ITU-T Q13/15, NETWORK SYNCHRONIZATION AND TIME DISTRIBUTION PERFORMANCE

Stefano Ruffini, Ericsson
stefano.ruffini@ericsson.com

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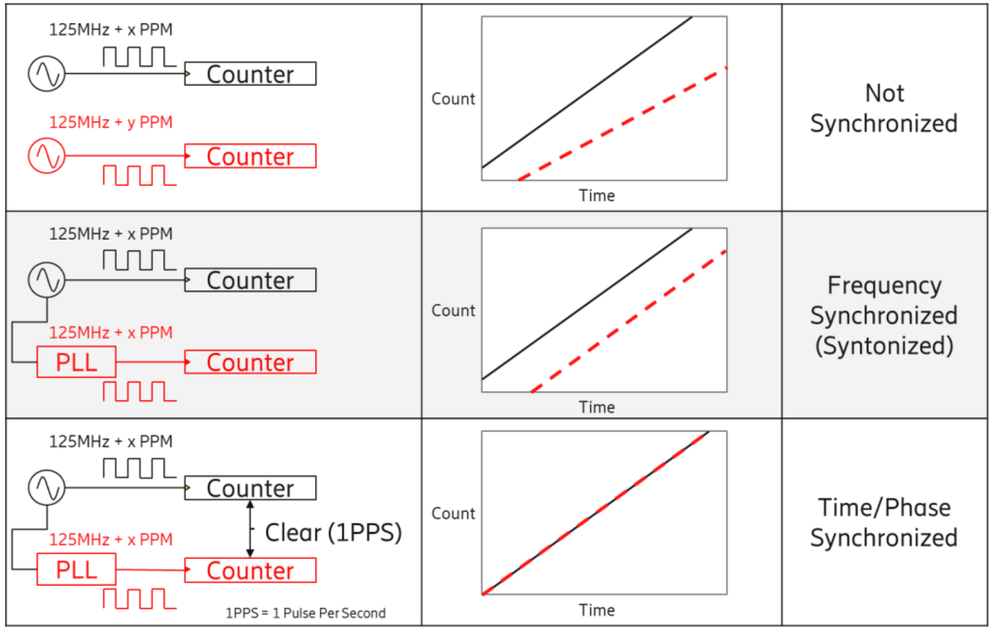
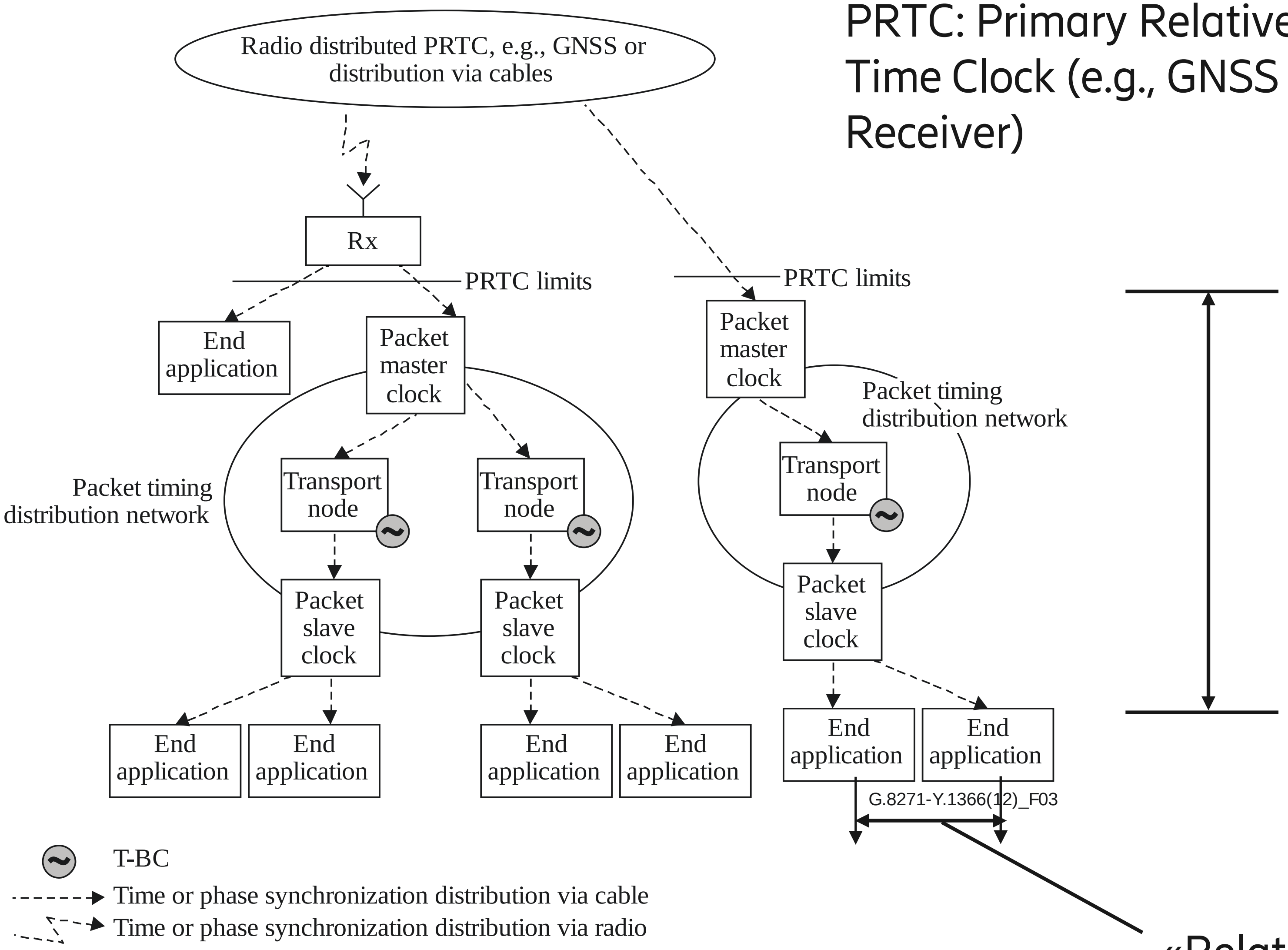
Q13: Introduction

