5G Transport Requirements

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Extreme networks

5G Drives Transport Network Changes

In Many Dimensions

Mobile opearators will **demand new transport services** – Significant transport operator revenue at stake

4G	**5G**
One key service	Many disparate services
One shared transport network	Network isolation / slicing
Consumer focus	Consumer and enterprise applications
Best effort	Best effort and critical data
Latency not critical	Low latency and latency tolerant
Statistical SLA for backhaul transport	Assured QoS etc.
Point-to-Point backahaul	Multi-destination x-haul
Carrier Ethernet transport ok	CU-CU and MEC
	Routing required
Simple RAN architecture	Multiple RAN architectures
Monolithic core	Virtualized core and CUPS
Big business for transport operators	Big business for transport operators

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5G is Transforming Network Architectures

- **Distributed RAN (D.-RAN)**: traditional integrated base station with backhaul connection to first point of aggregation; will still be relevant in 5G era
- **Centralized RAN (C-RAN)**: an architecture in which the base station is split into 2 parts; the radio head and the baseband unit
- **Virtualized RAN (vRAN)**: an evolution of a centralized RAN which consists of a centarlized pool of baseband units (BBUs), virtualized RAN control functions and service delivery optimization; with a virtual RAN, baseband modules are moved away from the base station to a data center
- **Open RAN (ORAN)**: this is not specifically an architecture but refers to the ability to integrate, deploy and operate radio access networks using components, subsystems and software sourced from multiple suppliers, connected over open interfaces – and is seen as vital in supporting the adoption of newer architectures

Evolution in 5G RAN **drives challenges for transport network**: capacity, latency, complexity, flexibility, etc.

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Is Your Network Prepared for Evolution to 5G?

		Baseline Capacity and coverage	LTE Evolution Gigabit introduction	5G on Mid-bands Dual connectivity with 5G on mid bands	5G on High-bands Increased capacity and ultra lowlatency
High bands (24GHz – 40GHz)					
Mid bands (3.5GHz – 8GHz)					
Mid bands (1GHz-2.6GHz)					
Low bands (sub-1GHz)					
			Inflection point		
Transport requirements	Capacity Interface Sync	< 200Mbps GE Frequency only	< 1.5Gbps N x GE / 10GE Frequency / time	1 to 5 Gbps 10GE Frequency, time and phase	5 to 20 Gbps 2 x 10GE / 25GE Frequency, time and phase
Transport technology	Backhaul Fronthaul	MW / Fiber -	MW / Fiber -(CPRI)	MW / Fiber CPRI / eCPRI	MW / Fiber / IAB CPRI / eCPRI
RAN architecture		DRAN	DRAN (CRAN / ERAN)	DRAN / CRAN / ERAN / VRAN / ORAN	DRAN / CRAN / ERAN / VRAN / ORAN

