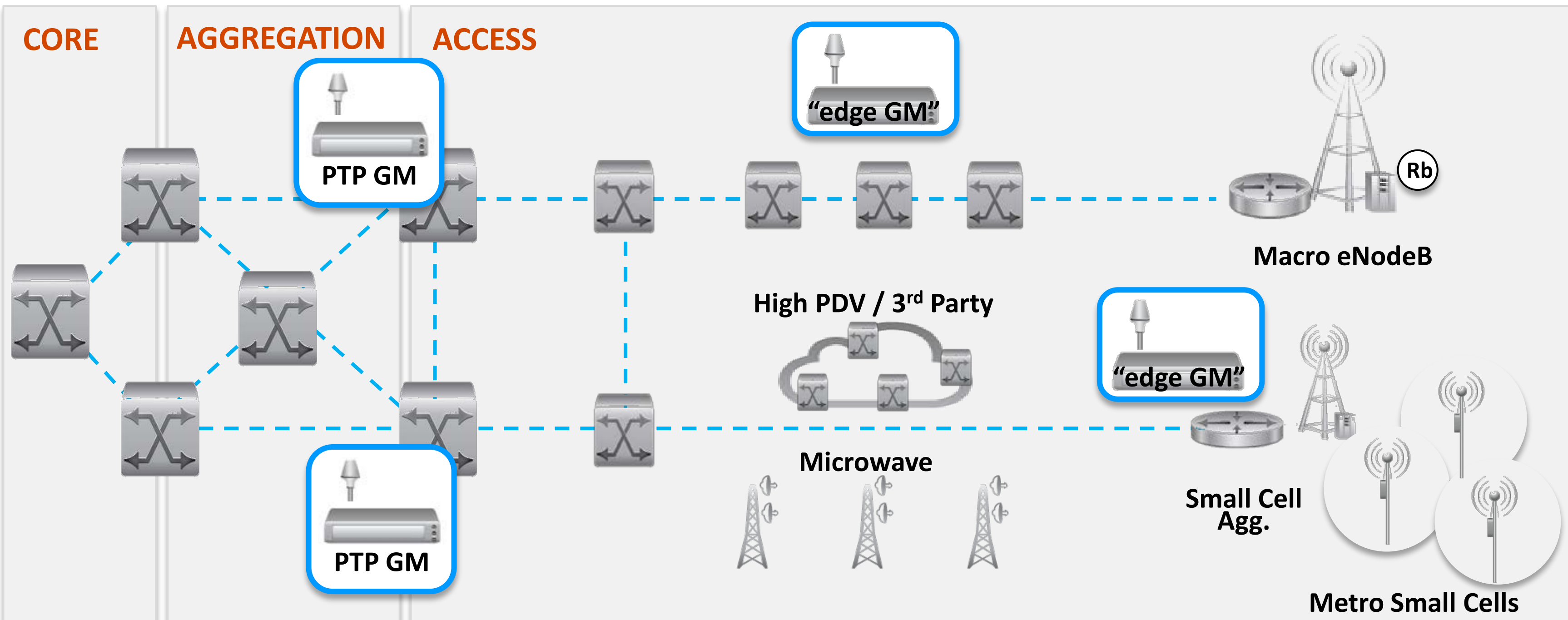
Existing backhaul, good performance

"Last mile" of network supports accuracy needed for phase to macro

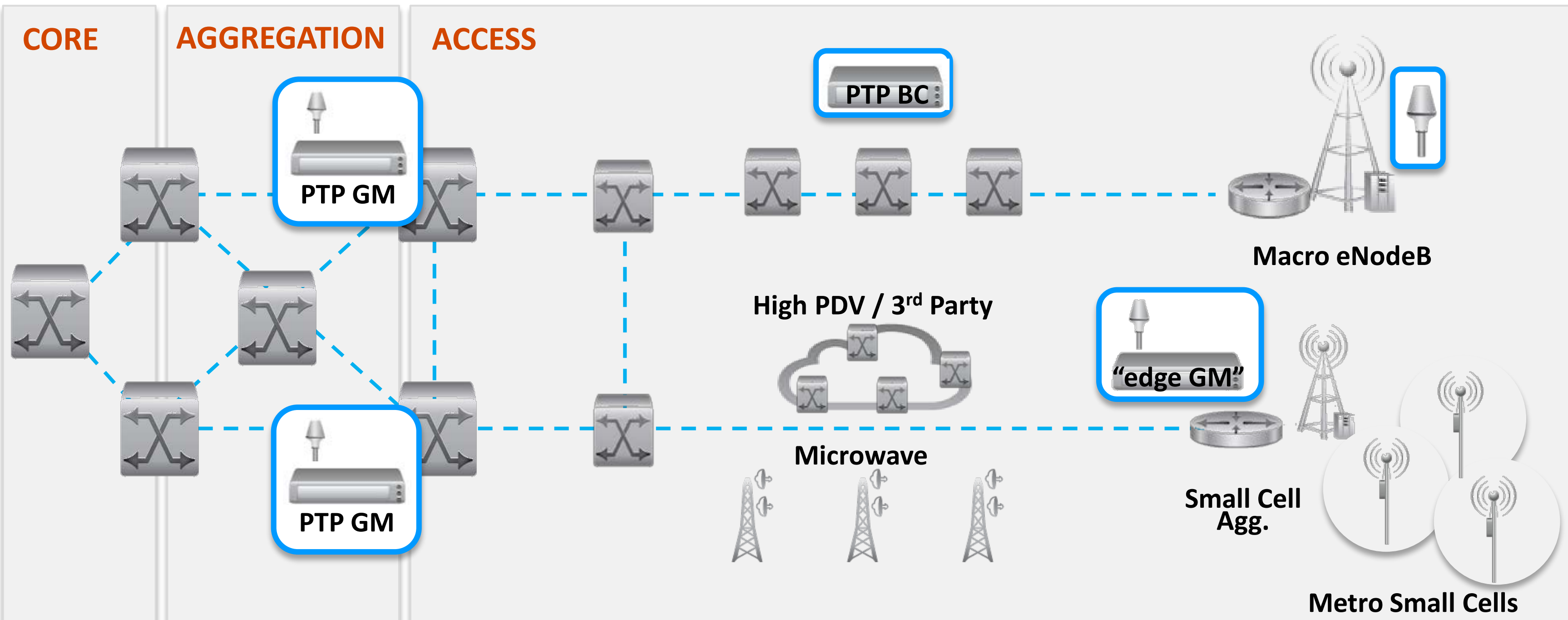


- Set time/phase with PTP
- Hold time/phase with PTP or Rb
- Consistent with G.8265.1 profile
- Requires high quality PTP slave

4b. LTE Phase: G.8275.2 Partial OPS Overlay Arch. (pre-standard)

Existing backhaul, diverse tech and/or noisy

Multiple technologies, many hops/paths, high PDV, 3rd party, etc.



- Set time/phase with GNSS
- Hold time/phase with PTP

- Pre-G.8275.2 (consistent with G.8265.1)
- Requires intelligent, high quality implementations of BC in access network and PTP slave at macro

G.8275.2 Profile for Time and Phase

