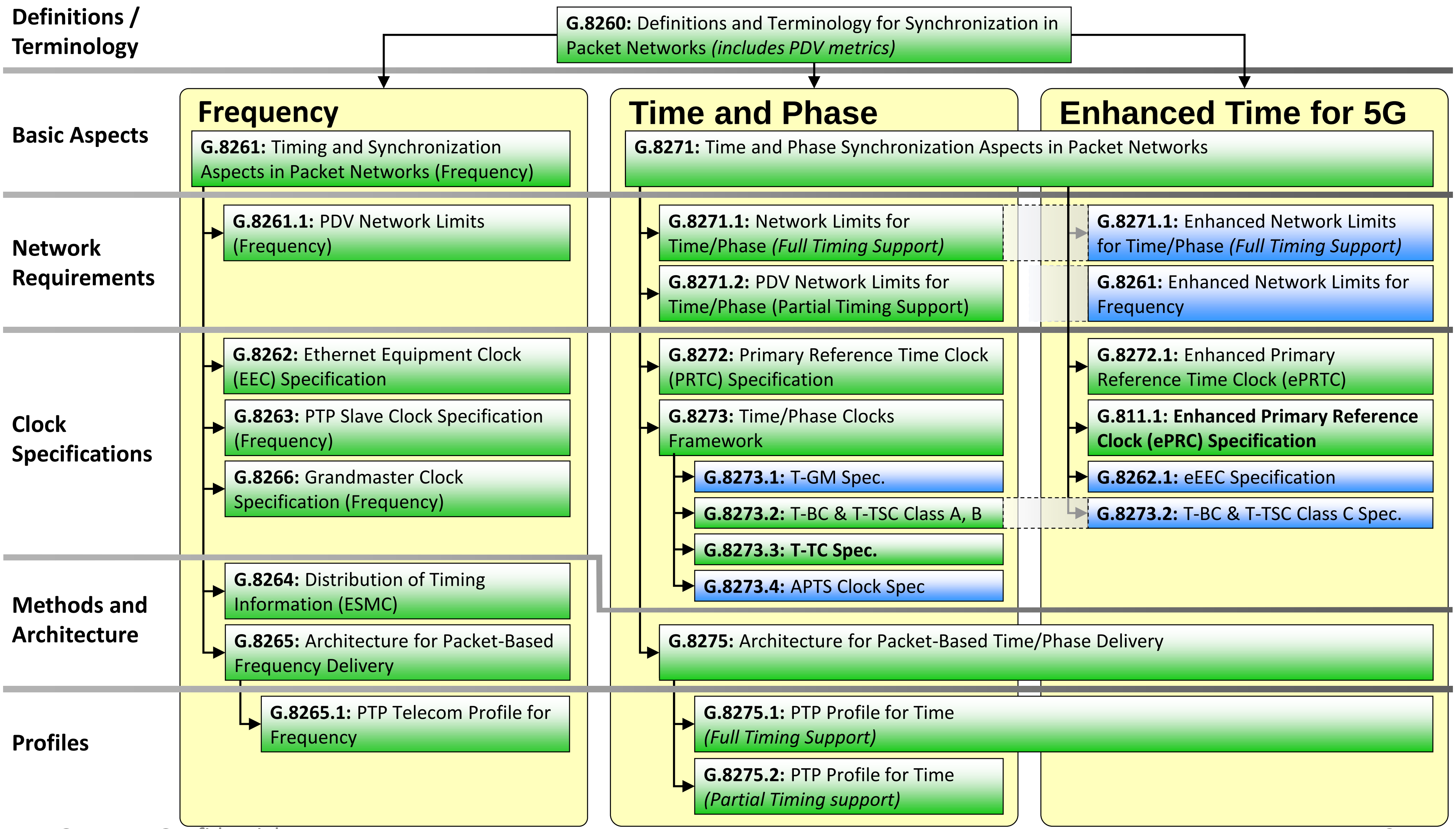
# Standards Update

February 2018

Tim Frost

# ITU-T Packet Sync Recommendations

Calnex




Published | 1st version agreed | Under development

# ITU Sync Standards Categories

- Transfer of frequency to meet 50ppb *(2G/3G/4G FDD)*

- Transfer of time to meet 1.5μs *(3G/4G TDD, LTE-A)*
  - Using new networks with T-BC and SyncE at every node

- Transfer of time to meet 1.5μs *(3G/4G TDD, LTE-A)*
  - Using existing networks


- Transfer of time to meet 100 – 200ns *(5G potential)*
  - “Enhanced” clock specifications


- Sync OAM *(general)*

# What's new?

# Consented Recommendations, Feb. 2018

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- "Consent" means they have been agreed in the technical committee, but there will be a one month commenting period before they are finally approved
- Amended or Revised Recommendations:
  - G.8264 Amd. 1 – modifications to the QL codes for the enhanced clocks
  - G.8266 Amd. 1 – additional information on measuring noise transfer
  - G.8271 Amd. 1 – addition to appendix on asymmetry compensation
  - G.8271.1 Amd. 1 – new appendix on measuring relative time error; various other minor changes
  - G.8271.2 Amd. 1 – added network limits at clock output (point D)
  - G.8273 Revision – includes previous amendments, plus various minor changes
  - G.8275.1 Amd. 2 – revised appendix on clock states, plus various minor changes
  - G.8275.2 Amd. 2 – revised appendix on clock states, new section on handling PTSF (loss of sync), plus various minor changes

