ITU-T Sync Standards Update

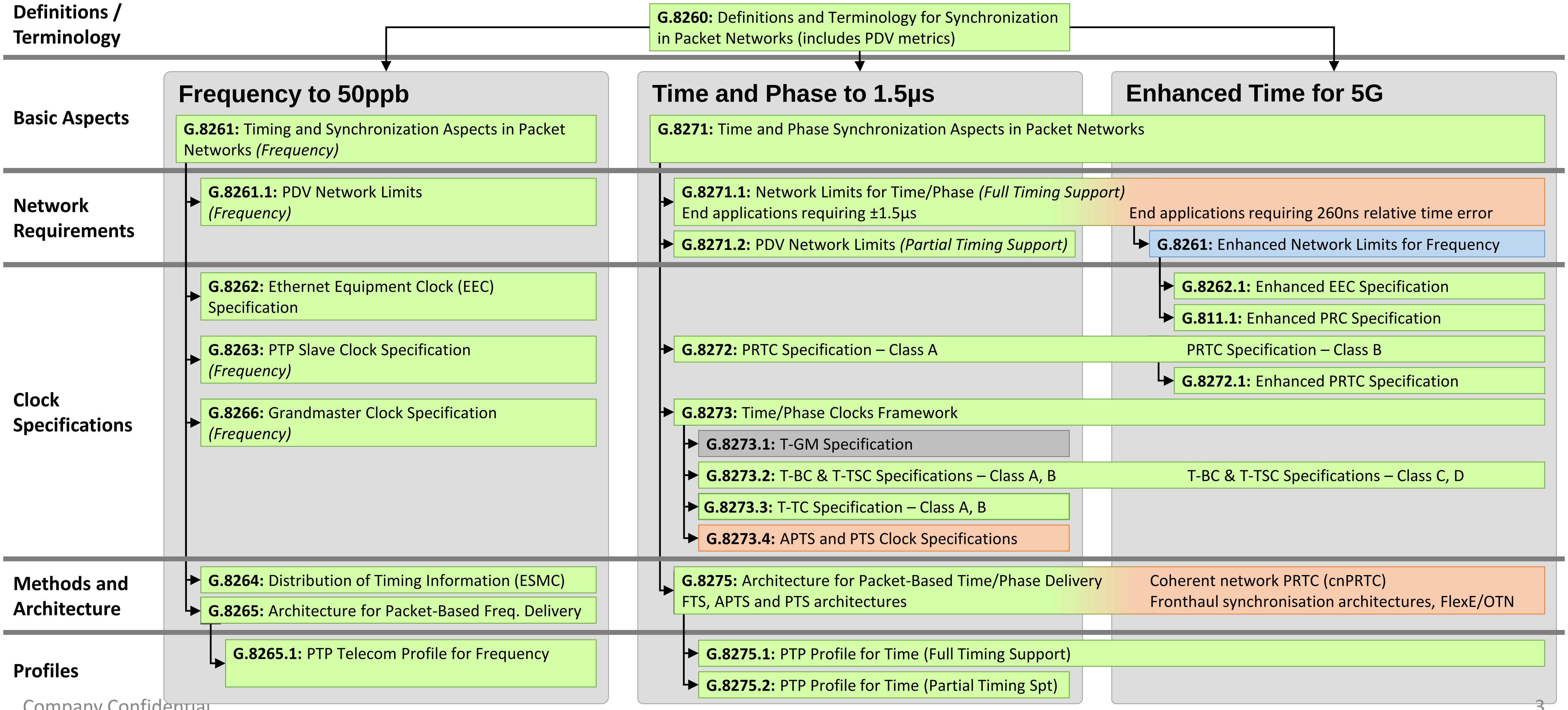
July 2019

Tim Frost

ITU Sync Standards Categories

- Transfer of frequency to meet 50ppb *(2G/3G/4G FDD)* ✓
    - Using SyncE, or using PTP over existing networks
- Transfer of time to meet 1.5µs *(3G/4G TDD, LTE-A)* ✓
    - Using PTP over new networks with T-BC and SyncE at every node
- Transfer of time to meet 1.5µs *(3G/4G TDD, LTE-A)* WORK IN PROGRESS
    - Using PTP over existing networks
- Transfer of time to meet 130ns *(5G potential)* ALMOST DONE!
    - “Enhanced” clock specifications
- Sync OAM *(general)* WORK IN PROGRESS

