ITU-T Sync Standards Update

February 2020

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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 $1.5\mu s$ *(3G/4G TDD, LTE-A)*
  - Using PTP over new networks with T-BC and SyncE at every node

- Transfer of time to meet $1.5\mu s$ *(3G/4G TDD, LTE-A)*
  - Using PTP over existing networks

- Transfer of time to meet 130ns *(5G NR)*
  - PTP over Fronthaul networks

- Sync OAM *(general)*

ITU-T Packet Sync Recommendations

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Definitions / Terminology

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

Frequency to 50ppb

Basic Aspects

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

Network Requirements

- **G.8261.1:** PDV Network Limits *(Frequency)*

Clock Specifications

- **G.8262:** Ethernet Equipment Clock (EEC) Specification
- **G.8263:** PTP Slave Clock Specification *(Frequency)*
- **G.8266:** Grandmaster Clock Specification *(Frequency)*

Methods and Architecture

- **G.8264:** Distribution of Timing Information (ESMC)
- **G.8265:** Architecture for Packet-Based Freq. Delivery

Profiles

- **G.8265.1:** PTP Telecom Profile for Frequency

Time and Phase to 1.5µs

Enhanced Time for 5G

Basic Aspects

- **G.8271:** Time and Phase Synchronization Aspects in Packet Networks

Network Requirements

- **G.8271.1:** Network Limits for Time/Phase *(Full Timing Support)* End applications requiring ±1.5µs — End applications requiring 130/260ns relative time error
- **G.8271.2:** PDV Network Limits *(Partial Timing Support)*
- **G.8261:** Enhanced Network Limits for Frequency

Clock Specifications

- **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.8275:** Architecture for Packet-Based Time/Phase Delivery FTS, APTS and PTS architectures — Coherent network PRTC (cnPRTC) Fronthaul synchronization architectures, FlexE/OTN

Profiles

- **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 Feb. 2020

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(to be published by end of March 2020)

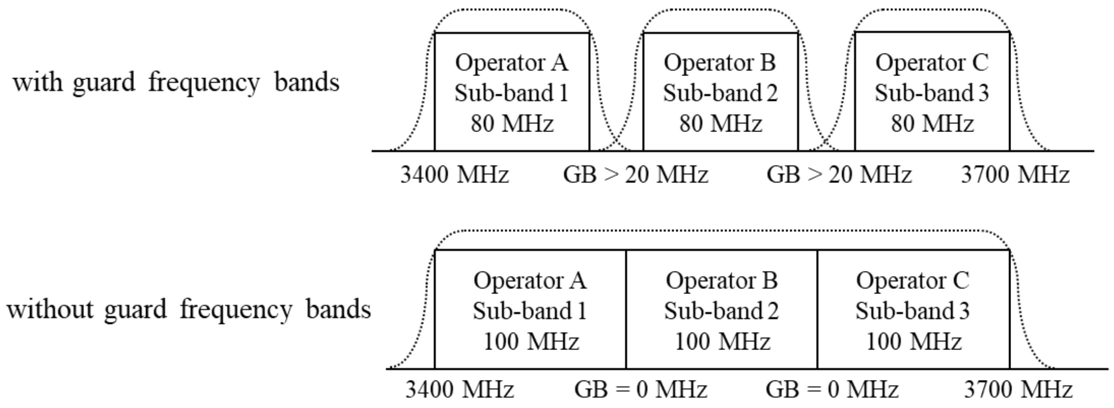
Main new performance spec. at Feb.'20 meeting

- Clock specifications:
  - **G.8273.4** – APTS and PTS clock specification
  - **G.8262 Amd. 1** – Adds PAM4 (50G, 100G, 200G) interfaces to the list of SyncE-capable interfaces
  - **G.8272 Rev.** – Scope change to remove restrictions on PRTC-B deployment
  - **G.8273.2 Amd. 1** – Mostly editorial changes
- Network limit specifications:
  - **G.8261 Amd. 1** – Adds the TDEV network limit for a chain of enhanced clocks (e.g. eEECs)
  - **G.8271.1 Rev.** – Adds discussion on how to estimate relative TE from existing measurements
- PTP Profile updates:
  - **G.8275.1 Rev.** – Adds reference to IEEE1588-2019 (PTP version 2.1)
  - **G.8275.2 Rev.** – Guidance on clockAccuracy values for enhanced PRTCs in holdover
- General Information:
  - **G.8260 Rev.** – Guidelines on relative TE measurement
  - **G.8271 Rev.** – Information on inter-operator sync requirements for 5G NR
  - **G.8273 Rev.** – Appendix on least-squares filtering for noise transfer testing
  - **G.Sup.SyncOAM** – Informative supplement detailing what OAM parameters clocks should support
  - **GNSS Tech. Rep.** – Informative document on using GNSS for timing

