Providing Reliable, Accurate Time for Mobile Networks

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  - Features/Benefits/Challenges
  - Potential Timing Budget
- Measuring Performance

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Base Station Use Cases

Base Station Backhaul Use Cases

- Service providers are deploying cost effective all Carrier Ethernet mobile backhaul circuits for LTE base stations
  - Macro: Using Environmental Controlled Cabinets (e.g. -40C to +55C)
    - Heaters (humidity control)
    - Forced air (cooling support)
  - Small cell: Indoor/Outdoor

  Note: Small cells consists of Micro (<2km), Pico (<200m) & Femto (<10m)

- Carrier Ethernet fall into two major categories
  1. Fiber Ethernet Circuits (Point to Point and Point to Multi Point)
  2. Microwave Ethernet solutions

- US Service Providers are NOT going to abandon GPS as the primary distribution of frequency, phase and time but PTP remains an option for:
  - Extending synchronization distribution
  - Possible redundancy

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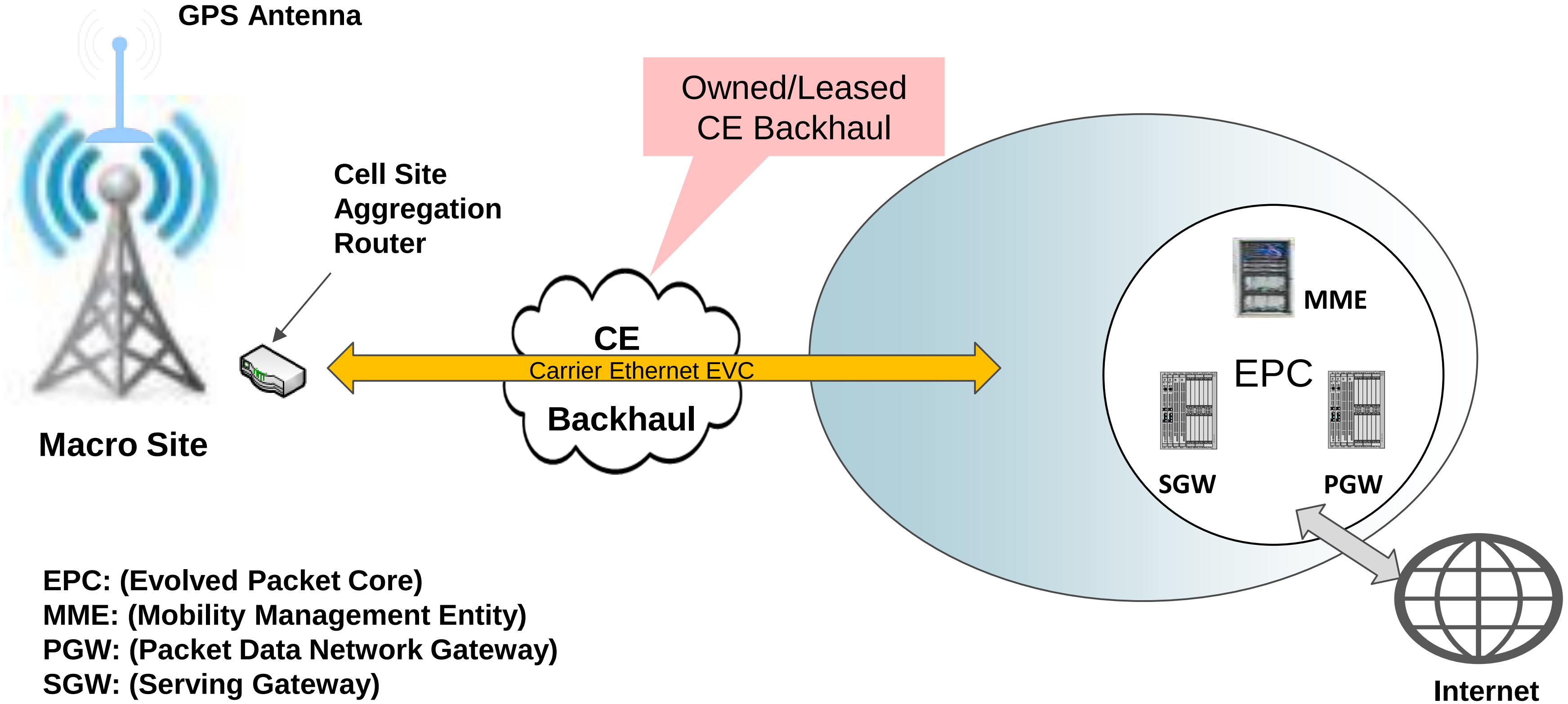
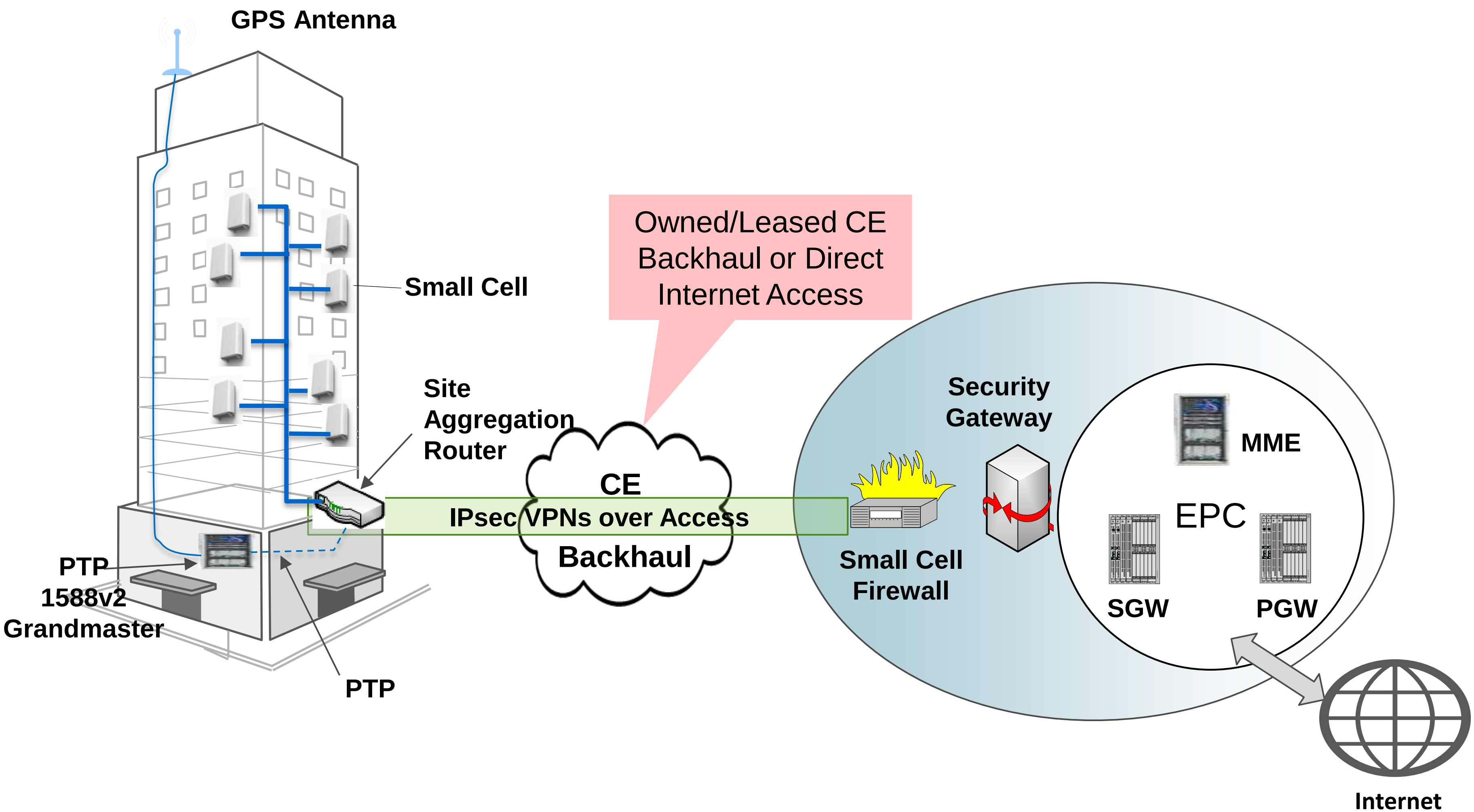
LTE Macro Use Case