ITU-T Packet Sync Recommendations



Definitions / Terminology

G.8260: Definitions and Terminology for Synchronization in Packet Networks (includes PDV metrics)

Frequency to 50ppb

Time and Phase to 1.5µs

Enhanced Time for 5G

Basic Aspects

- **G.8261:** Timing and Synchronization Aspects in Packet Networks *(Frequency)*
- **G.8271:** Time and Phase Synchronization Aspects in Packet Networks

Network Requirements

- **G.8261.1:** PDV Network Limits *(Frequency)*
- **G.8271.1:** Network Limits for Time/Phase *(Full Timing Support)*
  End applications requiring ±1.5µs
  End applications requiring 260ns relative time error
  - **G.8261:** Enhanced Network Limits for Frequency
- **G.8271.2:** PDV Network Limits *(Partial Timing Support)*

Clock Specifications

- **G.8262:** Ethernet Equipment Clock (EEC) Specification
- **G.8263:** PTP Slave Clock Specification *(Frequency)*
- **G.8266:** Grandmaster Clock Specification *(Frequency)*
- **G.8262.1:** Enhanced EEC Specification
- **G.811.1:** Enhanced PRC Specification
- **G.8272:** PRTC Specification – Class A
  PRTC Specification – Class B
  - **G.8272.1:** Enhanced PRTC Specification
- **G.8273:** Time/Phase Clocks Framework
  - **G.8273.1:** T-GM Specification
  - **G.8273.2:** T-BC & T-TSC Specifications – Class A, B
    T-BC & T-TSC Specifications – Class C, D
  - **G.8273.3:** T-TC Specification – Class A, B
  - **G.8273.4:** APTS and PTS Clock Specifications

Methods and Architecture

- **G.8264:** Distribution of Timing Information (ESMC)
- **G.8265:** Architecture for Packet-Based Freq. Delivery
- **G.8275:** Architecture for Packet-Based Time/Phase Delivery
  FTS, APTS and PTS architectures
  Coherent network PRTC (cnPRTC)
  Fronthaul synchronisation architectures, FlexE/OTN

Profiles

- **G.8265.1:** PTP Telecom Profile for Frequency
- **G.8275.1:** PTP Profile for Time (Full Timing Support)
- **G.8275.2:** PTP Profile for Time (Partial Timing Spt)

🟩 Published
🟦 Approved
🟧 Under development
⬜ Not active

What’s new?