New development, see next slide

Inter-operator synchronization

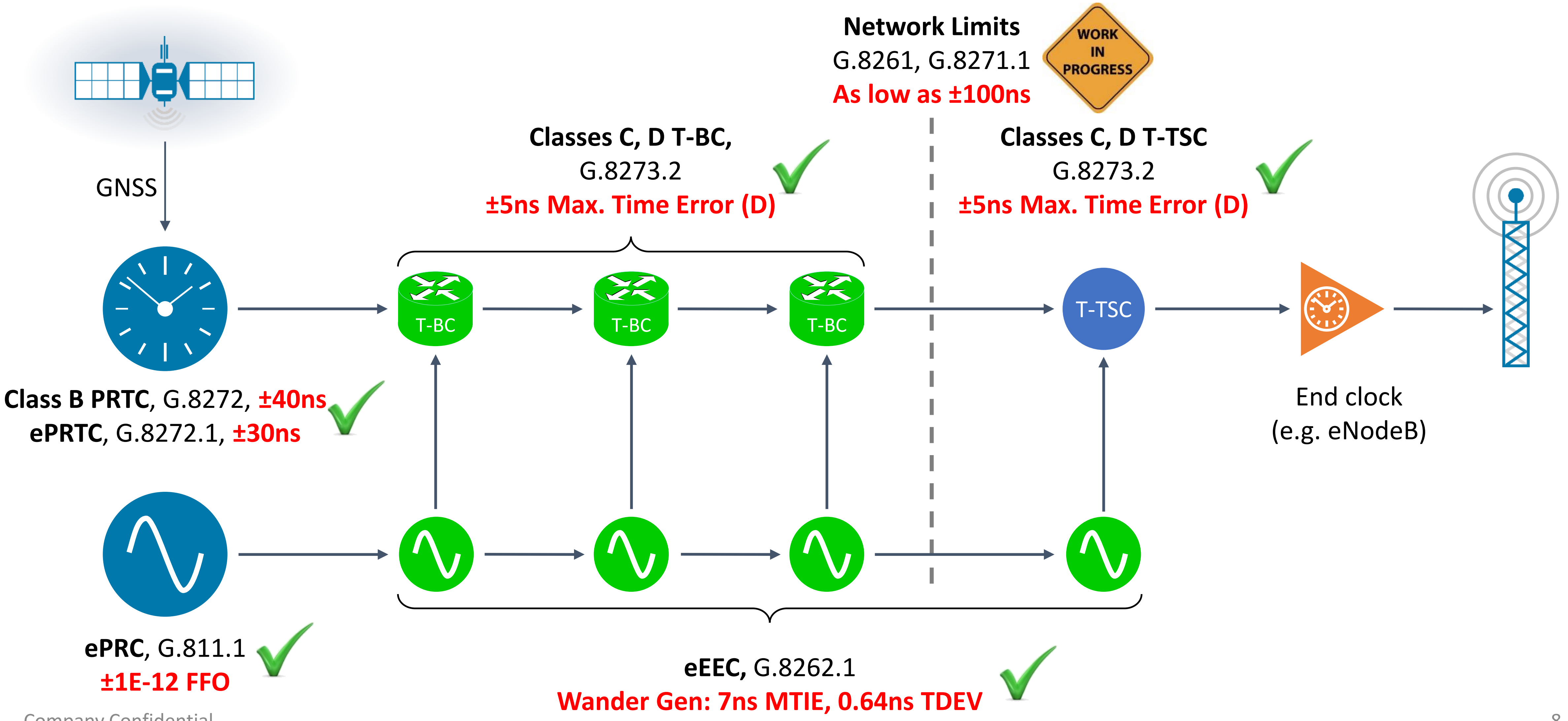
- At 5G, operators want to remove frequency guard bands to gain spectrum:



- To avoid interference, all operators must synchronize to the same reference (e.g. UTC)
  - Currently there is a “gentleman’s agreement” between Japanese operators to all synchronize to within 1.5µs of UTC
  - European operators are also raising the topic
  - New Appendix VI in G.8271 discusses the issue
- Expect this to start to become a regulatory requirement for 5G TDD operators
  - This will therefore require ongoing testing and validation, particularly field test
- May even lead to spectrum sharing in some cases

Enhanced Clocks and Network Limits

Enhanced Clock Specifications for 5G



Enhanced Specifications for 5G

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- 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 end 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: proving more difficult than expected
    Expected completion now 2021

WORK IN PROGRESS

Fronthaul networks – what's the issue?