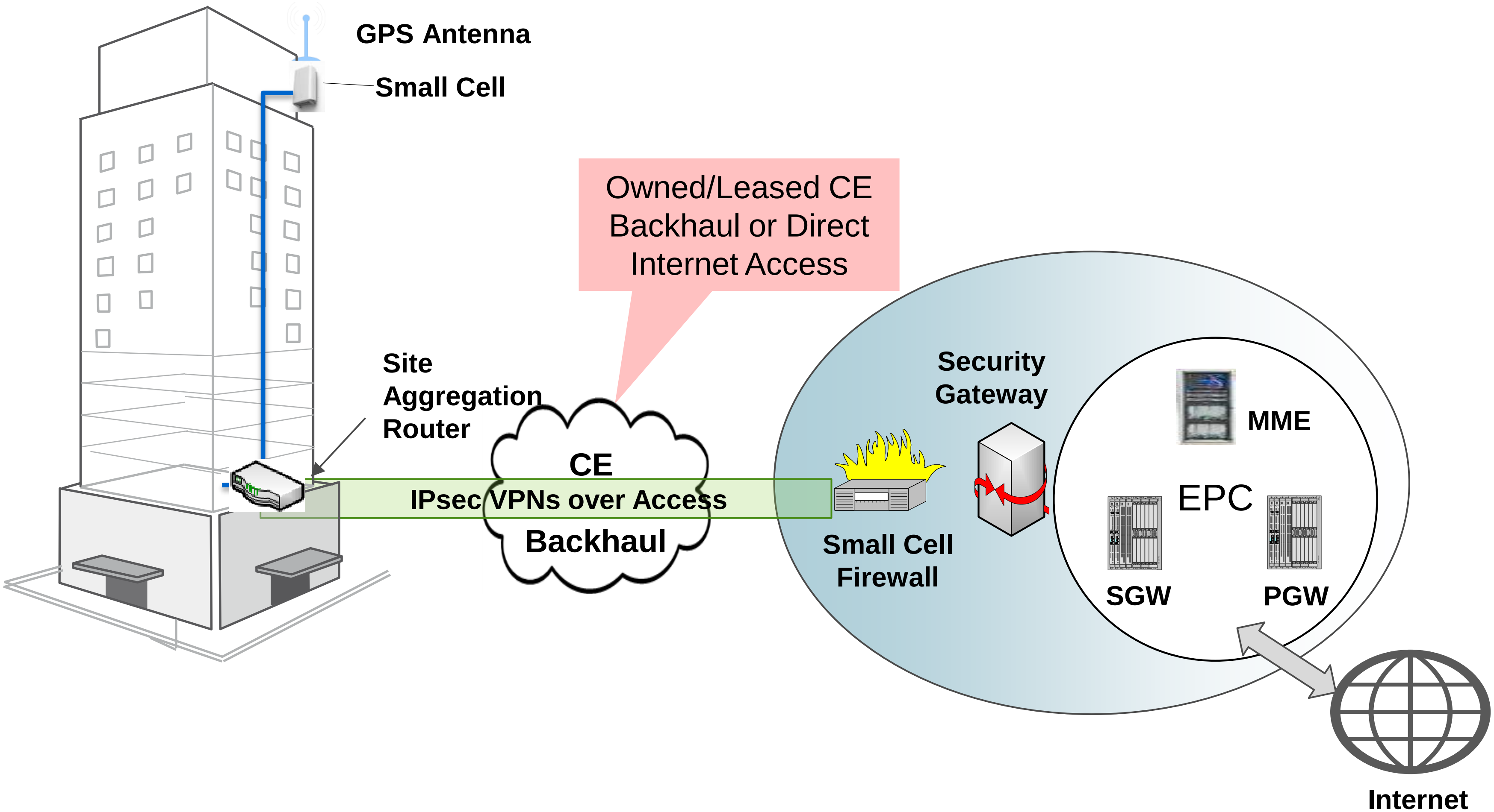


EPC: (Evolved Packet Core)
MME: (Mobility Management Entity)
PGW: (Packet Data Network Gateway)
SGW: (Serving Gateway)

LTE Indoor Small Cell Use Case

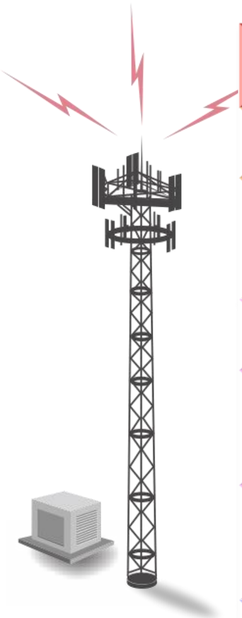


LTE Outdoor Small Cell Use Case



Synchronization Landscape

LTE Sync Requirements



Application	Frequency	Time	Backhaul Spec
LTE (FDD)	**±50 ppb**	**N/A**	**±16 ppb** *(G.8261.1)*
LTE (TDD)	**±50 ppb**	**±1.5 μs** *(< 3km radius)* **±5 μs** *(> 3km radius)*	**±16 ppb** *(G.8261.1)* **±1.1μs** *(G.8271.1)*
LTE-A MBSFN	**±50 ppb**	**±1 to 5 μs** *implementation dependent*	**±16 ppb** *(G.8261.1)* **±1.1μs** *(G.8271.1)*
LTE-A CoMP *Network MIMO*	**±50 ppb**		
LTE-A eICIC *HetNet Coordination*	**±50 ppb**		
Small Cells	**±100 ppb**	**N/A** (FDD) **±1.5 μs** (TDD) **±1 to 5μs** (eICIC)	**±33 ppb** **±1.1μs** *(G.8271.1)*
Home Cells	**±250 ppb**	**N/A** (FDD) **±1.5 μs** (TDD)	**±100 ppb** **±1.1μs** *(G.8271.1)*

Synchronization Landscape

Base Station	Time Source	Holdover	Oscillator Type
Macro Cell - (FDD/TDD)	GPS	As high as 72 hours	Crystal-based
Small Cell - (FDD/TDD)	GPS	As high as 24 hours	Crystal-based

General Synchronization Statements

- UTC Time is distributed using GPS in US
- GPS vulnerability and lack of redundancy may be a major issue for wireless Providers
- For prolonged GPS outages (i.e. 24 hours):
  - Frequency is easy to meet for Frequency Division Duplex (FDD) & CDMA
  - Phase is hard to maintain for macro Time Division Duplex (TDD), CDMA and even harder for small cells
- Most base stations use Crystal-based oscillators

Recent Activity:

- ATIS has recommended that the US Department of Homeland Security perform further study on GPS vulnerability of current communication systems and threat scenarios

Further GPS Related Challenges

Piezoelectric Resonators Final Source of Holdover after GPS loss

- Business models dictate that small cells be low cost - this translates into low cost crystal-based oscillators
- Crystal-based oscillators suffer during SMALL temperature fluctuations of greater than ±1.0 Degree Celsius (±1.8 Degree F)