- Network synchronization and time distribution performance
  - Networks Timing Needs (e.g., OTN)
  - End Applications Timing Needs (e.g. 5G Base Stations)
- Distribution of *Time-Phase* and *Frequency*
  - Methods (e.g., over physical layer, via packets, GNSS)
  - Architectures
  - Clocks
  - PTP profiles
  - Performance, Redundancy, Reliability, etc.
- Networks
  - From SDH to Ethernet, IP-MPLS, OTN, xPON, ... -> MTN
- Recommendations
  - G.826x series (distribution of frequency synchronziation)
  - G.827x series (Distribution fo time synchronzation)
  - G.781, G.781.1 (Sync Layer Functions)
  - «Historical» (G.803, G.810, G.811, G.812, G.813, G.823, G.824, G.825...)



Target Requirements: Absolute vs. Relative Time Error



PRTC: Primary Relative Time Clock (e.g., GNSS Receiver)

«Absolute»:

Measured with respect to a Primary Master

«Relative»: Measured between two end points

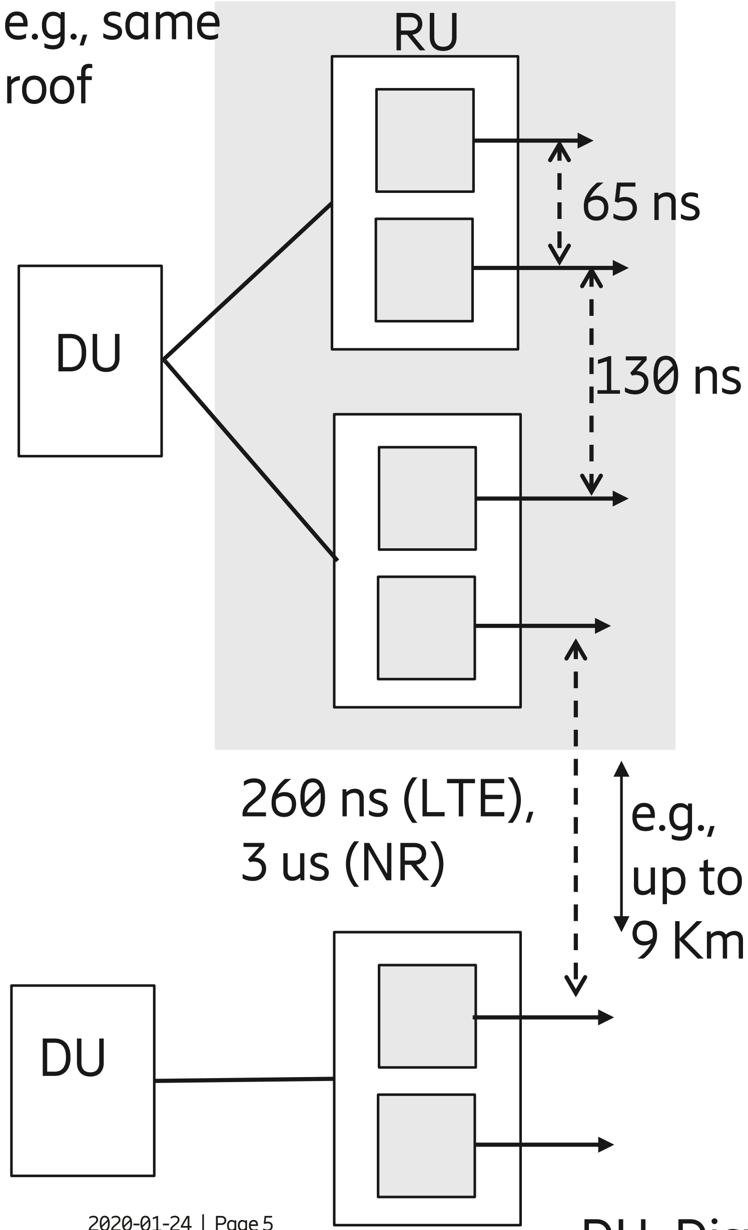
Target Applications (Time sync), G.8271

Level of accuracy	Time error requirements (Note 1)	Typical applications (for information)
1	500 ms	Billing, alarms
2	100 µs	IP Delay monitoring
3	5 µs	LTE TDD (large cell) Synchronous Dual Connectivity (for up to 7 km propagation difference between eNBs/gNBs in FR1) (Note 2)
4	1.5 µs	UTRA-TDD, LTE-TDD (small cell), NR TDD, WiMAX-TDD (some configurations) Synchronous Dual Connectivity (for up to 9 km propagation difference between eNBs/gNBs in FR1) (Note 2) NR Intra-band non-contiguous and Inter-band carrier aggregation, with or without MIMO or transmit (TX) diversity.