# Major Work Items In Progress

- G.8262.1 (enhanced SyncE clock)
  - Simulations on noise generation for different bandwidths and oscillator types, plus noise accumulation in a chain of clocks
  - Noise generation spec should be finalised by next meeting
  - Status: to be approved by end 2018
- G.8273.2 (Class C T-BC and T-TSC)
  - Based on enhanced SyncE clock
  - Noise accumulation simulations for long chains under way
  - Noise generation limit to be in the ±5ns to ±10ns range
  - Status: to be approved by end 2018
- G.8273.4 (APTS and PTS clock specifications)
  - Restructured document to separate APTS and PTS clocks
  - Provisional agreement on noise generation (50ns wander, and ±50ns cTE)
  - Noise tolerance agreed (G.8271.2 network limit)
  - Noise transfer and holdover still work in progress
  - Status: possible approval by end 2018, might be 2019

# Transfer of frequency to meet 50ppb

# Mobile Technology

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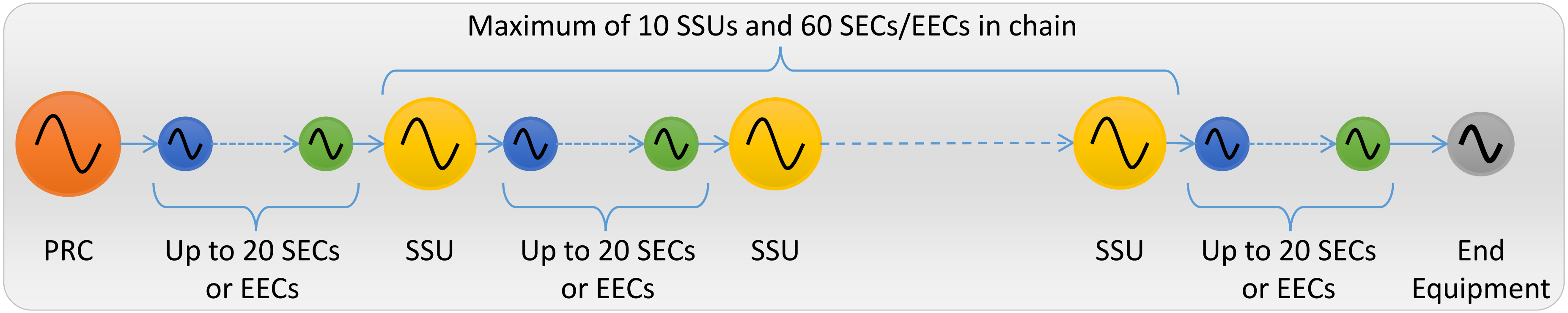
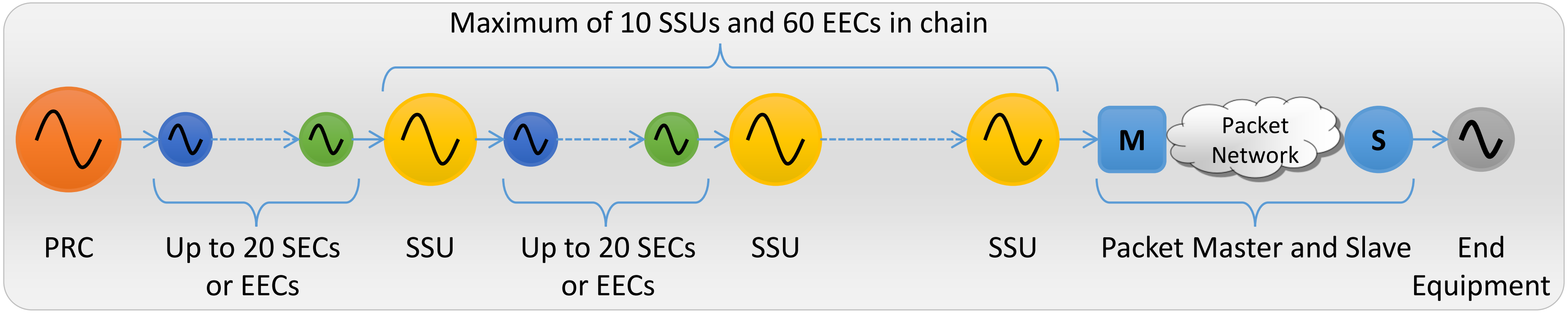
- ***1G and 2G:*** basestations connected using E1 or T1 circuits
  - Basestations required frequency accuracy of 50ppb (5 parts in $10^8$)
  - "Freeloaded" off the known frequency accuracy of the E1 or T1 circuits from the SDH system
- ***3G:*** initially used E1 and T1 connectivity as before
  - Then data services came along…
  - HSDPA *(as used by iPhone 3G)* offered up to 14Mbit/s download speeds (although more typically 3.5Mbit/s)
  - Basestations needed to move to Ethernet connectivity to accommodate the higher data rates on the backhaul interface
- *Now where is that nice stable frequency again?*