Using PTP for GPS Substitution or Redundancy has Security Implications

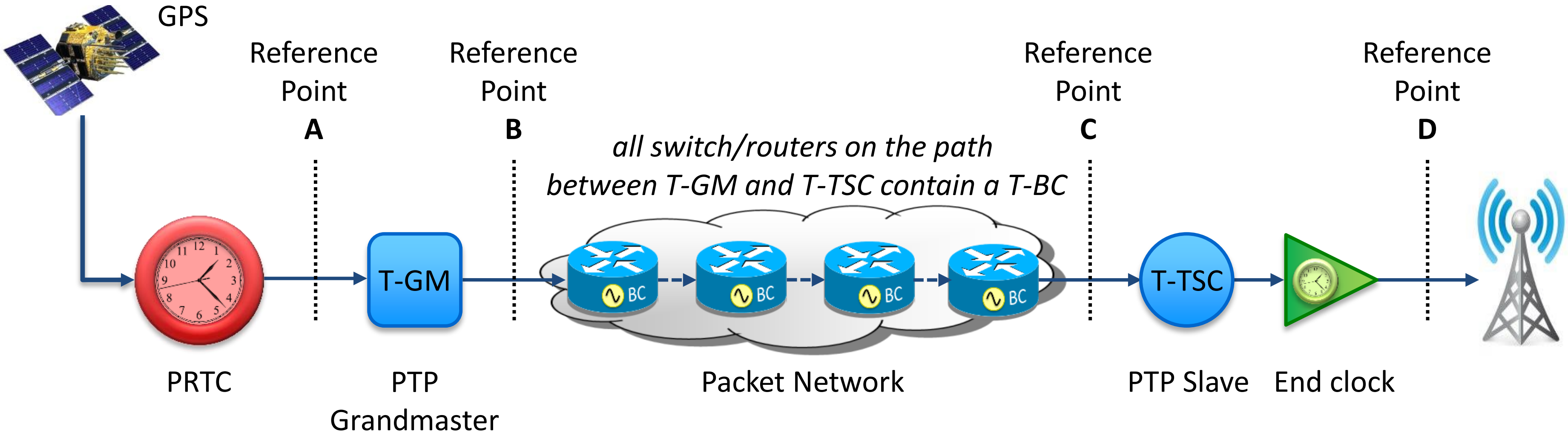
- Using IPSec poses major issues for supporting PTP over the access network. An alternative solution to IPSec which offers deterministic authentication and encryption security is needed. PDV is a PTP killer.

Location for Emergency 9-1-1 remains challenging

- Increased dependencies on small cells are causing providers to consider innovative methods of providing synchronization and location of the user at the cell
- Providers are looking for “Plug-and-Play” synchronization and location solutions for small cells without GPS line-of-sight:
  - Urban canyon Pico cells
  - Home and Enterprise Femtocells

PTP with Full Timing Support

PTP with Full Timing Support (G.8275.1)



Features

- Every network element in the path must be "PTP aware"
  - Each node contains a Telecom Boundary Clock (T-BC), avoiding accumulation of PDV along the path
- Can use a combination of SyncE & PTP, where SyncE provides the frequency and the PTP the phase/time