5	1 µs	WiMAX-TDD (some configurations)
6	x ns (Note 4)	Various applications, including location based services and some coordination features (Note 3)

Typically Absolute Time Error (levels 1–5)

Generally Relative Time Error (level 6)

Target Applications: Fronthaul



Level of accuracy	Maximum Relative Time error requirements (Note 1)	Typical applications (for information)
3A	5 μs	LTE MBSFN
4A	3 μs	NR Intra-band non-contiguous (FR1 only) and Inter-band carrier aggregation; with or without MIMO or TX diversity.
6A	260 ns	LTE Intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity, and inter-band carrier aggregation with or without MIMO or TX diversity NR (FR1) Intra-band contiguous (both FR1 and FR2) and Intra-band non-contiguous (FR2 only) carrier aggregation, with or without MIMO or TX diversity
6B	130 ns	LTE Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity NR (FR2) Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity
6C (Note 2)	65 ns	LTE and NR MIMO or TX diversity transmissions, at each carrier frequency

DU: Distributed Unit; RU: Radio Unit

Ongoing Studies: Clocks (G.8273.2)

T-BC/T-TSC Class	Maximum absolute time error – max|TE| (ns)
A	100 ns
B	70 ns
C	30 ns
D	For further study

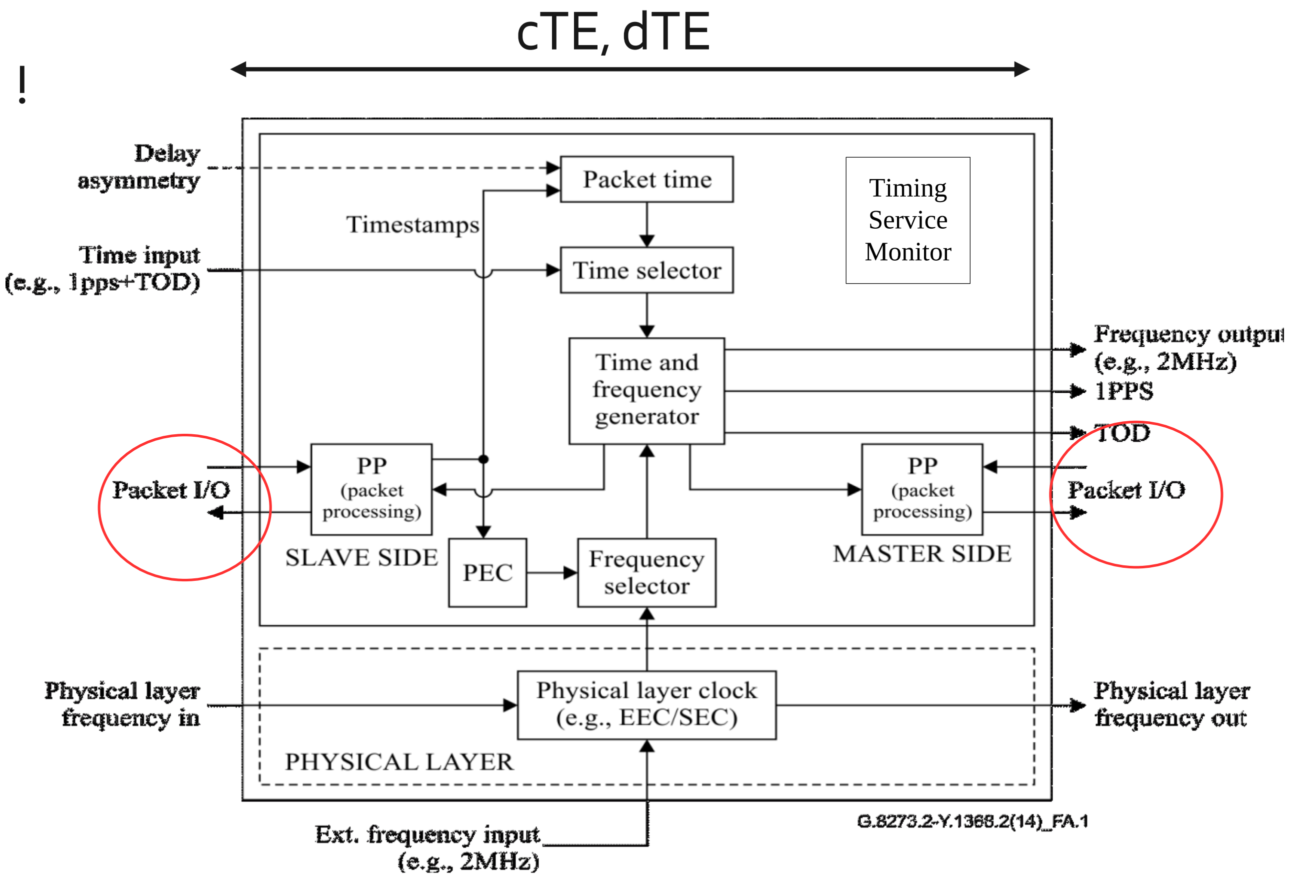
Unfiltered !