2G+3G 4G 5G 4G+5G

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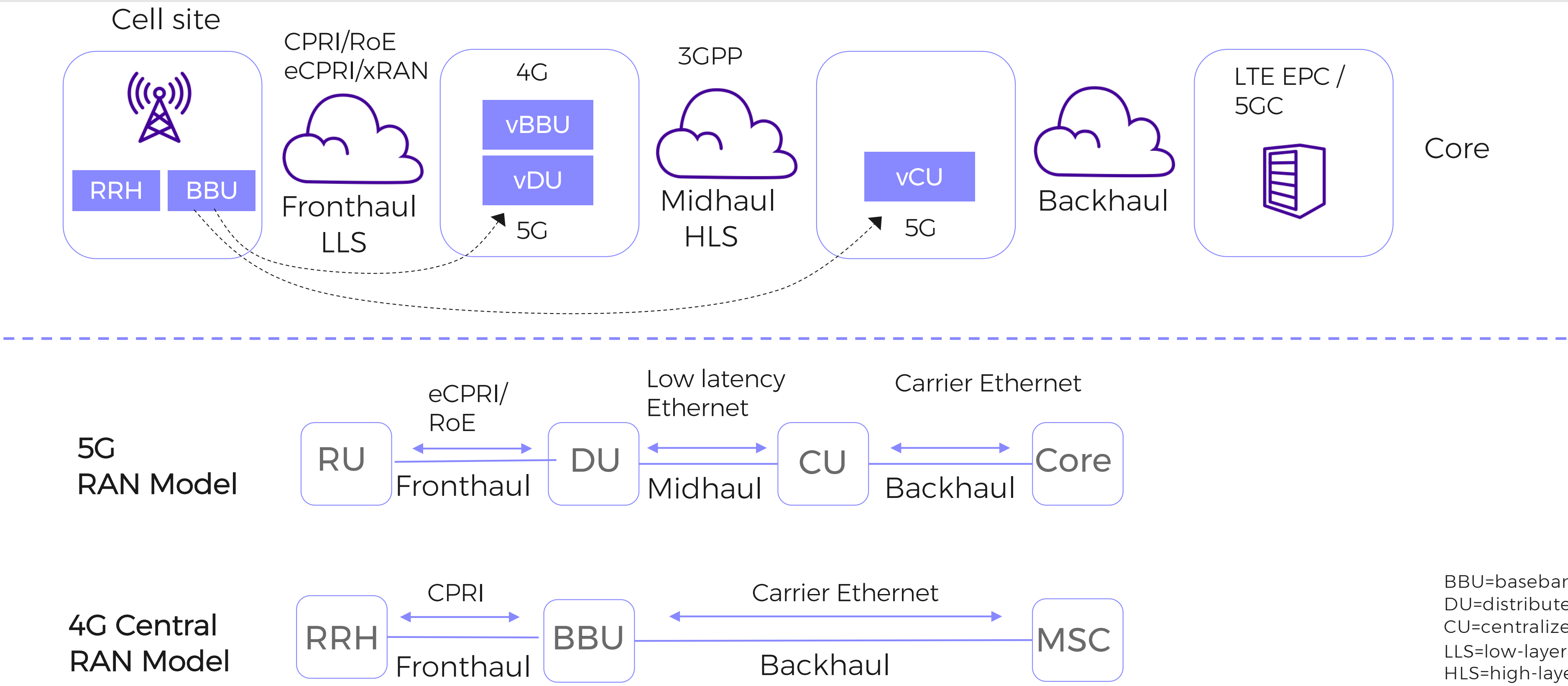
4G to 5G Network Evolution Challenges



BBU=baseband unit
DU=distributed unit
CU=centralized unit
LLS=low-layer split
HLS=high-layer split

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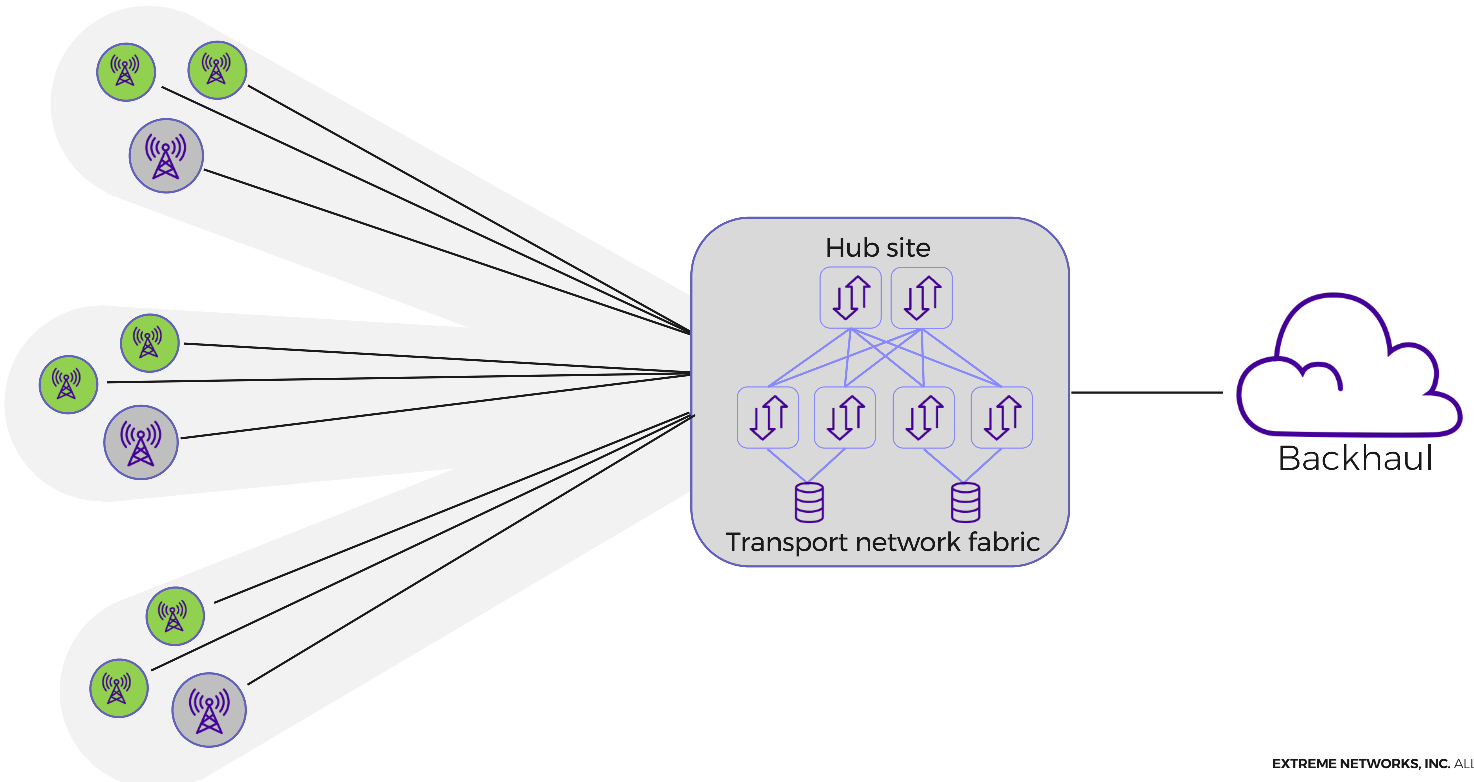
C-RAN