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- This architecture has been proposed to the ATIS / ITU standards bodies:

  “a new profile to support time and phase distribution over existing deployed networks…compatible with the PTP profile for frequency distribution defined in G.8265.1”

- Contribution submitted by: Symmetricom, AT&T, Verizon, Sprint Nextel, and T-Mobile-USA

Quality of the PTP Client Affects Performance

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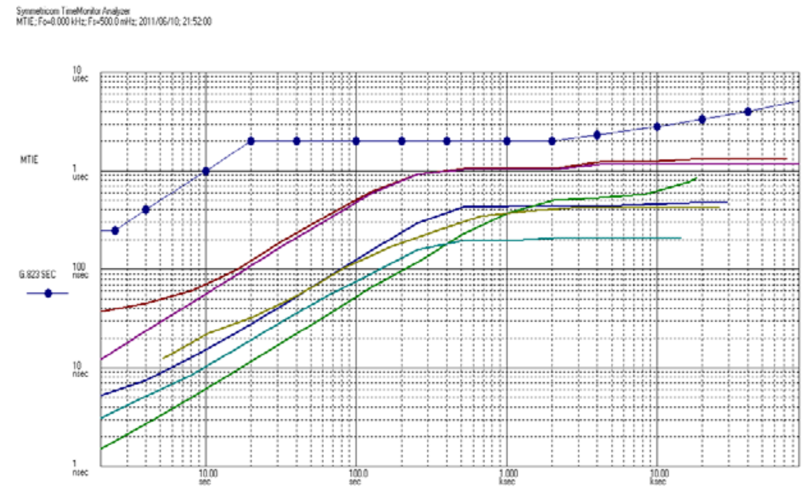
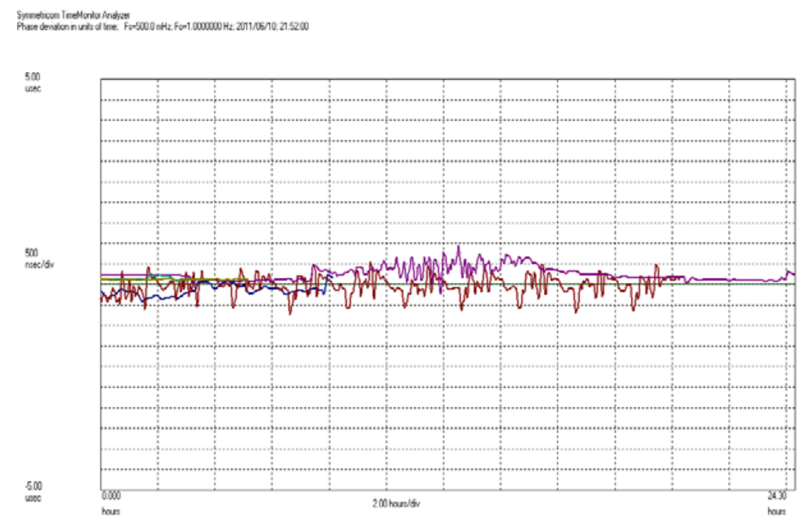
- Symmetricom clients, G.8261 test cases
  - Frequency performance: MTIE "beneath the mask" (G.8261 SEC mask)
  - Phase performance tests: consistently under 500 ns
- Consistency of the clients
  - Differences in vendor implementations yield different results