T-BC/T-TSC Class	Maximum absolute time error – max|TE_L| (ns)
D	5 ns

Filtered !

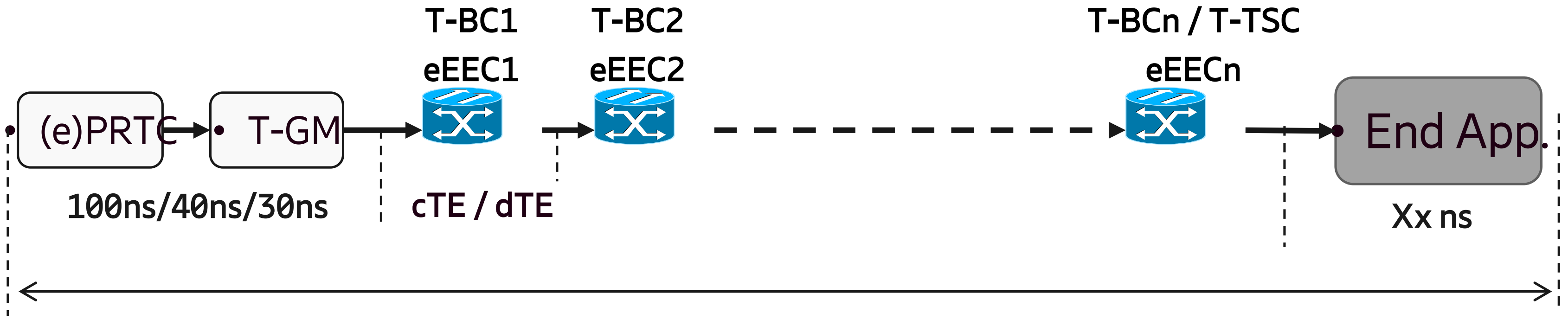
Constant Time Error (cTE)

T-BC/T-TSC Class	Permissible range of constant time error – cTE(ns)
A	±50
B	±20
C	±10
D	For further study



Dynamic Time Error (dTE) expressed in terms of MTIE and TDEV

Noise (Time Error) Accumulation (G.8271.1)



- PRTC = Primary Reference Time Clocks; T-BC = Telecom Boundary Clock; T-GM = Telecom Grand Master;
- T-TSC = Telecom Time Slave Clock; EEC = synchronous Ethernet Equipment Clock

Simplified estimation:

cTE accumulates linearly; dTE as square root of sum of squares (RSS)

$$\max|TE_N| \le \sum_{i=1}^{N}|cTE_i| + \sum_{j=1}^{N-1}|linkTE_j| + \sqrt{\left\{\sum_{i=1}^{N}\left[\max\left|d^L TE_i(t)\right|\right]^2\right\} + \left[\max\left|d^H TE_N(t)\right|\right]^2}$$