Cloud RAN (virtualized RAN) would provide benefits such as site simplifications (RU), inter-site coordination and operational gains by centralizing resources into the hub sites.



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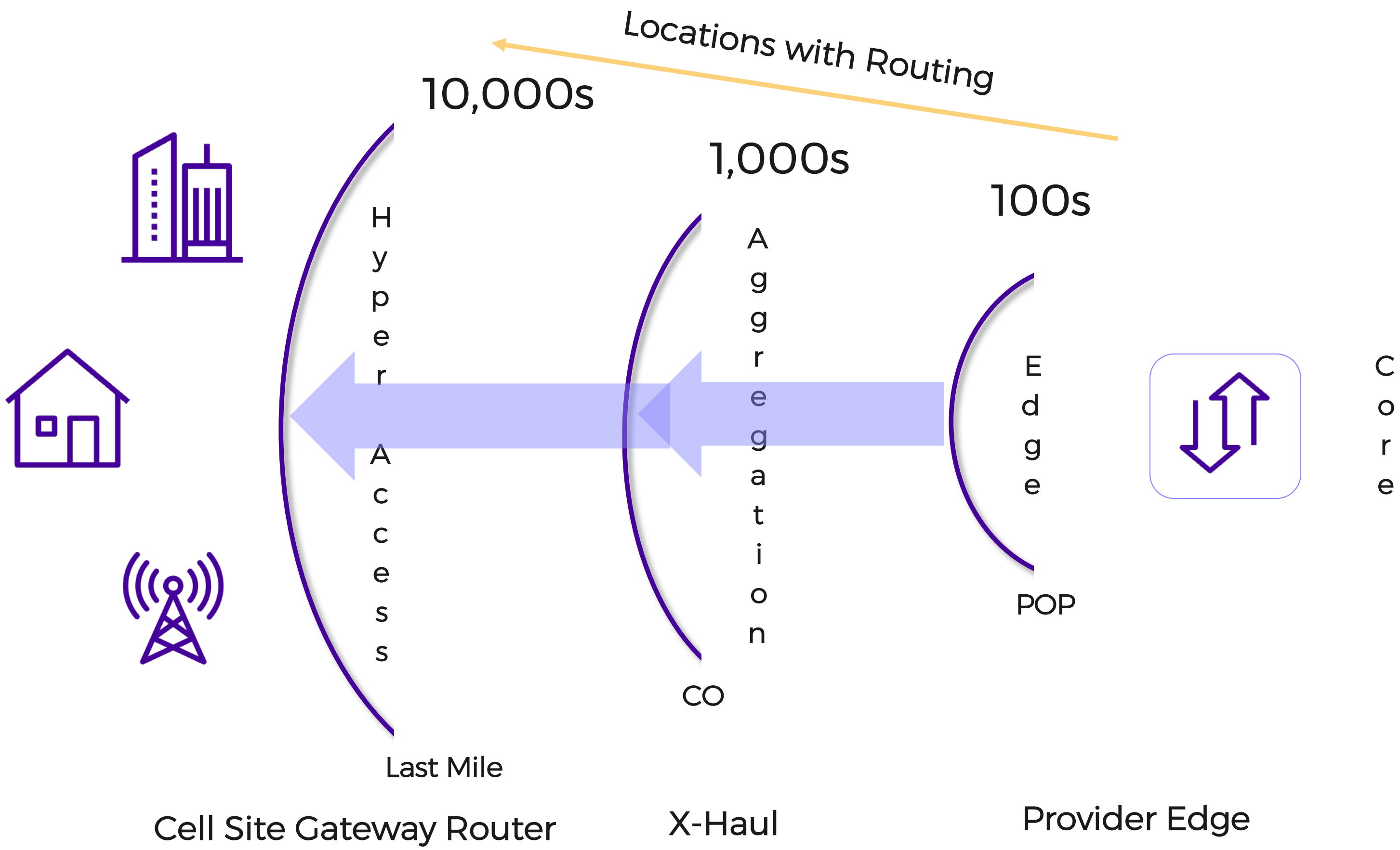
Order of Magnitude