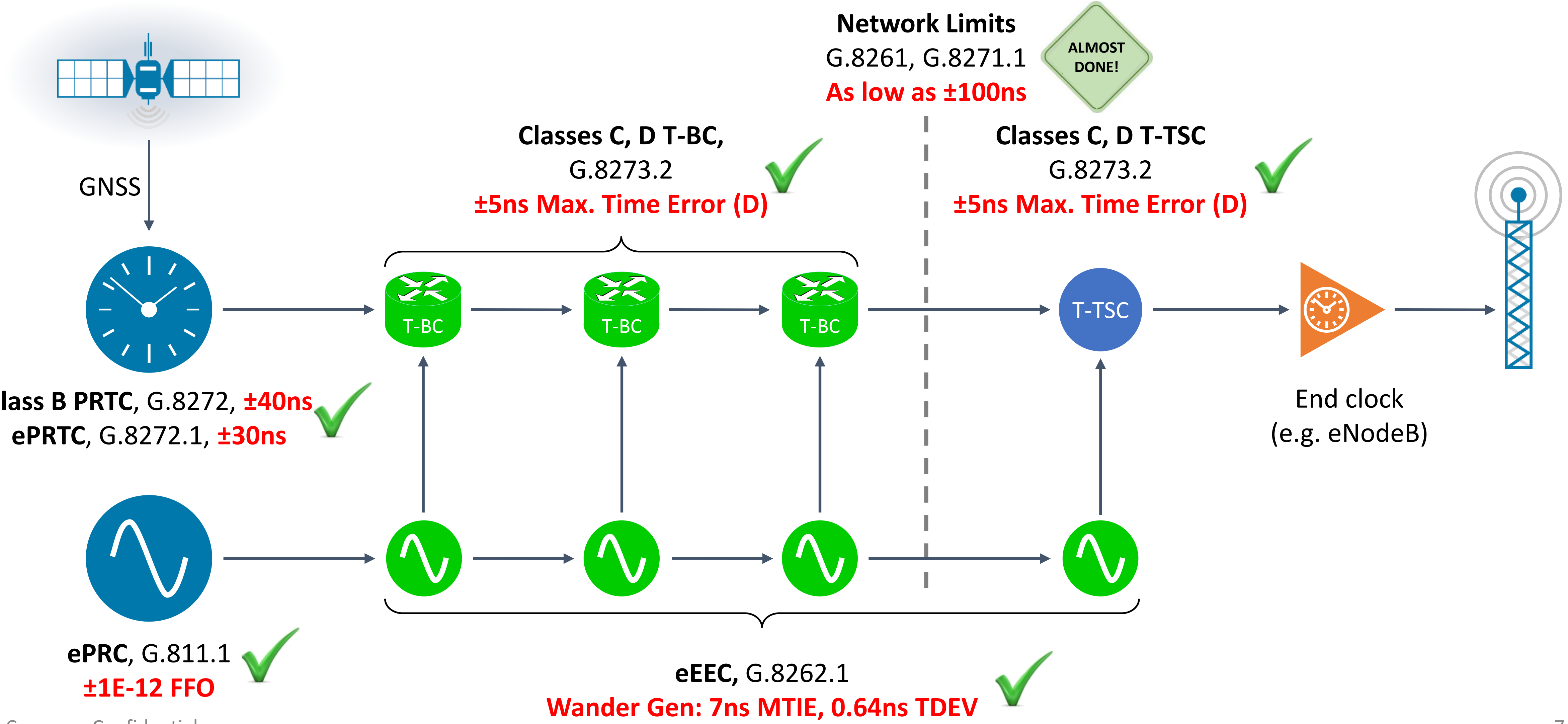
Recommendations approved in July 2019

Main new performance spec at this meeting

- Network limit specifications:
  - **G.8261 Revision** – Adds the network limit for a chain of enhanced clocks (e.g. eEECs)
  - **G.8271.1 Amd. 2** – Adds new appendix about fronthaul architectures
    – *No new performance specifications*
- High-accuracy “enhanced” clock specifications for 5G:
  - **G.8262.1 Amd. 1** – Adds wander tolerance spec, adds parameters S and T to transient response
    – Adds Appendix on back-to-back testing for media converters *(e.g. µW, OTN)*
  - **G.8272.1 Amd. 2** – Adds an integrated ePRTC/T-GM function *(same performance)*
  - **G.8273.2 Rev.** – Re-organizes the document to bring all clock classes into the main body
    – Includes guidelines on back-to-back testing of Class C clocks *(as well as A & B)*
- PTP Profile updates:
  - **G.8265.1 Amd. 1** – Adds a brief note about processing of Quality Levels. No technical change.
  - **G.8275.1 Amd. 3** – Adds support for transmission of PTP over OTN OSMC channel
  - **G.8275.2 Amd. 3** – Adds an Appendix describing operation of the profile over a LAG
- General Information:
  - **G.8275 Amd. 2** – Adds information about inter-working between G.8275.1 and G.8275.2
    – Adds information about timescale combination for the cnPRTC