# G.8261: Frequency over Packet Interfaces

- Approach 1: ***Use the physical layer clock***
  - SyncE clocks (EEC) made identical to SECs in performance terms




- Approach 2: ***Use a packet timing protocol***
  - Packet timing protocols such as PTP or NTP used to deliver frequency



# Relevant Standards for Frequency

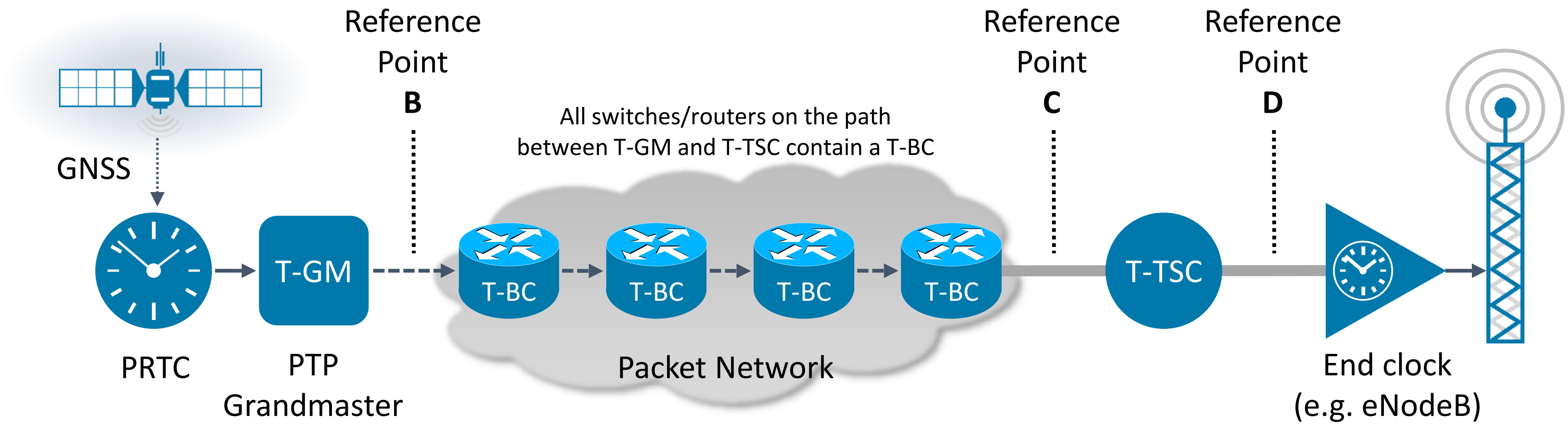
- Published recommendations related to frequency synchronization:
  - G.8261 – General aspects, network limits for frequency synchronization
  - G.8262 – Ethernet Equipment Clock Specification
  - G.8264 – Ethernet Synchronization Messaging Channel (ESMC)

  - G.8265 – General network architecture for packet-based frequency sync
  - G.8265.1 – PTP Profile for frequency
  - G.8261.1 – Network limits for packet-based frequency synchronization
  - G.8263 – PTP Slave Clock for frequency
  - G.8266 – Telecom Frequency Grandmaster Specification

- Standards complete and stable for several years

# Transfer of time to meet 1.5μs

# PTP with Full Timing Support




**Features**

- Every element in the path must be “PTP aware”
- Both T-BC (boundary clocks) and T-TC (transparent clocks) covered in standards
- Uses a combination of SyncE and PTP, where SyncE provides the frequency and PTP the phase/time

# PTP with Full Timing Support

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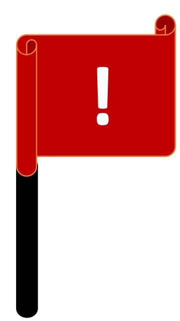
**Benefits**

- Controlled, deterministic environment suitable for both frequency and time/phase transfer
- “Building block” approach to network construction, with example time error budgets in G.8271.1
- Profile, architecture and clock performance well defined by ITU-T

**Challenges**

- All equipment in path needs to be PTP aware
- No control of asymmetry in the network



# Synchronization in Access

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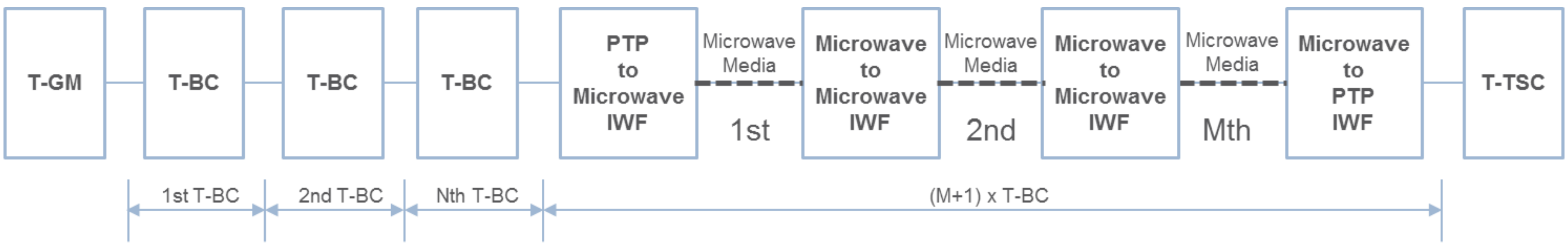
- From a performance perspective, each network element is allocated the equivalent budget to one T-BC:




- Internally, the communication between units does not have to be PTP (e.g. GPON may use the native time transfer mechanism)
  - This is a performance budget, not a protocol specification
- SyncE-assisted TCs to have same budget as SyncE-assisted BCs
  - i.e. G.8273.3 performance spec will be based on G.8273.2

# Relevant Standards for FTS

- Published recommendations related to full timing support:
  - G.8271 – General considerations for time synchronization
  - G.8275 – General network architecture for time synchronization
  - G.8275.1 – PTP Profile for full timing support
  - G.8271.1 – Network limits for full timing support
  - G.8272 – Primary Reference Time Clock Specification
  - G.8273.2 – Telecom Boundary Clock Specification
  - G.8273.3 – Telecom Transparent Clock Specification

- Standards complete, but some recommendations are undergoing minor revisions and enhancements

# Transfer of time over existing networks

# Partial Timing Support Use Cases - 1

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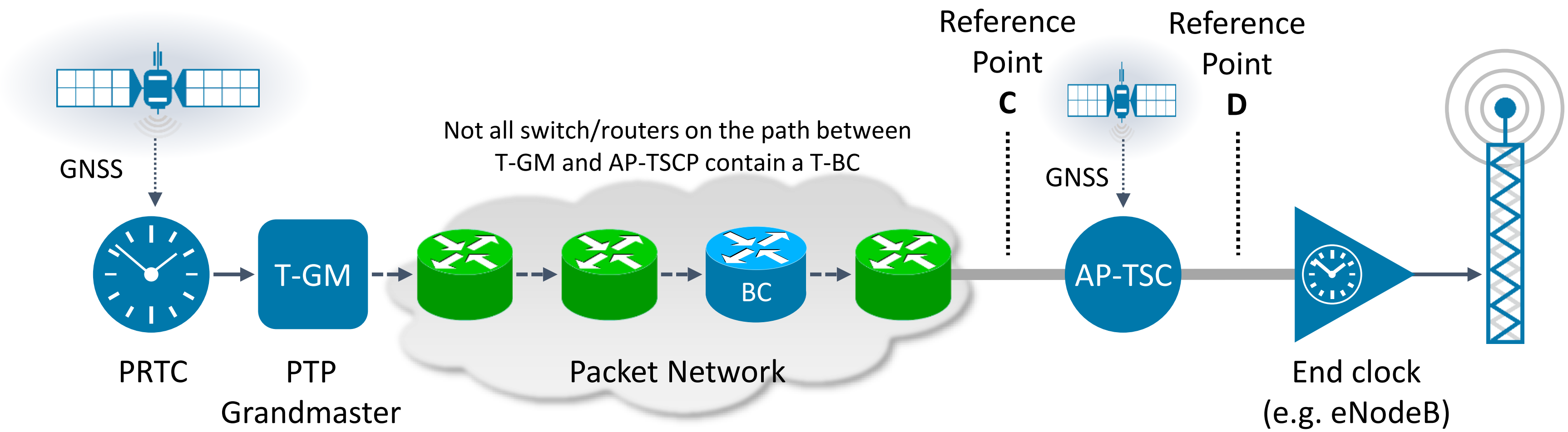
## PTP backup to GNSS *("assisted partial timing support", or APTS)*




### Features

- Objective is backup to GNSS, i.e. "assisted holdover"
- GNSS monitors PTP service quality and network asymmetry
- PTP can maintain timebase when GNSS is out of service (e.g. due to jamming or antenna failure)

# Partial Timing Support Use Cases - 2

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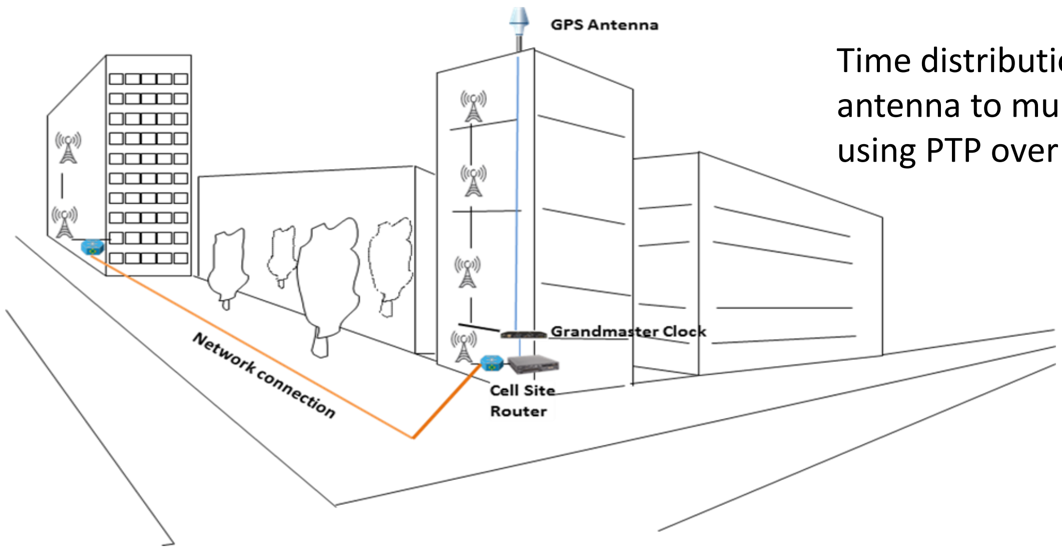
**PTP distribution over a local LAN** *("partial" or "no timing support")*