PTP with Full Timing Support

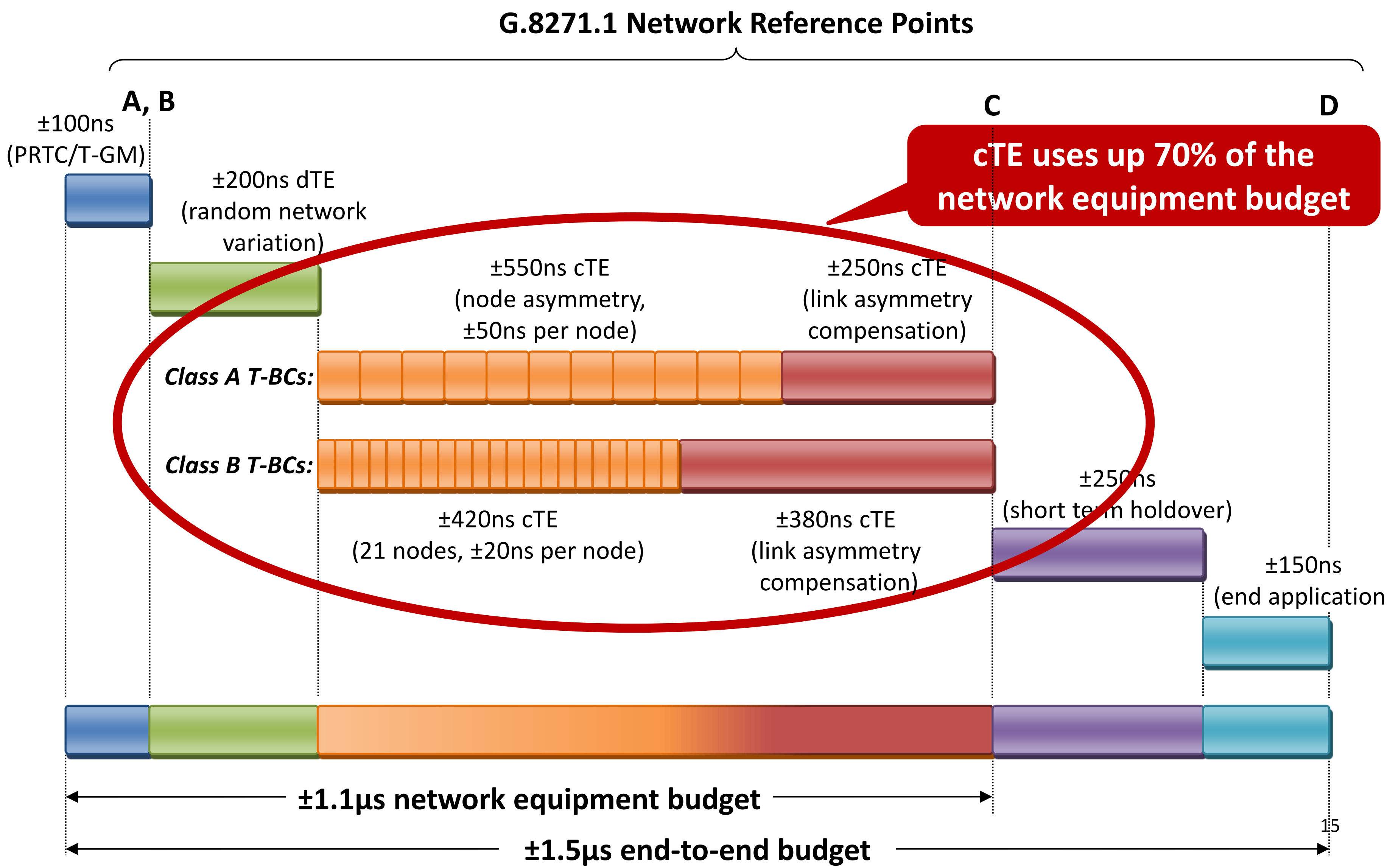
Benefits

- 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 defined by ITU-T, published May 2014

Challenges

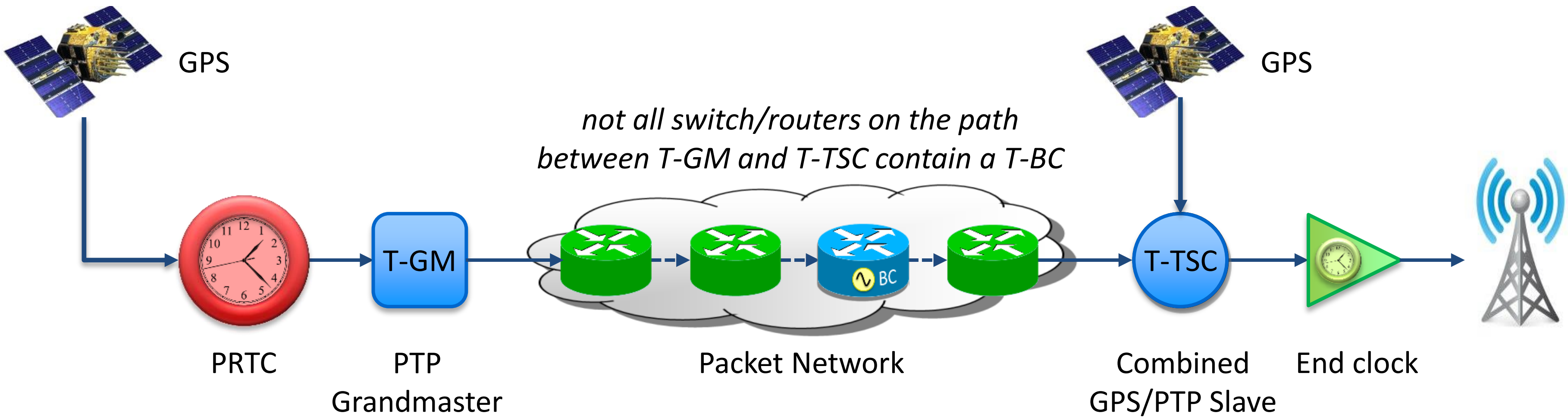
- All equipment in path needs to be PTP aware
- No control of asymmetry in the network

G.8271.1: Time Error Budget Example



PTP with Assisted Partial Timing Support

PTP with Assisted Partial Timing Support



Features

- Objective is backup to GPS: i.e. "assisted holdover"
- Can use GPS when in service to monitor PTP service quality and measure network asymmetry
- PTP can maintain timebase when GPS is out of service (e.g. due to jamming or antenna failure)

PTP with Assisted Partial Timing Support

Benefits

- Mutual co-operation between GPS and PTP
  - PTP provides an initial time fix to assist the GPS during signal acquisition
  - GPS calibrates the PTP asymmetry, and monitors its suitability for service
  - PTP can monitor GPS timing quality, e.g. antenna failure, spoofing, jamming
- Operates over existing networks, including third party access networks that may not have built-in PTP support
- Profile, architecture and clock performance under definition in ITU-T, planned for consent in December 2014

Challenges

- Less deterministic path from T-GM to T-TSC, because not every network element assists in the timing flow
- May need constraints on traffic load and span of the packet network