- Additional noise sources: Holdover, Link Asymmetries, SyncE Rearrangements …

cTE Accumulation: Linear vs. RSS

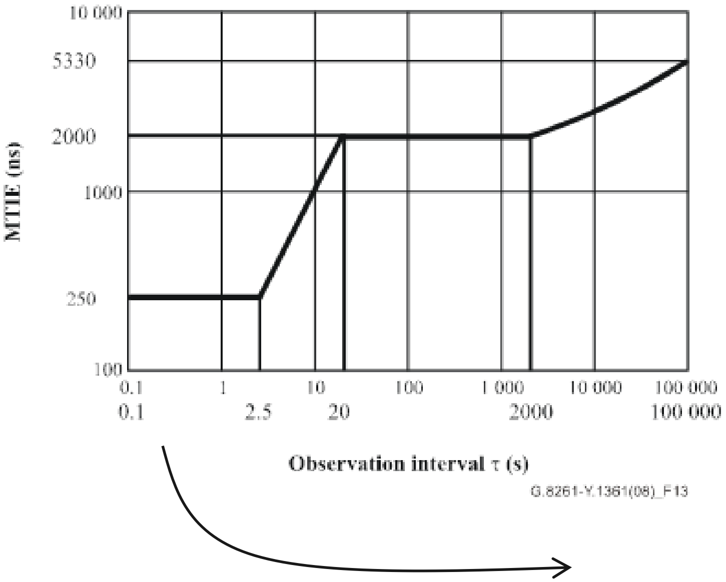
- *cTE is generally modeled to accumulate linearly in order to provide the worst case estimation.*
  - *in many cases the time error in cascaded clocks may compensate and the result will be much lower;*
  - *Nevertheless, over a large number of deployments there can be a significant number of occasions where this will not happen:, and will not change over time…*
    - *not acceptable in case of critical functions (e.g. TDD)*

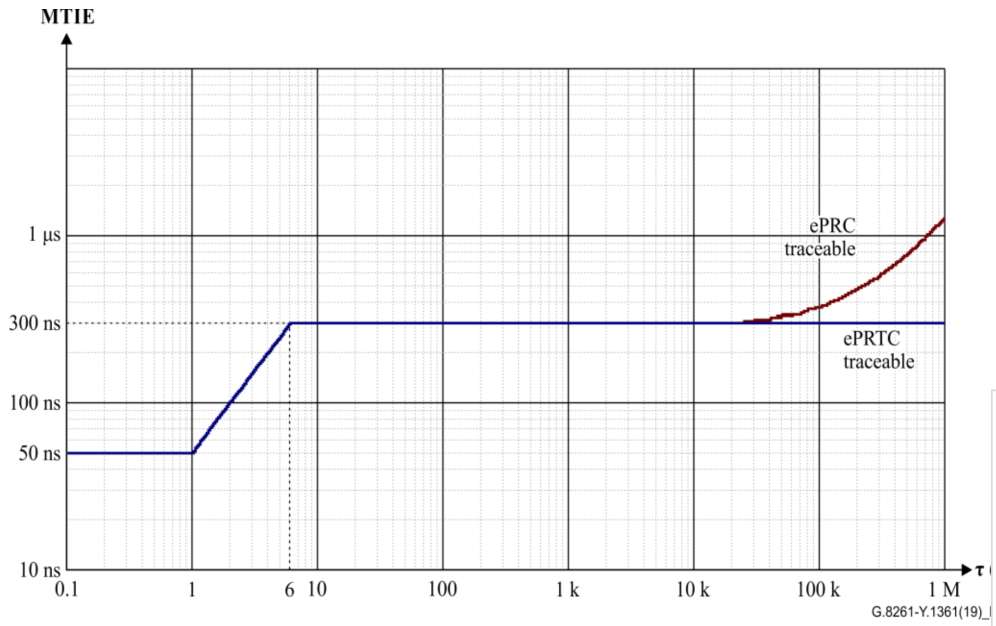
- *Another case where linear accumulation may lead to wrong conclusions is when same vendors/components are used in most of the nodes*
  - *Same error may be generated in each node*

- *In conclusion:*
  - *RSS approximation may be acceptable only for non-critical functions and over long chain of clocks (compensation may be less likely in case of short chains)*
  - *In all other cases linear accumulation should be generally considered*

Ongoing Studies: Enhanced Synchronous Ethernet (G.8261, G.8262.1)

- Enhanced Clock support frequency sync distribution over the phyical layer (e.g. Synchronous Ethernet in case of Ethernet): G.8262.1
- Network Limits Improvements: further improvements to support fronthaul?