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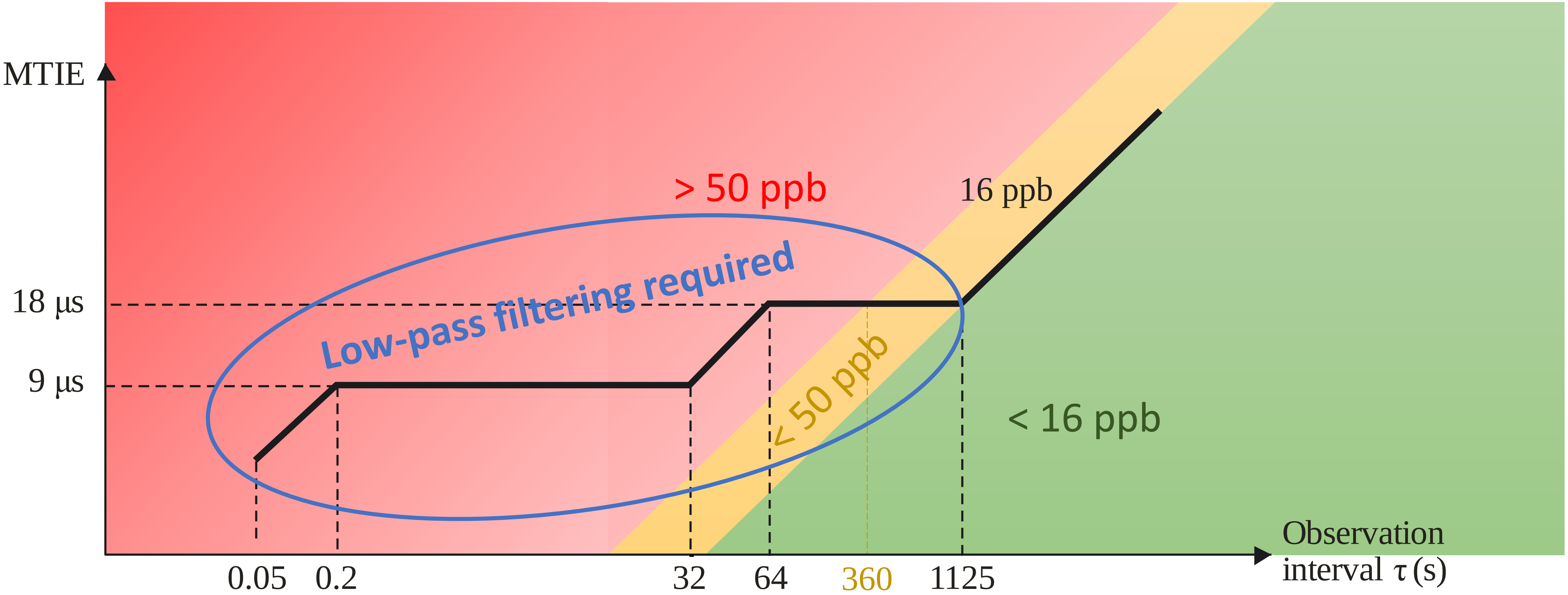
- Up to now, it has commonly been thought that the relative TE requirements (130 or 260ns TAE) is the biggest problem
- New issue emerging is frequency accuracy to meet 50ppb
- Problem is that the Radio Units cannot provide the low-pass filtering that previous NodeB or eNodeB's provided
  - Small cheap devices, with much worse thermal environments
  - Old network limits meet the 50ppb requirements over the long term, but not the short term
  - Even chains of Class C clocks look to have too much short term wander
- Frequency network limits currently under discussion between ITU-T and ORAN
  - ORAN want around 15ppb from the network, with 75mHz filtering
  - Acceptable solution is not readily apparent at present (Feb. 2020)