Possible Time Error Budget for APTS

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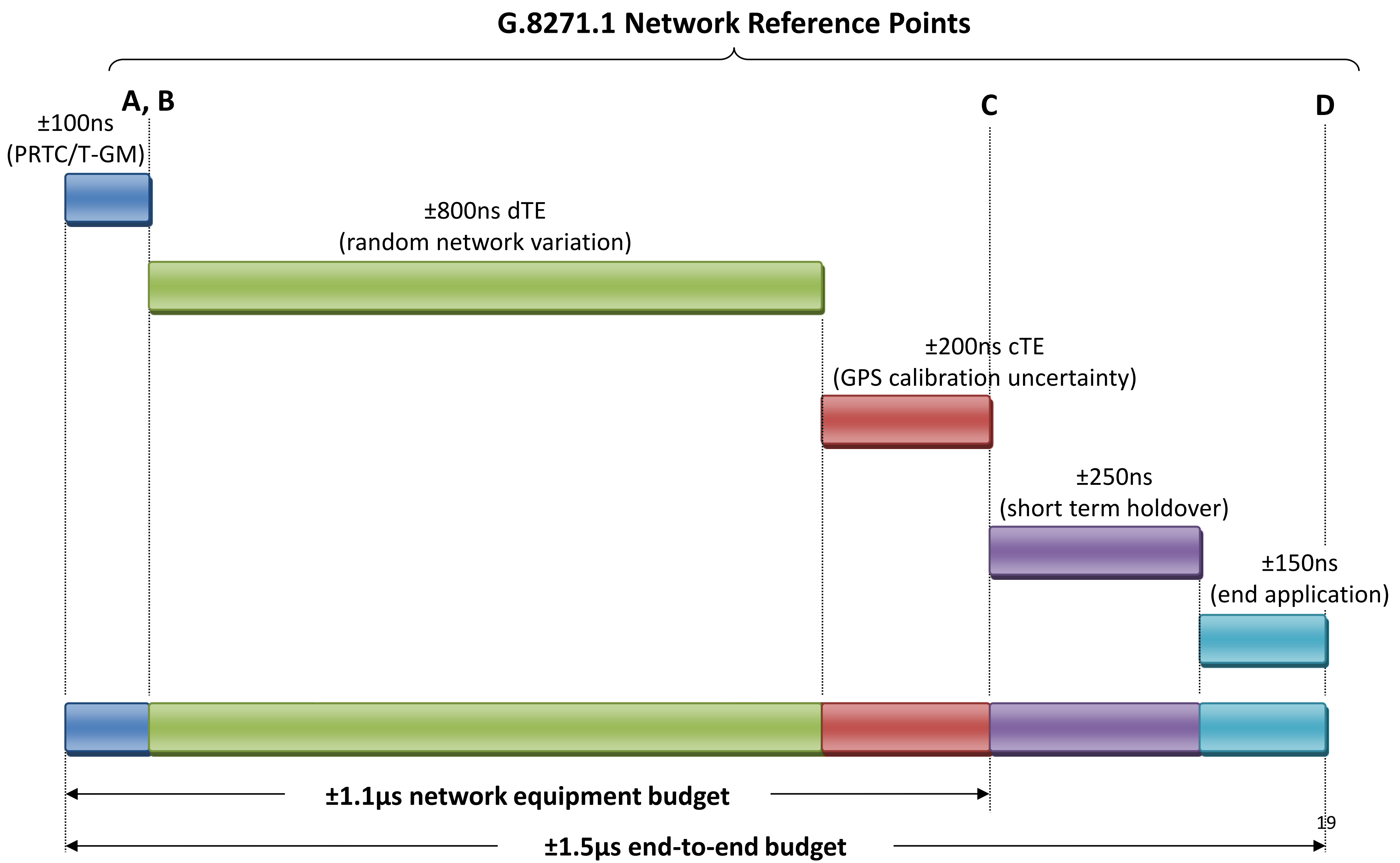