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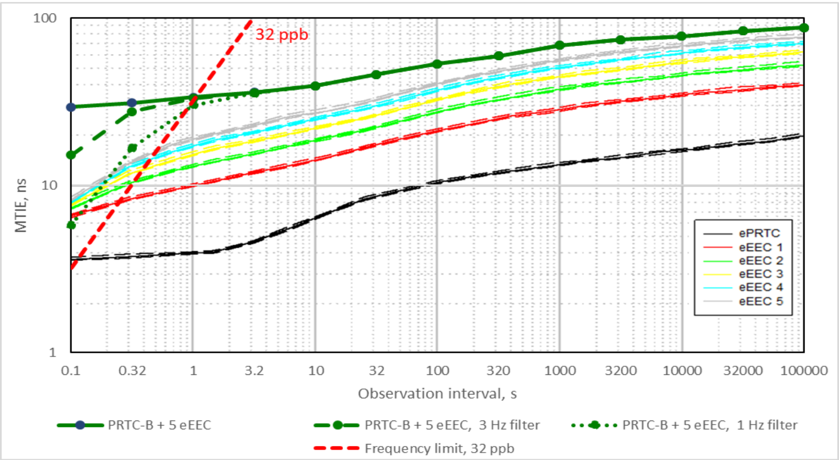
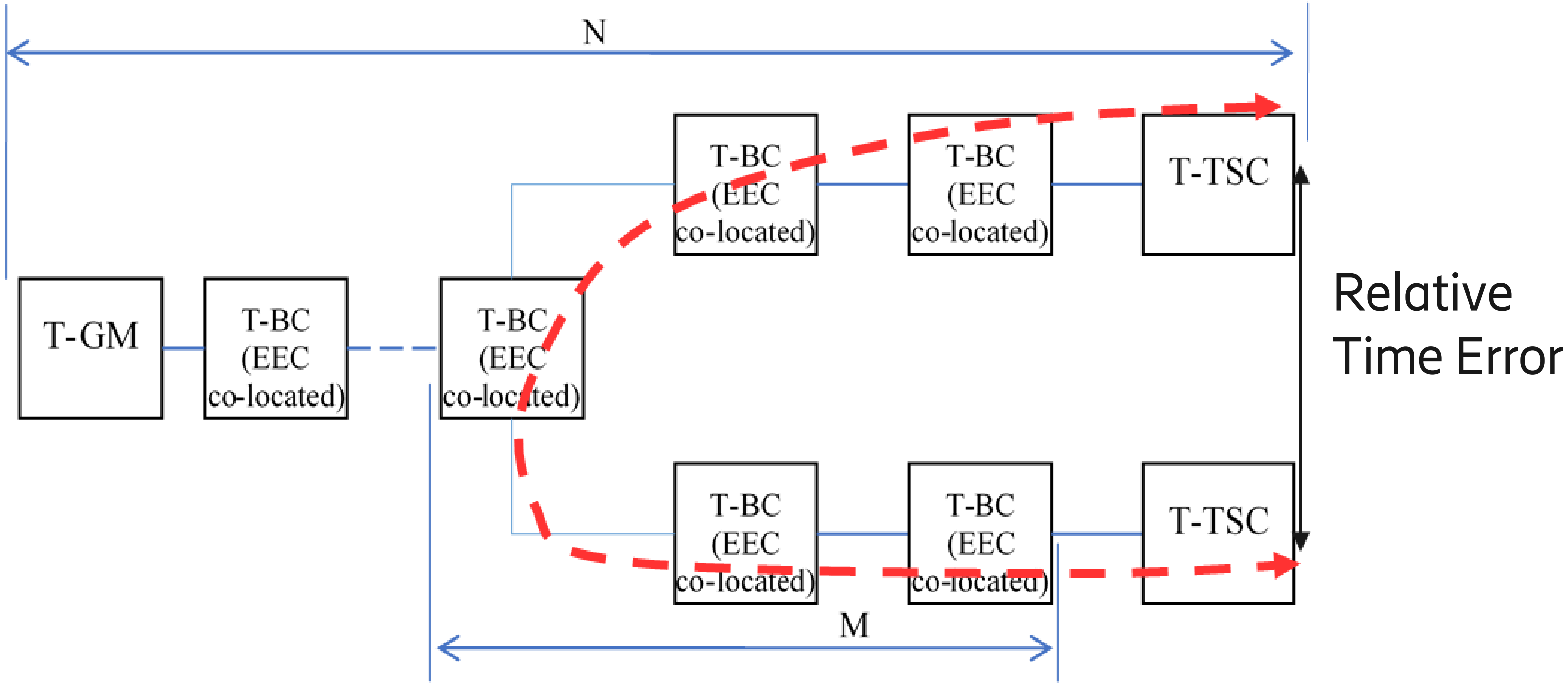
- To simplify generation of 50ppb over the radio interface



Ongoing Studies: Fronthaul (G.8271.1)

- Under analysis guidelines for network dimensioning
- Clock Class C from G.8273.2 is generally assumed
- Use of enhanced Synchronous Ethernet
- Initial assumptions : short clock chain (e.g., M < 3-5)