Time distribution from rooftop antenna to multiple small cells, using PTP over the building LAN

## Features

- Objective is to distribute time over a small PTP-unaware (or partially unaware) network
- Small network, potentially only a single in-building network
- Places GNSS source as close to the end clock as possible

# Partial Timing Support Use Cases - 3

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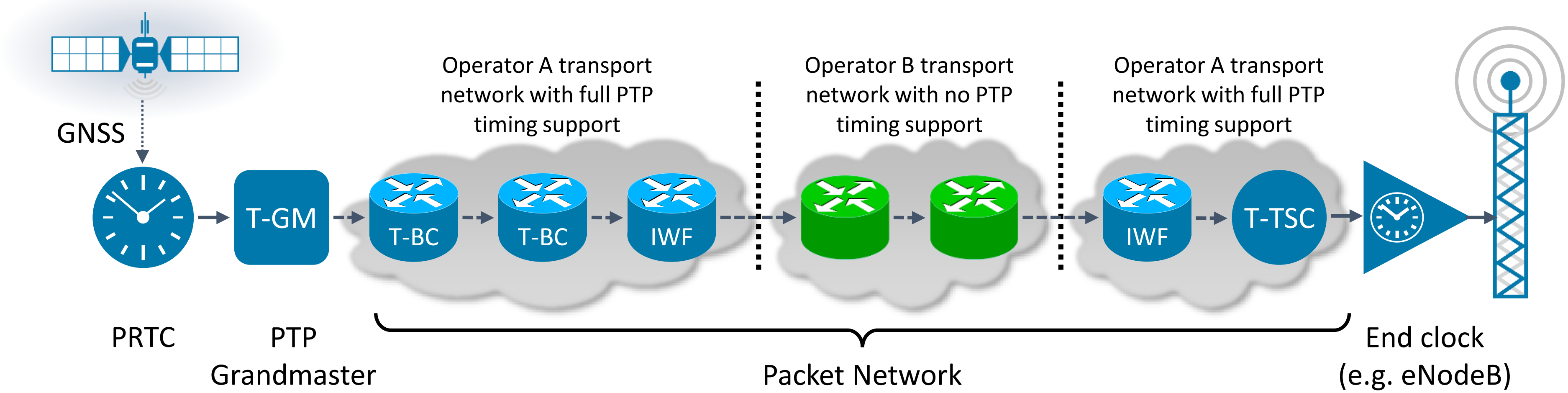
## Network Bridging




### Features

- Objective: bridge between two full timing support networks
- Example: a mobile operator may not own the access network, and need to bridge across a third party network
- Requires inter-working functions (IWF) to link between the networks