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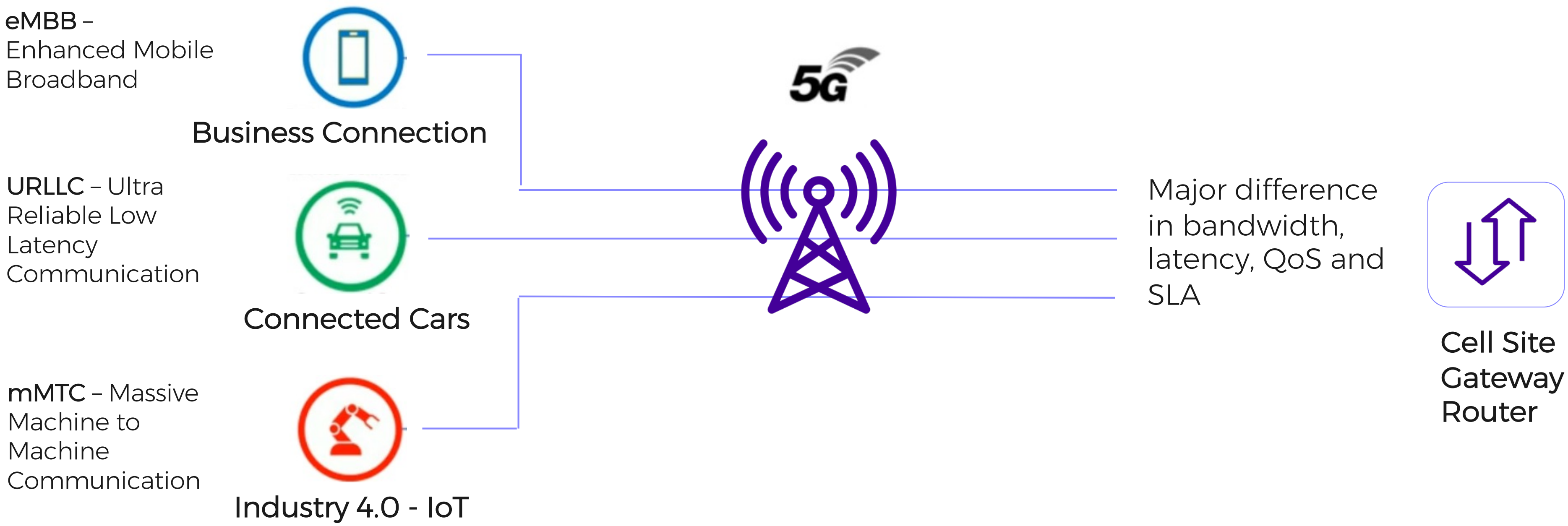
5G Network Slicing



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What is PTP?