Advanced algorithms, high quality oscillator, design implementation





Residential and Enterprise Indoor Small Cells

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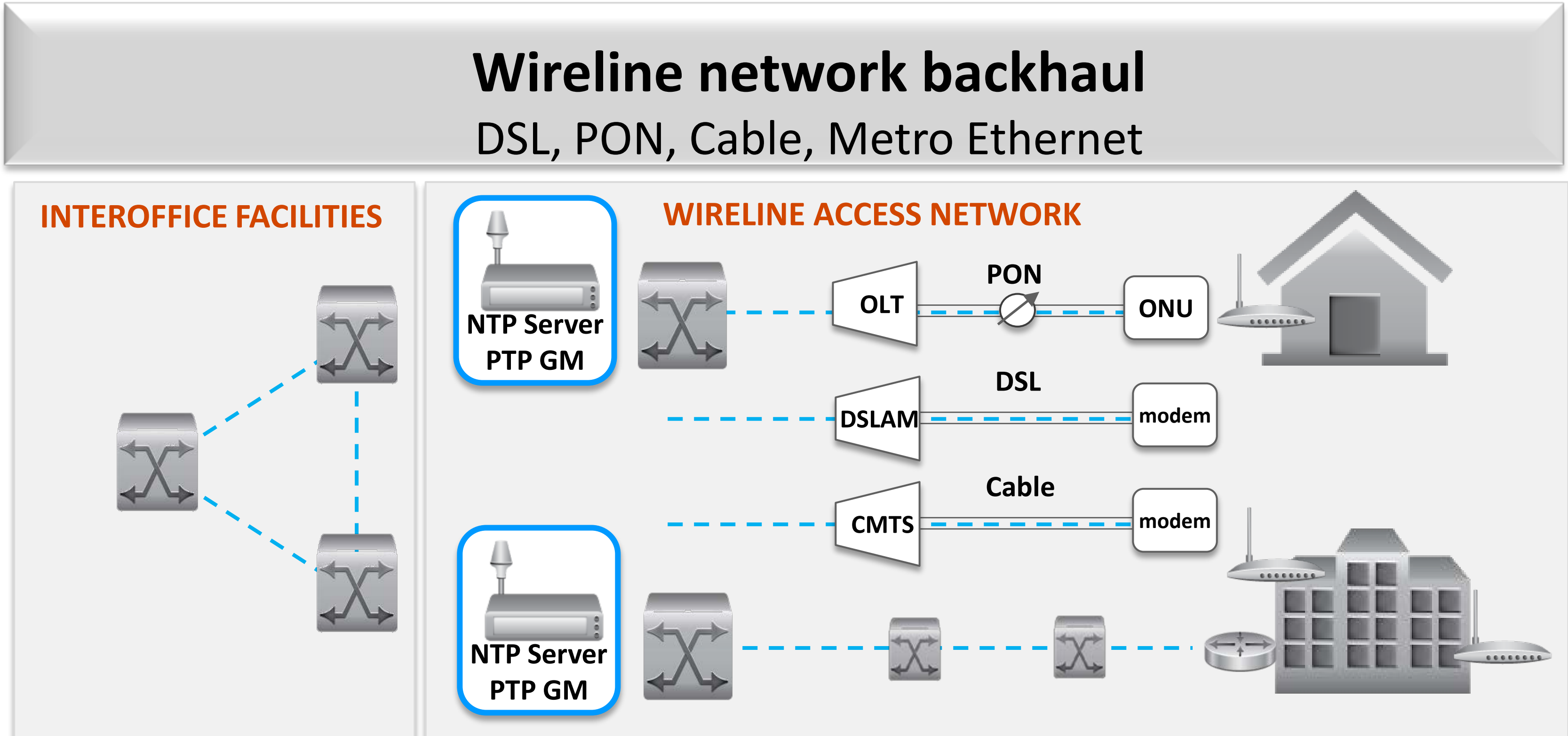

Synchronization Distribution Architecture

- Sync equipment and deployment
  - Core: high capacity, carrier grade NTP server (or PTP grandmaster); redundant equip. configuration and network protected
  - High quality embedded clients in the small cell; with or without "softGPS"

Summary

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- LTE technologies drive new requirements for synchronization
- Backhaul network technologies, topology and performance drive synchronization equipment and deployment decisions

- Emerging boundary clock-based solutions will work for some scenarios—but not all
- GNSS (GPS) requires back up and is not feasible for some deployment scenarios, especially small cells

- An alternative architecture that places a PTP master “at or near the edge” is the solution for many of these situations

Thank You!

Synchronization Distribution Architectures for LTE Networks

Questions & Answers

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