Enhanced Clocks and Network Limits

Enhanced Clock Specifications for 5G



Network Limits
G.8261, G.8271.1
As low as ±100ns

Classes C, D T-BC,
G.8273.2
±5ns Max. Time Error (D) ✓

Classes C, D T-TSC
G.8273.2
±5ns Max. Time Error (D) ✓

Class B PRTC, G.8272, ±40ns
ePRTC, G.8272.1, ±30ns ✓

End clock
(e.g. eNodeB)

ePRC, G.811.1
±1E-12 FFO ✓

eEEC, G.8262.1
Wander Gen: 7ns MTIE, 0.64ns TDEV ✓

Enhanced Specifications for 5G

Calnex

- Enhanced specifications agreed:
  - G.811.1 ePRC – published August 2017 ✓
  - G.8272.1 ePRTC – published August 2017 ✓
  - G.8272: PRTC Class B – published January 2019 ✓
  - G.8262.1: eEEC – published January 2019 ✓
  - G.8273.2: Class C and Class D T-BC and T-TSC – published January 2019 ✓
- 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: agreed, to be published by Sept. 2019 ✓
- G.8271.1: Network Limit for chain of T-BCs
  - New budget to meet 1.5µs using Class C clocks, even under long outages (2-3 days)
  - New network limit based on Class C, D T-BC specification, targeting around ±130ns end-to-end
  - New network limit for relative time error, targeting fronthaul clusters
  - Status: expected completion by early 2020

G.8272: Comparing PRTC Classes

Parameter	Conditions	Class A	Class B	ePRTC (G.8272.1)
Max|TE_L|	1pps: unfiltered PTP: 100-sample moving average low-pass filter	100ns	40ns	30ns
dTE_L MTIE	1pps: unfiltered PTP: 100-sample moving average low-pass filter	100ns (max)	40ns (max)	30ns (max)
dTE_L TDEV	1pps: unfiltered PTP: 100-sample moving average low-pass filter	3ns up to 100s, rising to 30ns @ 1000s	1ns up to 100s, rising to 5ns @ 500s	1ns up to 30Ks, rising to 10ns @ 300Ks

- ePRTC has very long-term holdover, requiring high-performance Caesium oscillator
- PRTC-B intended for distributed applications where an ePRTC would not be practical
  - Expected to be based on multi-band GNSS receivers to compensate for the ionosphere
  - Holdover provided by SyncE rather than a Cs oscillator

SyncE: Comparing G.8262 to G.8262.1

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Parameter	EEC (G.8262)	eEEC (G.8262.1)
Frequency Accuracy	4.6ppm	Same value
Pull-in/Hold-in	4.6ppm	Same value
Wander generation	MTIE: 40ns @ 0.1s, rising to 113ns @1000s TDEV: 3.2ns @ 0.1s, rising to 6.4ns @1000s	MTIE: 7ns @ 0.1s, rising to 25ns @1000s TDEV: 0.64ns @ 0.1s, rising to 1.28 ns @1000s
Wander tolerance	250ns @ 0.1s, rising to 5000ns @ 1000s	Same value *(allows mixed chains)*
Jitter generation	0.5UI *(1G, 10G)* 1.2UI *(25G lanes)*	Same value (1G) 10G, 25G: for further study
Jitter tolerance	250ns @ 10Hz, reducing to 1.5UI (3.6UI for 25G lanes)	Same value (1G) 10G, 25G: for further study
Clock Bandwidth	1 – 10Hz	1 – 3Hz
Transient response	120ns initial step, then 50ns/s *(const. temp)*	10ns initial step, then 10 ns/s *(const. temp)*
Holdover	120ns initial step, then 50ns/s frequency offset, plus 1.16 x 10^{-4} ns/s^2 drift *(const. temp)*	10ns initial step, then 10 ns/s frequency offset, plus 1.16 x 10^{-4} ns/s^2 drift *(const. temp)*