- ✅ Protocol for distributing precise time and frequency over packet networks
- ✅ Defined in IEEE Standard 1588
  - First version (2002) targeted LAN applications
  - Second version (2008) expanded applicability to cover telecommunications networks
  - Third version now under discussion
- ✅ Time is carried in “event messages” transmitted from a Grandmaster Clock to a Slave Clock and vice versa
- ✅ Runs over Ethernet and/or IP networks
- ✅ Commonly referred to as:
  - PTP (Precision Time Protocol) or PTPv.2
  - IEEE1588-2008 or IEEE1588 v.2

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Transport Option - Time Sensitive Networking (TSN)

- Packet Aggregation using IEEE 802.1 CM TSN
  - Precision Time Protocol (PTP)
  - Pre-emption (CPRI, eCPRI)
- IEEE 1914.3 Radio over Ethernet (RoE)
  - Optimized for cell tower deployments
- Significantly lower TCO than active WDM approach

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What is a PTP Profile?

- What is a profile?
  - Profiles were introduced in IEEE1588-2008, to allow other standards bodies to tailor PTP to particular applications
  - Profiles contain a defined combination of options and attribute values, aimed at supporting a given application
  - Allows inter-operability between equipment designed for that purpose
- PTP Telecom Profile for Frequency (G.8265.1) published Oct. 2010
  - Supports frequency synchronization over telecoms networks
  - Main use-case is the synchronization of cellular base-stations

The G.8265.1 PTP Telecom Profile enables the deployment of PTP-based frequency synchronization by telecoms operators

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PTP Telecom Profiles

- ITU two new PTP Telecom Profiles:
  - G.8275.1 –"Full Timing Support"
  - G.8275.2 –"Partial Timing Support"
  - Both profiles target accurate time/phase distribution
- G.8275.1 is aimed at new build networks
  - Requires boundary clocks at every node in the network
- G.8275.2 is aimed at operation over existing networks
  - Permits boundary or transparent clocks, but not required
  - Boundary clocks placed at strategic locations to reduce noise
  - Main target use case is the time/phase requirements of mobile cellular TDD and LTE-A systems
- Target accuracy is time synchronization to within 1.5µs

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G.8275.1 “Full Timing Support” Profile

Uses a boundary clock at every node in the chain between PTP Grandmaster and PTP Slave

- Reduces time error accumulation through the network
- Boundary clocks defined with a filter bandwidth of 0.1Hz
- Recommends the use of Synchronous Ethernet to synchronize boundary clock to a stable frequency
    - Defines **Sync** and **Delay_Request** message rate of 16 messages/s
- Operates over L2 Ethernet network
    - Uses the Ethernet addresses identified in IEEE1588-2008 Annex F
    - Support of unicast IP has been proposed but not agreed (yet?)
- Supports multiple active grandmasters for redundancy

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G.8275.2 “Partial Timing Support” Profile

Why a second time/phase profile?

- Some service providers need to operate time/phase synchronisation over existing networks
- Reduces barriers to entry into LTE-A systems; don’t need to build an entirely new network
- Allows operation over 3rd party network providers (given appropriate quality guarantees)
- Result: “Partial Timing Support Profile”
- Key features:
  - Operates over existing switches and routers, using unicast IP
  - Uses boundary or transparent clocks where necessary to “clean up” time signal as it passes through the network
  - Supports multiple active grandmasters for redundancy