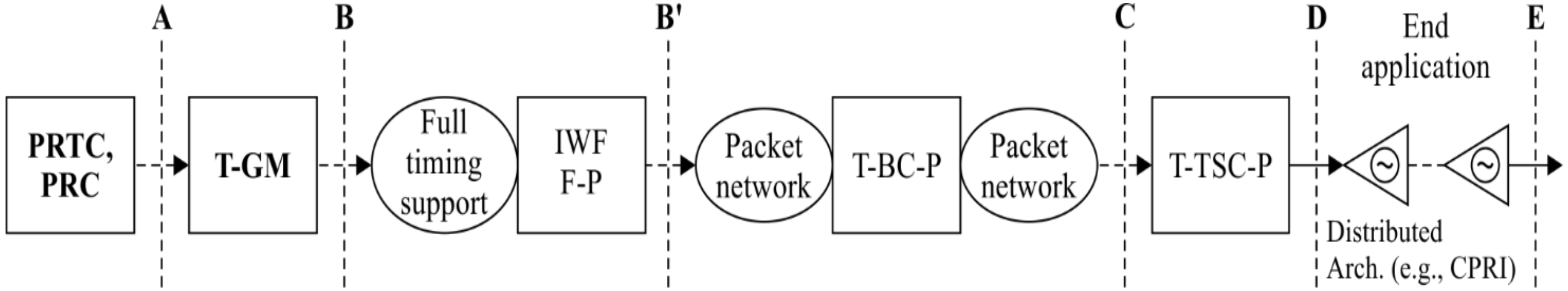
Network Performance measurement still with respect to a common master ?
Some options exist …

IEEE1588: now and future

- Methods to distribute time sync includes use of Precision Time Protocol (PTP) as specified by IEEE1588
- Use of PTP by a specific Industry requires definition of ad-hoc “Profiles“:
  - G.8275.1, G.8275.1, G.8275.2 defined by ITU-T
  - Based on IEEE1588-2008
- New version recently completed by IEEE1588, v2.1 (IEEE1588-2019)
- Several optional features have been added in the IEEE1588 v2.1 :
  - Definition of Special PTP ports
  - Management configuration of PTP port states
  - Cumulative rate ratio
  - Options for greater security (PTP built in security option and guidelines for providing external security i.e. Macsec and IPsec)
  - Performance monitoring tools
  - TLV carrying performance network information
  - High accuracy PTP profile

Ongoing Studies: PTP Profile Interworking

In some deployment scenarios an inter-working function (IWF) may be used to translate between different segments of a network that are running different PTP profiles (G.8275)



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Topic strictly related to TSN Time sync (3GPP TS 23 501) ...