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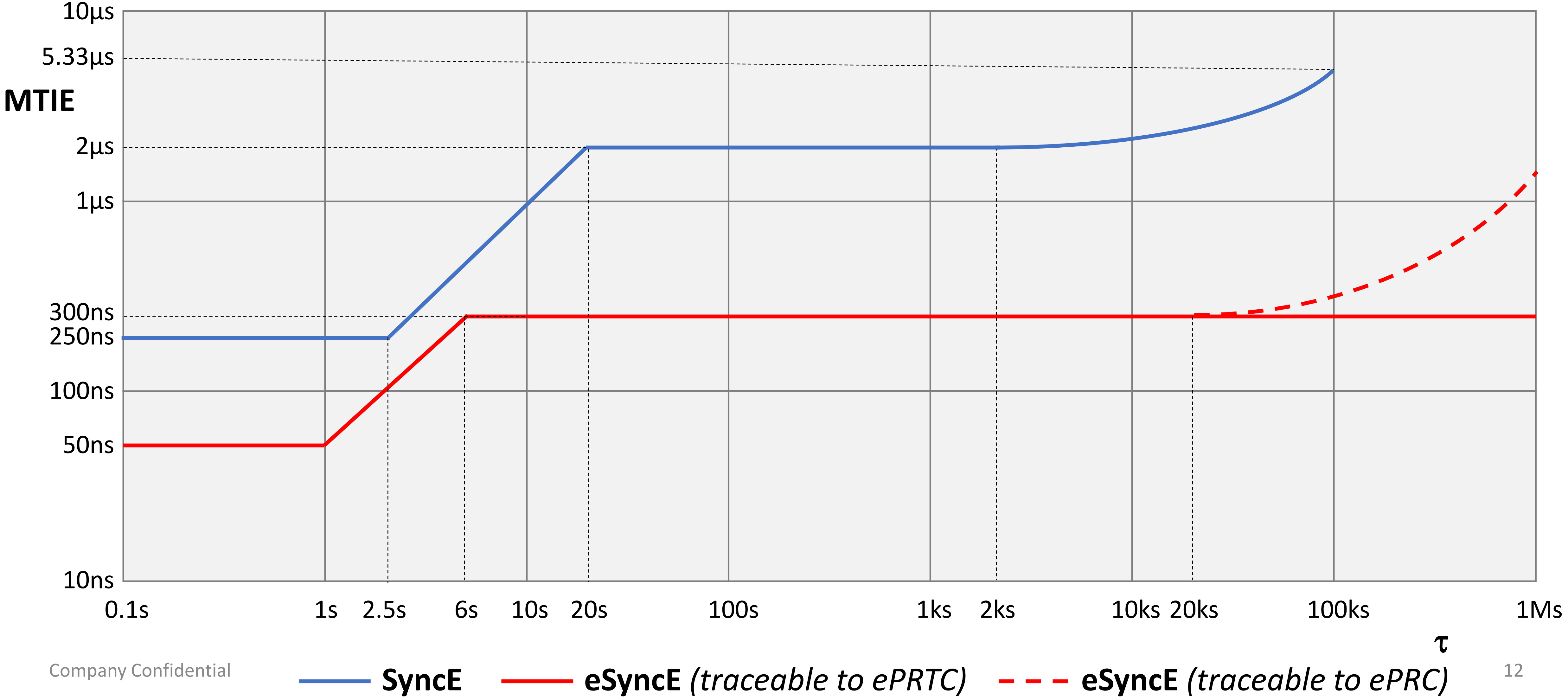
Key: Green – same as G.8262 EEC spec
Red – changes to G.8262 EEC spec

G.8273.2: Comparing T-BC Classes

Parameter	Conditions	Class A	Class B	Class C	Class D
Max|TE|	Unfiltered, 1000s	100ns	70ns	30ns	*FFS*
Max|TE_L|	0.1Hz low-pass filter, 1000s measurement	-	-	-	5ns
cTE	Averaged over 1000s	50ns	20ns	10ns	*FFS*
dTE_L MTIE	0.1Hz low-pass filter Const. temp, 1000s	40ns	40ns	10ns	*FFS*
	0.1Hz low-pass filter Var. temp, 10000s	40ns	40ns	*FFS*	*FFS*
dTE_L TDEV	0.1Hz low-pass filter Const. temp, 1000s	4ns	4ns	2ns	*FFS*
dTE_H	0.1Hz high-pass filter Const. temp, 1000s	70ns	70ns	*FFS*	*FFS*