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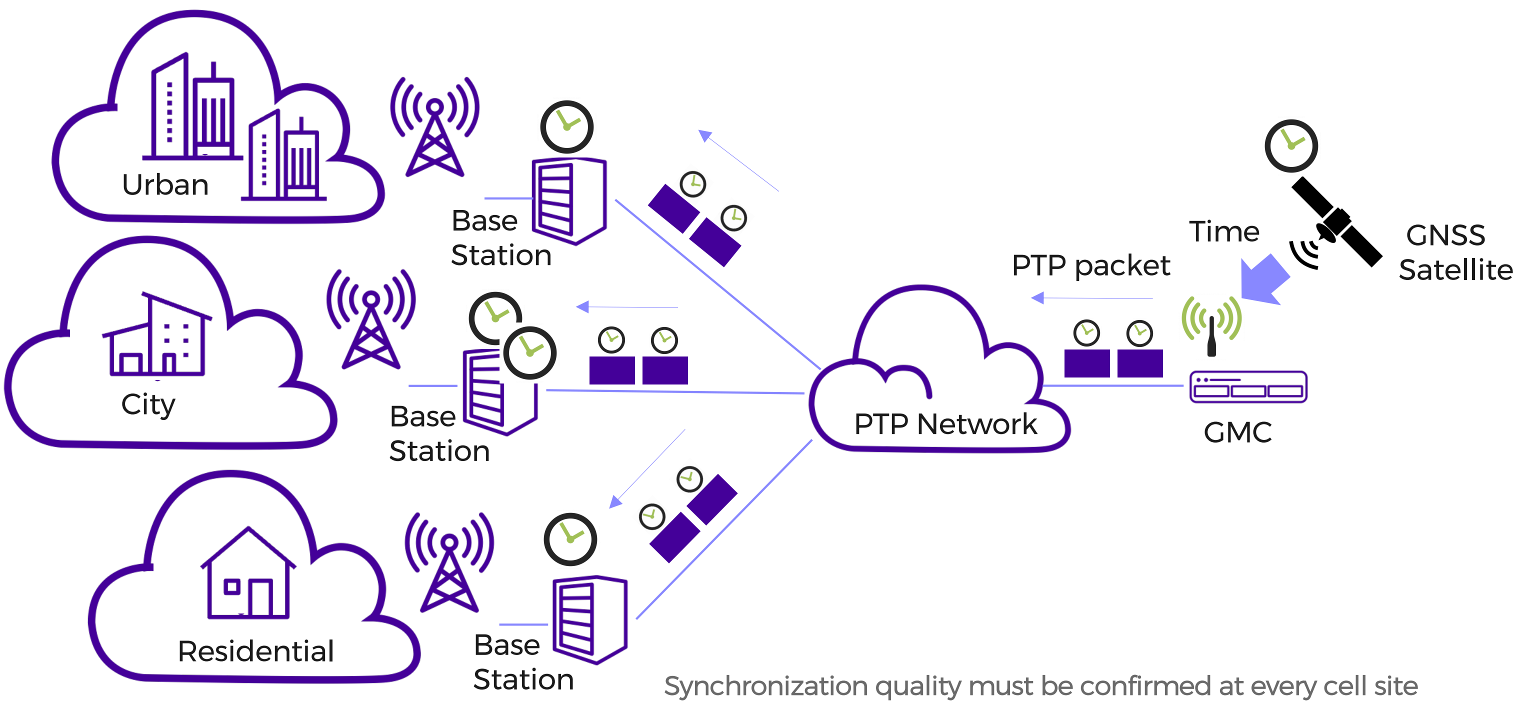
5G Requires Timing Distribution to Cell Site

- IEEE1588v2 PTP is utilized for synchronization not only by frequency, but also by phase
- A Grand Master Clock (GMC) distributes timing to all cell sites via a packet network
- Every cell site has it's own path



Synchronization quality must be confirmed at every cell site

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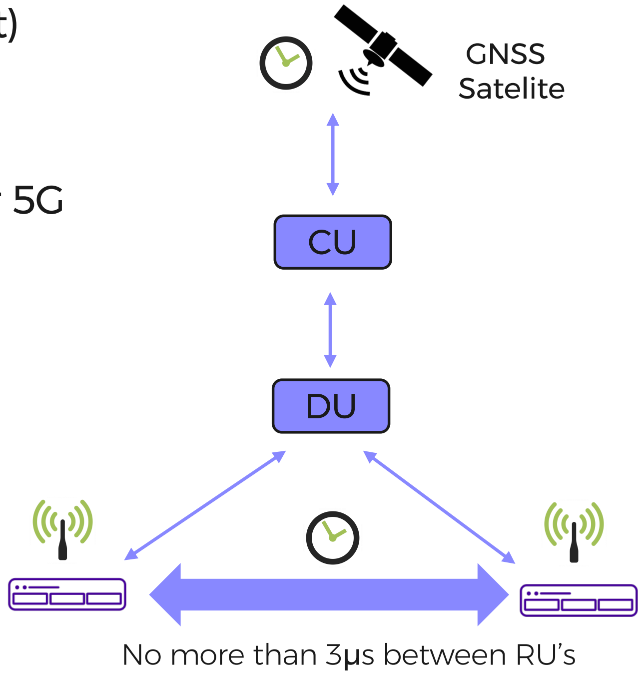
LTE-A and 5G TDD Network Synchronization and Timing