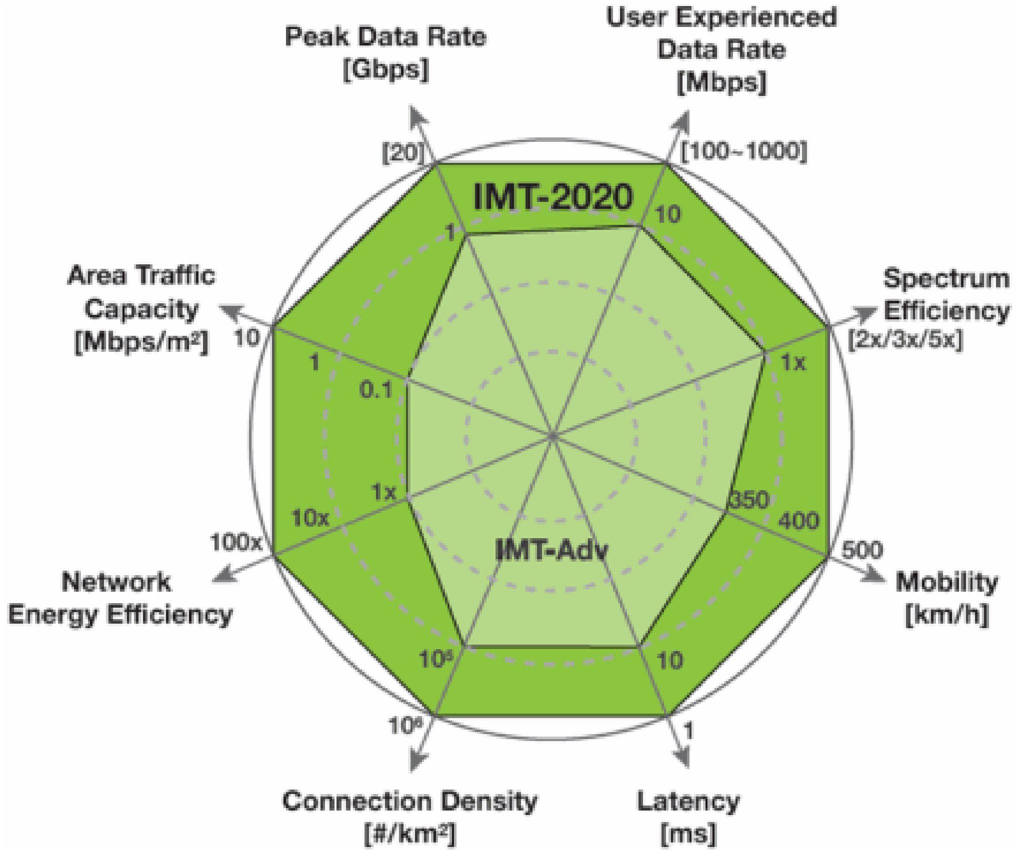
# Relevant Standards for APTS and PTS

- G.8271.2: Partial Timing Support Network Limits
  - Uses ***pktSelected2WayTE*** as primary metric
    - This is the time error calculated on the 2-way flow, after packet selection
  - Two limits: APTS *(PTP backup of GNSS)*, PTS *(PTP-unaware networks)*
  - Network limit for APTS
    - Peak-to-peak *pktSelected2WayTE* < 1100ns at input to slave
    - Selection criteria: 0.25% fastest packets in each 200s window
  - Network limit for PTS
    - Maximum absolute *pktSelected2WayTE* < 1100ns at input to slave
    - Selection criteria: 0.25% fastest packets in each 200s window
  - Status: Published August 2017
- G.8273.4: Assisted Partial Timing Support Clock
  - GNSS primary time source, PTP backup
  - Uses GNSS to measure PTP asymmetry during normal operation
  - Status: possible completion by end 2018

# Enhanced Specifications for 5G

# What is 5G?

- **IMT-2020** – the ITU's vision of "5G", to roll out in 2020




IMT-Advanced (LTE, 4G)

IMT-2020 (5G), relative to IMT-Advanced

# What are the implications?

- Peak data rate of 20Gbit/s
  - High speed backhaul of 25Gbit/s or more
- User experienced data rate of 100-1000Mbit/s
  - Co-operative processing and interference management
- Connection density of 1M connections/km$^2$
  - Requires dense small cell deployment
- Latency < 1ms
  - Distributed architecture, data processing and switching at the edge
  - Fronthaul, distributed radio units with co-located baseband and switching

# New 5G Frame Structure

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Six numerology options for 5G symbol length

| Using same CP overhead regardless of numerologies | | | | | | |
|---|---|---|---|---|---|---|
| Scaling factor ($2^n$) | -2 | -1 | 0 | 1 | 2 | 3 |
| Subcarrier spacing (kHz) | 3.75 | 7.5 | 15 | 30 | 60 | 120 |
| OFDM symbol duration (µs) | 266.67 | 133.33 | 66.67 | 33.33 | 16.67 | 8.33 |
| Normal CP length (µs) | (20.8,18.76) | (10.4, 9.38) | (5.2, 4.69) | (2.6, 2.34) | (1.3, 1.17) | (0.65,0.59) |

4G (column 0) — 5G Candidate (columns 1 and 2)

- In 4G, cyclic prefix length is 4.69µs
  - Requires time alignment for overlapping basestations of ±1.5µs
- In 5G, cyclic prefix could be as short as 1.17µs
  - Requires time alignment for overlapping basestations of ±0.39 µs

# Fronthaul sync requirements

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**Inter-site Carrier Aggregation** (CA)

- CA bonds two carriers together into a single channel
  - For two non-adjacent carriers in the same band, or two carriers in different bands, frame alignment must be better than 260ns
- But it's always been that, even in 4G. So what's new?
  - In 4G, aggregated carriers were transmitted from the same antenna, generated by the same eNodeB
  - In 5G fronthaul architecture, carriers may be transmitted from separate radio units, connected over an Ethernet fronthaul
- 260ns frame alignment translates to ±130ns from central clock