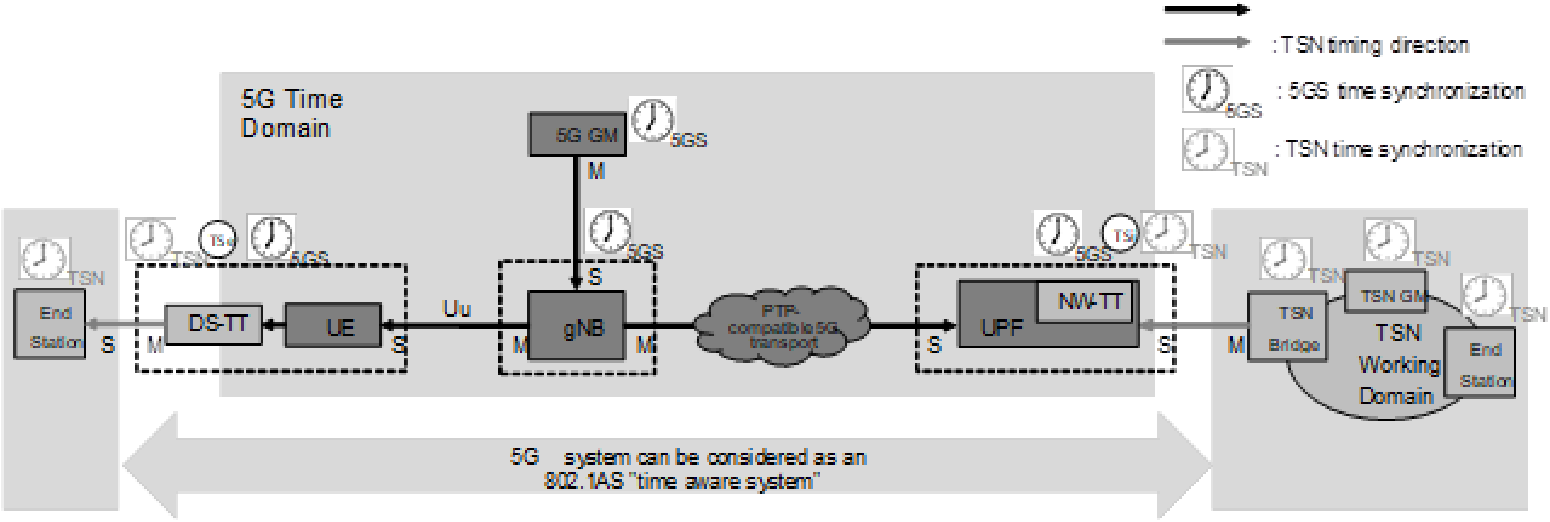
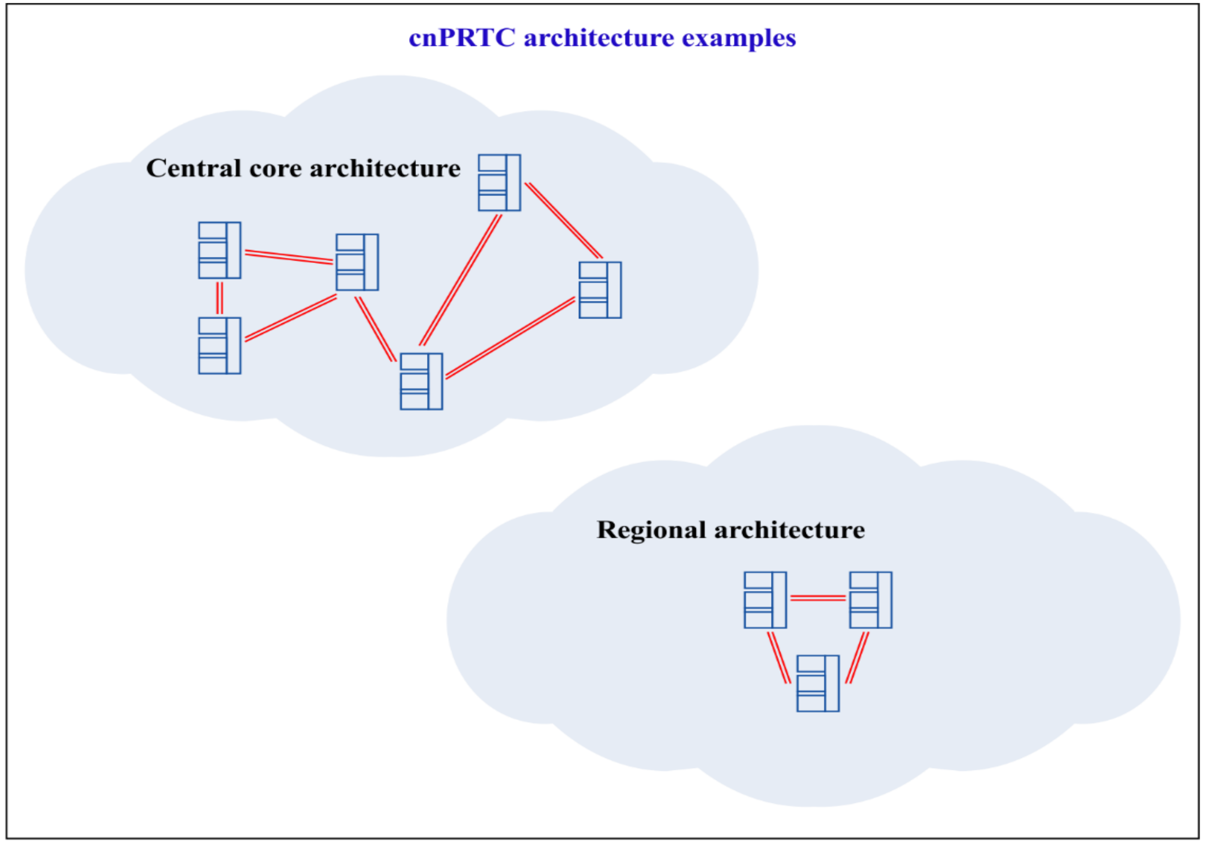


Figure from TS 23.501: 5G system is modelled as IEEE 802.1AS compliant time aware system for supporting TSN time synchronization

What is Next ?

- MTN, Metro Transport Network, (reuse of FlexE for 5G Transport)
  - Sync Requirements
  - Sync Architecture
  - PTP and syncE distribution
  - Clocks
- Complete work on Profile Interworking
- Complete work on cnPRTC (Coherent PRTC)
  - Requirements
  - Methods (high accuracy profile?)
- Address New Sync Requirements
  - Emerging needs in mobile networks (Positioning or even use cases with less stringent requirements);
  - Future needs ?

- *The coherent network PRTC connects primary reference clocks at the highest core or regional network level. This provides the ability to maintain network-wide ePRTC time accuracy, even during periods of regional or network-wide GNSS loss (G.8275)*



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