3GPP

- LTE advance and 5G **requires 3µs** TAE (Relative measurement)
  - Between any two RU's the synchronization time must be **within 3µs**
  - **Thus from any air interface back to the T-GM a max of 1.5µs is required**
- CoMP has been rolled out for 4G advance and will be used for 5G
  - **Many current networks have very tight timing constraints**
- Network density is increasing for multiple reasons
- Accurate timing is no longer nice to have **it's required**
- **Testing timing** is a **large and new challenge** for operators



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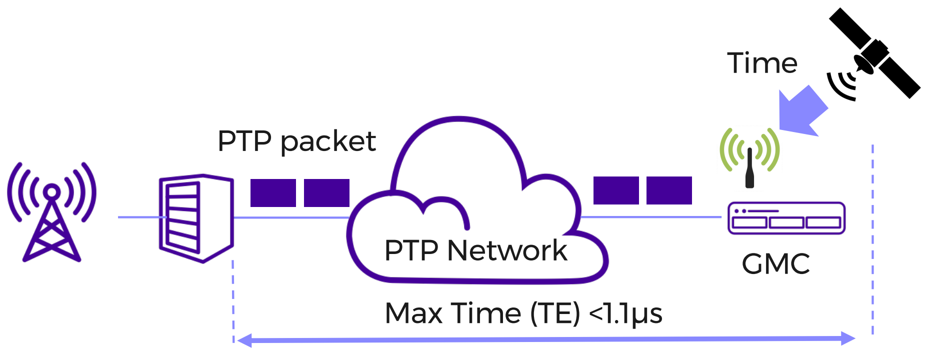
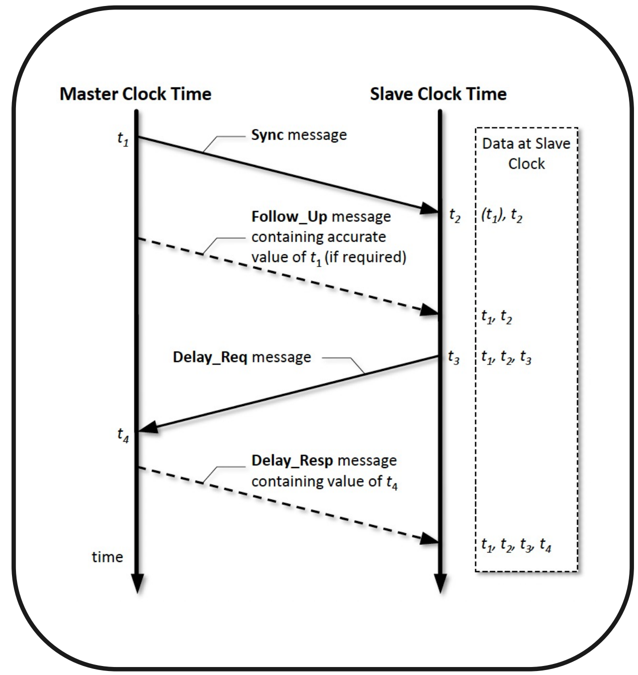
Key Factors for Accurate Synchronization

- What factors make synchronization poor?
  - Time Error (TE) = Constant TE (cTE) + Dynamic TE (dTE)
    - **cTE**: PTP packet **latency asymmetry**
    - **dTE**: PTP packet **latency variation**
- Maintaining synchronization quality = Maintaining latency
- Turning up the network to minimixe asymmetry and variation





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Budgets of different sections of the network