Frequency network limit

- G.8261.1 Frequency Network Limit



G.8261.1-Y.1361.1(12)_F04

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

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)*

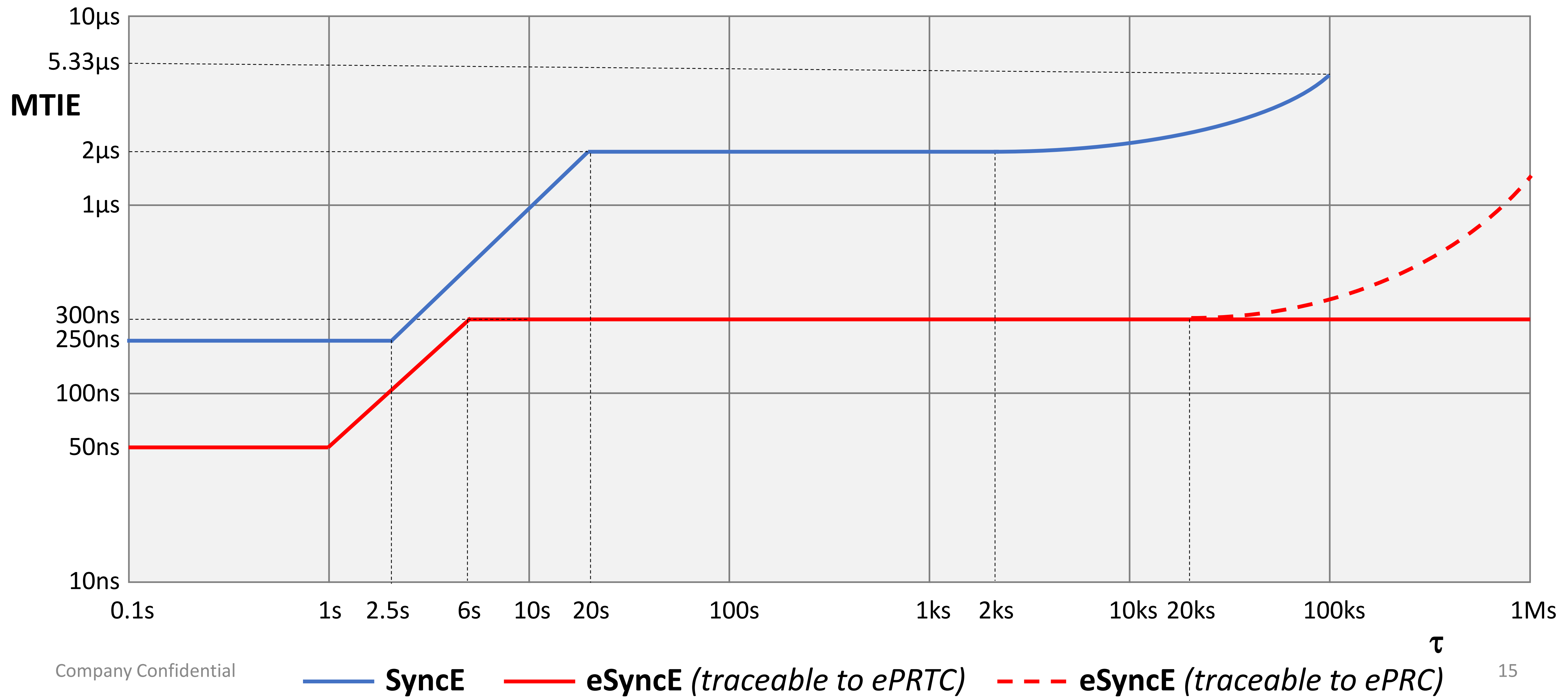
Key: Green – same as G.8262 EEC spec
Red – changes to G.8262 EEC spec

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 during 2020

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- **G.8261 Amd. 2** – *Network Limits for Frequency*
  - Network limit for short chains of enhanced clocks in fronthaul
- **G.8271.1 Amd. 2** – *Network Limits for FTS*
  - Network limits for ±130ns and relative TE
  - Frequency to meet 50ppb in an RU
- **G.8271.2 Revision** – *Network Limits for PTS*
  - Segmented networks for fronthaul
- **G.8262.1 Amd. 2** – *Enhanced SyncE Clocks*
  - Minor updates
- **G.8273.3 Amd. 2** – *Transparent Clocks*
  - Possible upgrade to Class C
- **G.8273.4 Amd. 1** – *APTS and PTS clocks*
  - Minor updates
- **G.8275 Amd. 2** – *Time Sync Architectures*
  - Further details on Coherent Network PRTC (cnPRTC)
  - Possibly also material on FlexE and OTN-based fronthaul architectures