# Fronthaul sync requirements

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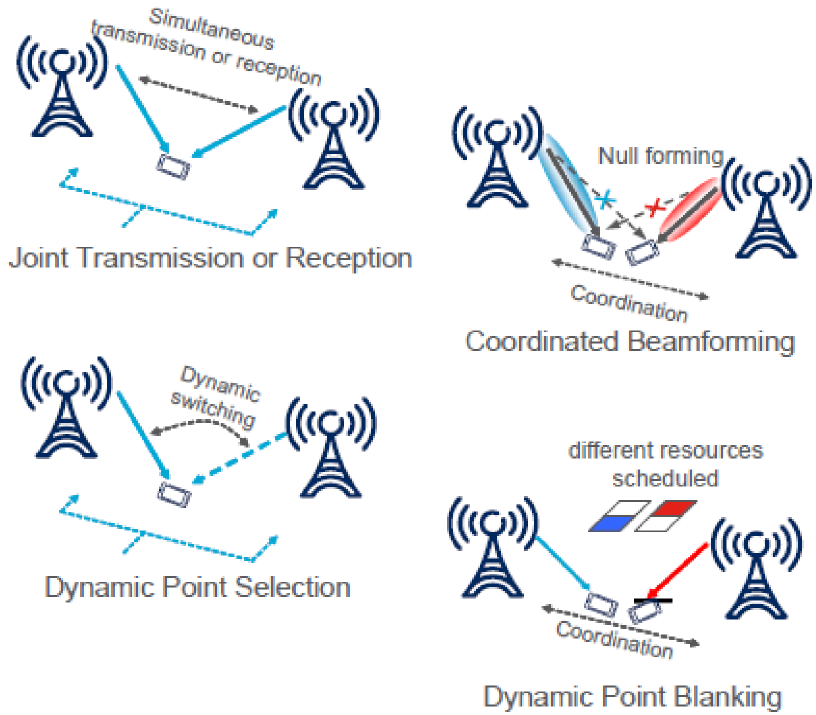
## Co-ordinated Multi-Point (CoMP)

- CoMP is a family of technologies
  - Joint Transmission or Reception
  - Co-ordinated Beamforming
  - Dynamic Point Selection
  - Dynamic Point Blanking
- Joint transmission requires frame alignment of ~0.5µs at the UE *(i.e. phone or user device)*
  - Translates to around 250ns at the radio unit



# Fronthaul sync requirements

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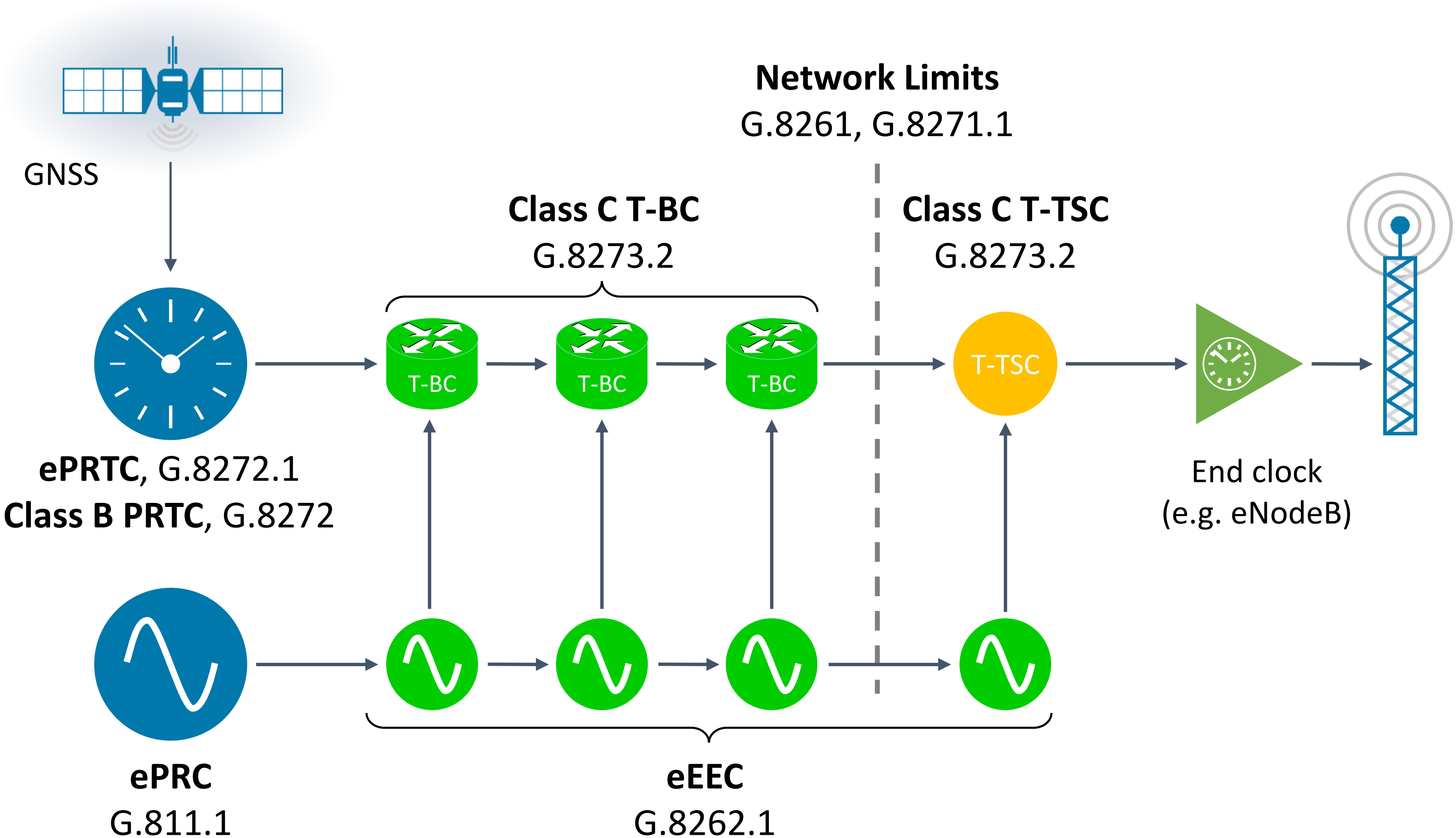
**Positioning**