- Class C aimed at shorter chains (up to 10 nodes)
- Class D aimed at longer chains (up to 20 nodes), and fronthaul networks in particular
- All classes now defined over 1, 10, 25, 40 and 100GE interfaces

SyncE vs. Enhanced SyncE Network Limits



Work in Progress

Future revisions planned for Feb. 2020

- **G.8261 Amd. 1** – *Network Limits for Frequency*
  - To add TDEV network limit for chains of enhanced SyncE clocks
  - To add network limit based on shorter chains for high-accuracy applications
- **G.8271 Amd. 3** – *Time Synchronisation in Telecom Networks*
  - General update
- **G.8271.1 Amd. 3** – *Network Limits for Full Timing Support*
  - Timing budget for 1.5us with Class C clocks
  - Network limits for ±130ns
  - Network limits for relative time error
- **G.8273.4** – *Partial Timing Support clocks* (first version)
  - Was to be agreed in July 2019, but agreement delayed until February 2020
- **G.8275 Amd. 2** – *Time Sync Architectures*
  - Further details on Coherent Network PRTC (cnPRTC)
  - Possibly also material on FlexE and OTN-based fronthaul architectures
- **G.781.1** – *Sync Layer Functions for Time/Phase*
  - Extended QL for enhanced time clocks
- **GNSS Technical Report** – *New report regarding use of GNSS for timing applications*

PTP over existing networks: APTS and PTS

- G.8271.2 (Network Limits) published August 2017
  - Updated October 2018
  - No new updates planned at present
- G.8273.4 (Slave Clock Specification) work in progress
  - Contains two clock specifications, for APTS clock and PTS clock
  - APTS Clock:
    - GNSS primary time source, PTP backup
    - Uses GNSS to measure PTP asymmetry during normal operation
    - Operates over switches/routers without PTP support (e.g. BCs, TCs)
  - PTS Clock:
    - Uses PTP as sole means of transferring time
    - Operates over switches/routers without PTP support (e.g. BCs, TCs)
  - Status: first agreement expected Feb. 2020

Coherent Network PRTC

- Network of PRTCs for improved resiliency and accuracy
  - PRTCs exchange time information directly, enabling both ensembling and redundancy
  - “Rogue” PRTCs can be detected and eliminated from timing network
  - Interconnect might be PTP, high accuracy PTP (e.g. White Rabbit), or dedicated optical interconnect
- Possible connection to national lab for both highly accurate UTC(k) and legal time
- Information on cnPRTC to go into G.8275 (Architecture) document
- Status:
  - Initial information in G.8275 Amd. 1 (January 2019)
  - Update on timescale combination agreed (G.8275 Amd. 2), to be published by Sept. 2019
  - Expected completion by early 2020

GNSS Technical Report

- Technical Report looking at using GNSS receivers to obtain an accurate source of time
- Contents:
  - High level description of GNSS systems
  - Factors influencing the performance of a GNSS-based PRTC
  - Sources of time error in GNSS time distribution
  - Mitigation of time error in a GNSS-based PRTC
  - Operational schemes for mitigation of time error in GNSS time distribution
  - Appendices:
    - Cable delay effects and correction in a GNSS receiver
    - Ionospheric Delay and its effect on GNSS receivers
    - TRAIM (Time Receiver Autonomous Integrity Monitoring)
    - Solving GNSS equations to establish position and time
    - The effect of multiple reflections within the antenna cable
- Status: expected completion by early 2020

Sync OAM and Management

- Model proposed using an alternative PTP flow as a reference
  - Not a perfect reference, but a sanity check and indication of network-related issues
  - Described in G.SuppSyncOAM, a working document collecting Sync OAM material
- Frequency sync defects and parameters to be documented in a revised version of G.781
  - Status: Published August 2017
  - Update agreed, to be published by Sept. 2019
- Time sync defects and parameters to be documented in new recommendation G.781.1
  - Status: possible completion by early 2020

Calnex

Insight and Innovation

calnexsol.com

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