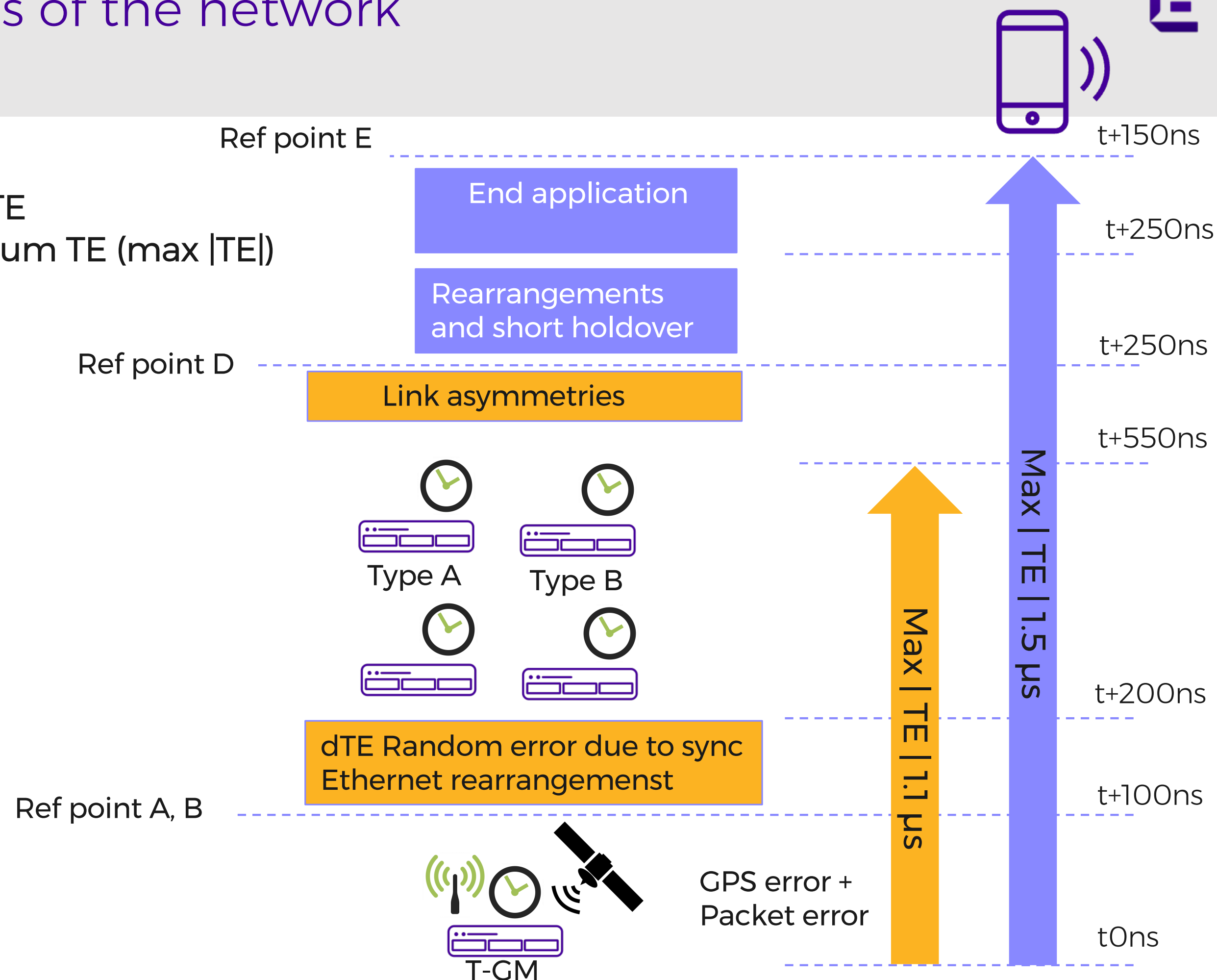
- TE is made of two components = dTE + cTE
- The key measurement is absolute maximum TE (max |TE|)

End application noice
150ns (consider for eNB)
Rearrangements and short term holdover
250ns

Link asymmetric delays
250ns (type A network element)
380ns (type B network element)

cTE of the T-BCs (additive)
50ns (type A network element)
20ns (type B network element)
dTE of the T-BCs (additive)
200ns (less than 20 nodes)

PRTC and T-GM
100ns (~35ns in placing the time in a packet)



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