Measuring Performance

The Nature of Time

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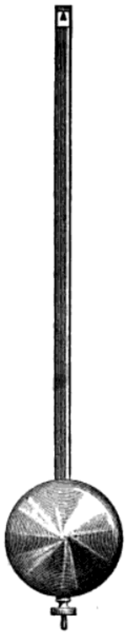
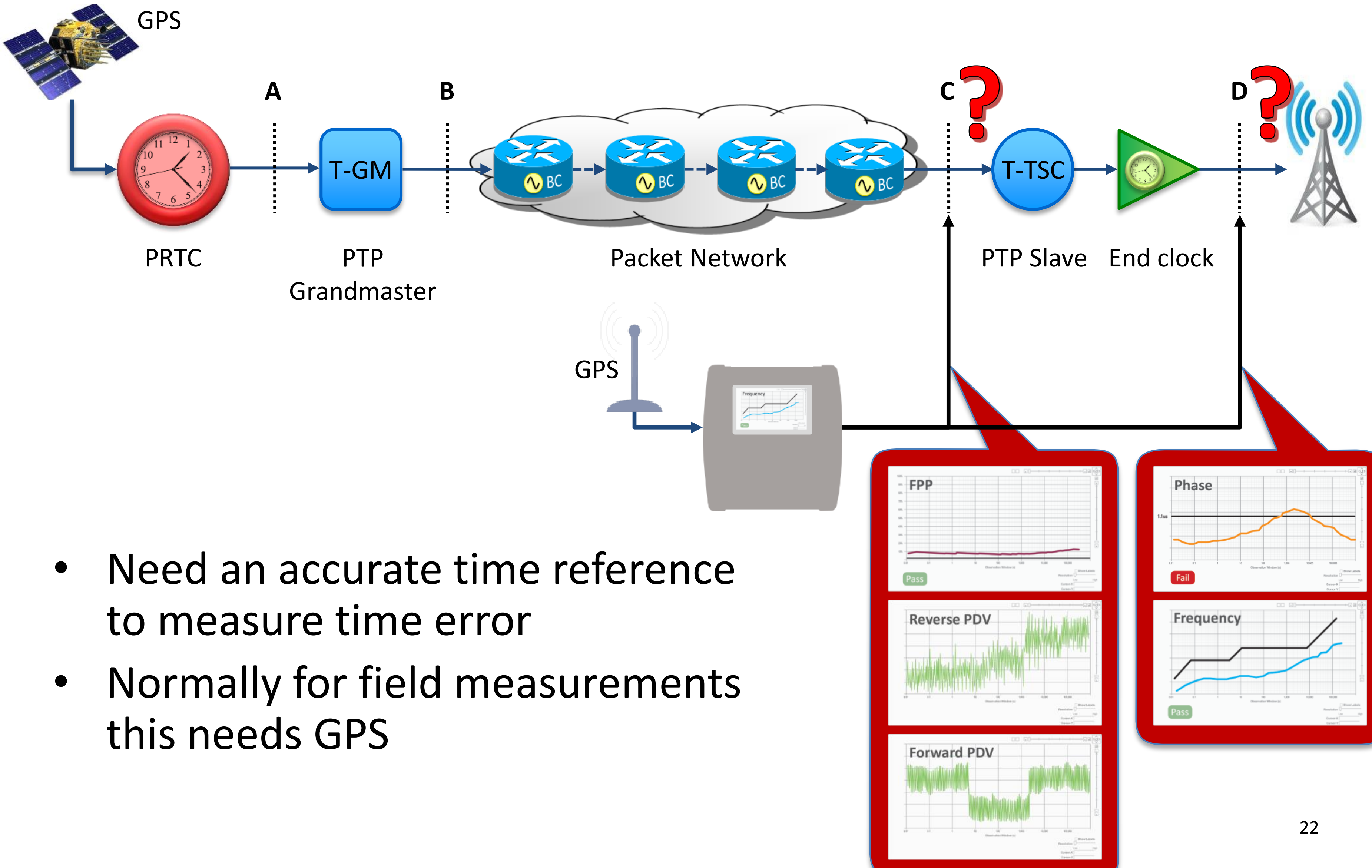


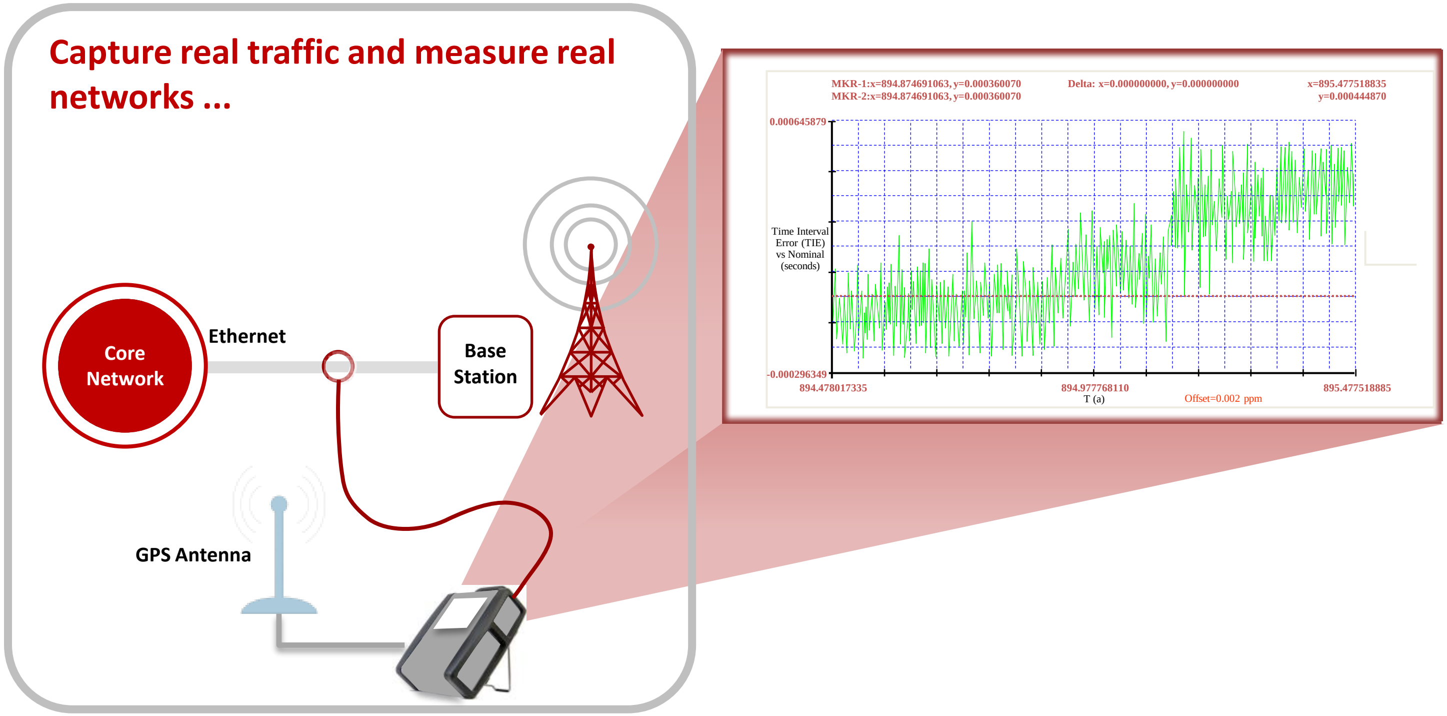
- Time is a fundamental physical dimension
- Passage of time measured by counting a regularly repeating event
  - Astronomical events, e.g. day/night, month, year
  - Physical events, e.g. pendulum, quartz resonance or atomic transitions
- Common time requires a reference point
  - Time at an instant has no meaning without a reference
  - Need to start counting from a common point, or ***epoch***
  - Example: the Gregorian calendar counts years from the birth of Christ
- A ***time reference clock*** is a device counting at a constant frequency from a known epoch