- OTDOA (Observed Time Difference of Arrival) calculates the position of the UE (User Equipment*) from the difference in the arrival time of the UE signal at three or more basestations
- This requires the basestations to be accurately synchronized
- Location accuracy requirements:
  - E911: within 50m horizontal accuracy for 80% of emergency calls
    - Requires time synchronization to within 150ns
  - IoT: indoor device location to within 3m (see 3GPP TR 22.862)
    - Requires time synchronization to within 10ns
- Techniques other than OTDOA also exist, probably multiple methods will be deployed



* e.g. mobile device, IoT sensor etc.

# Enhanced Clocks



# Enhanced Clock Specifications

Calnex

- G.8272.1: "ePRTC" – **DONE**
  - Time accuracy to better than 30ns
  - Holdover within 100ns for 14 days, effectively mandates Cs beam technology
  - Published November 2016
- G.811.1: "ePRC" – **DONE**
  - Most modern PRCs are at least 10x better than the 1996 G.811 standard
  - New version to have frequency accuracy around 0.5 to 1 part in $10^{12}$
  - Published August 2017
- G.8272: PRTC Class B
  - Time accuracy better than 30ns (similar to G.8272.1)
  - No long-term holdover specification, making non-Cs implementations possible, e.g. dual-band GNSS receivers
  - Cheaper solution for operators with distributed networks
  - Can use core-based enhanced frequency networks and SyncE to maintain time at distributed PRTCs
  - Status: scheduled for completion December 2018

# Enhanced Clock Specifications

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- G.8262.1: “eEEC”
  - Existing EEC based on 20-year old SEC technology
  - Enhanced version to be compatible with current EEC, but improve noise generation, transients and holdover
  - Facilitates long-term assisted holdover of accurate time clocks, plus lower-noise T-BCs
  - Status: possible completion by end 2018
- G.8273.2: “Class C” T-BC and T-TSC to be developed
  - Based on the eEEC specification
  - Exhibits lower noise generation and better SyncE-assisted holdover
  - Status: possible completion by end 2018

# Enhanced Network Limits

- G.8261: Network Limit for chain of eEECs
  - Network limit much lower, to permit better SyncE-assisted holdover of T-BCs and T-TSCs
  - Status: possible completion by end 2018
- G.8271.1: Network Limit for chain of T-BCs
  - To be based on Class C T-BC specification, around ±130ns end-to-end
  - Status: possible completion by end 2018

# Comparing G.8262 to G.8262.1

| Parameter | EEC (G.8262) | eEEC (G.8262.1) (agreed values) | eEEC (G.8262.1) (proposed values) |
|---|---|---|---|
| Frequency Accuracy | 4.6ppm | Same value | |
| Pull-in/Hold-in | 4.6ppm | Same value | |
| Wander generation | 40ns @ 1s, rising to 113ns @1000s | *Not agreed yet* | Values as low as 10ns proposed, but not agreed |
| Wander tolerance | 250ns @ 1s, rising to 5000ns @ 1000s | Same value *(mixed chains)* | Lower value discussed for all-eEEC chains. |
| Jitter generation | 0.5UI (1G, 10G)<br>1.2UI (25G lanes) | Same value | |
| Jitter tolerance | 250ns @ 10Hz, reducing to 1.5UI (3.6UI for 25G lanes) | Same value | |
| Clock Bandwidth | 1 – 10Hz | 1 – 3Hz | |
| Transient response | 120ns initial step, then 50ns/s (const. temp) | 5ns initial step provisionally agreed | 2.5ns/s slope proposed but not agreed |
| Holdover | 120ns initial step, then 50ns/s (const. temp)<br>2000ns/s (var. temp) | 5ns initial step provisionally agreed | 2.5ns/s slope (const. temp)<br>300ns/s slope (var. temp)<br>*(not agreed)* |

# Sync OAM

# Sync OAM and Management

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- Model proposed using an alternative PTP flow as a reference
  - Not a perfect reference, but a sanity check and indication of network-related issues
- Frequency sync defects and parameters to be documented in a revised version of G.781
  - Status: Consented June 2017, now in final approval
- Time sync defects and parameters to be documented in new recommendation G.781.1
  - Status: scheduled for completion in February 2018

# Insight and Innovation

calnexsol.com

Tim Frost,
Strategic Technology Manager,
tim.frost@calnexsol.com