Fronthaul Networks

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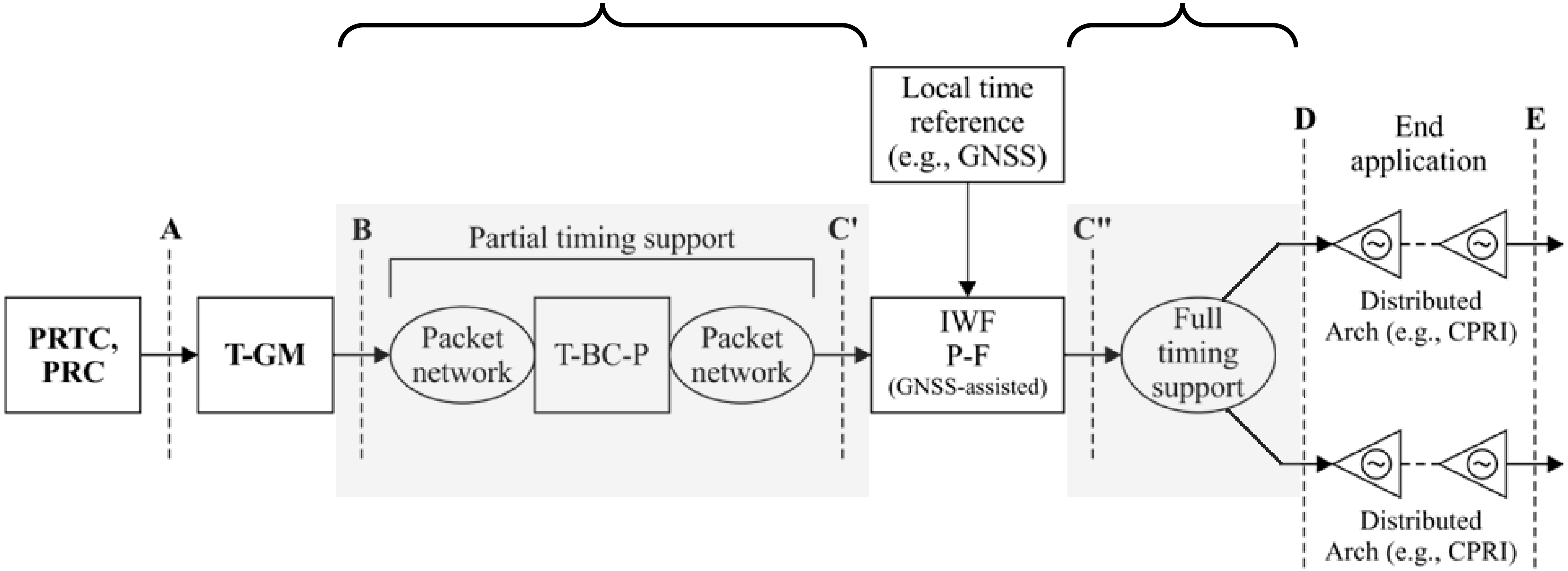
- Fronthaul networks have several ramifications
  - Tight relative TE requirements to meet TAE (Time Alignment Error) on the air interface
  - Low filtering capability of network elements such as RUs, leading to tighter frequency requirements on the network *(driven by requirements coming out of ORAN)*
  - Use of multiple segments (e.g. FTS in the fronthaul, but APTS or PTS to the "common point") *(also driven by requirements coming out of ORAN)*
  - New transport techniques (FlexE, FlexO, G.mtn)
- Affects various standards:
  - G.8271.1 for both relative TE and frequency error requirements
  - G.8271.2 for multiple segment architectures
  - G.8273.2 and G.8262.1 for enhanced clocks

Multiple Segment Architectures

- Example of multiple segment architecture:

First synchronization network segment
(Backhaul network: uses APTS method)

Second synchronization network segment
(Fronthaul network: uses FTS method)



Coherent Network PRTC

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- 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:
  - Expected completion by late 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
    - Status: consented February 2020
- Frequency sync defects and parameters to be documented in a revised version of G.781
    - Status: Published August 2017
    - Update consented February 2020
- Time sync defects and parameters to be documented in new recommendation G.781.1
    - Status: probable completion late 2020

Insight and Innovation

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