So is PTP working?



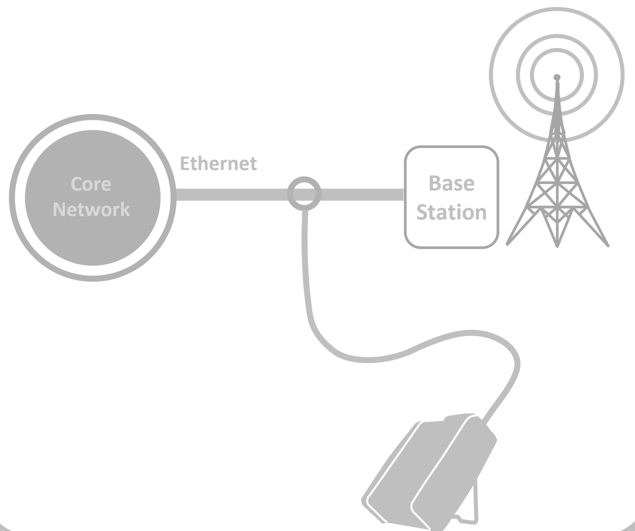
- Need an accurate time reference to measure time error
- Normally for field measurements this needs GPS

Fault finding – measure & capture live PDV

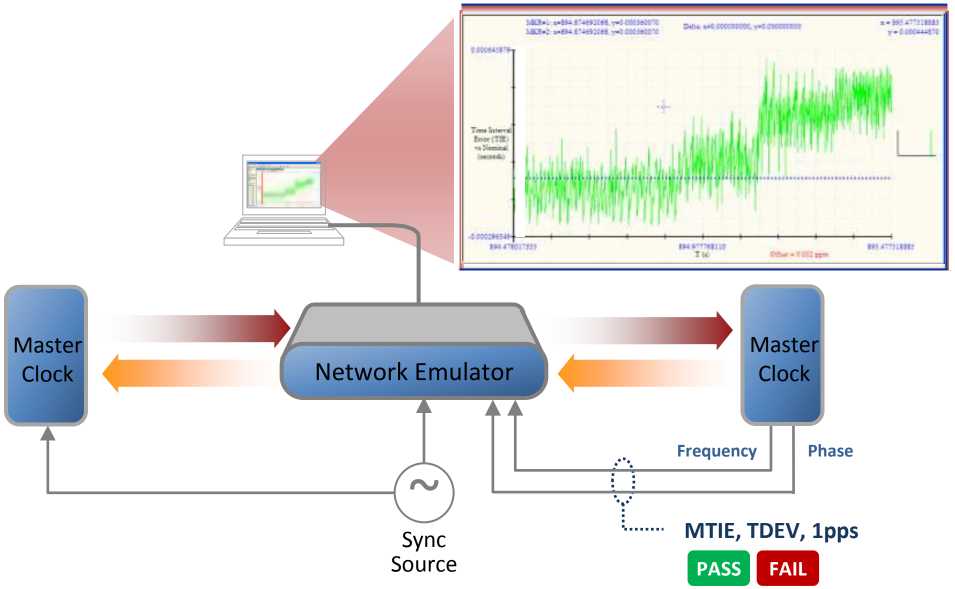


Fault finding – replay PDV in the lab

Capture real traffic and measure real networks …



… then replay the real-world PDV captures back in your lab.



Summary

- In many cases, North American Service Providers use GPS as their sole source of time/phase synchronization
  - Crystal based oscillators are not able to hold tighter time/phase in the event of prolonged GPS outages or failures (>24 hrs.)
- Assisted Partial Timing Support is a way of combining the benefits of both GPS and PTP
- Open issues:
  - PDV – can PTP support the accuracy required over real-world networks?
  - Security – Can PTP be secured outside the tunnel?
  - Oscillators – can crystals deliver stability required under real-world temperature conditions?
  - Location – can “plug-and-play” small cell solutions deliver location accuracy without line-of-sight GPS?

Thank you!

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