Standardization in ITU-T Study Group 15 and Q13/15

Networks, Technologies and Infrastructures for Transport, Access and Home:
Network synchronization and time distribution performance

Stefano Ruffini (Q13 Rapporteur)
Silvana Rodrigues (Q13 Associate Rapporteur)

WSTS 2025 (12-15 May 2025), Savannah (GA)

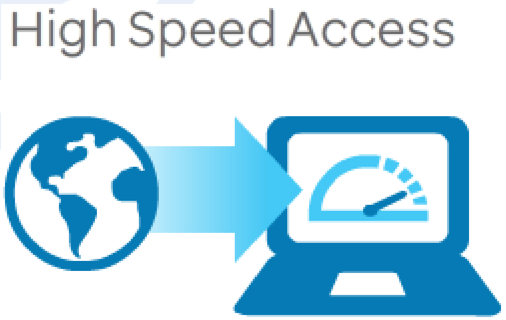
Study Group 15 (SG15) mandate

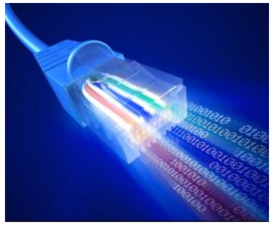
2025-2028 Study Period
SG15 is the Lead Study Group on :

- access network transport
- home networking
- optical technology

Home Networking

Smart Grid





Transport Technologies

✓ The **LARGEST** and **MOST PRODUCTIVE** group in ITU-T with broad, global industry participation

The Optical Transport Network

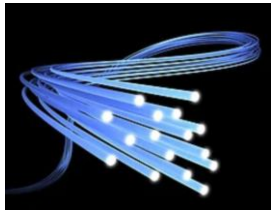
SG15 Working Parties (WPs)

- **WP1/15**: Transport aspects of access, home and smart grid networks
- **WP2/15**: Optical technologies and physical infrastructures
- **WP3/15**: Transport network characteristics

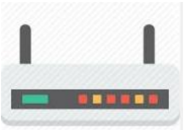
WP1 – Broadband Access

G.fastback — Multi-Gigabit copper backhaul

MGfast — Next generation copper access 5-10 Gbps



Optical systems for access networks
Bidirectional P2P
XGS-PON, HS-PON (50G)
TWDM-PON, TWLG-PON

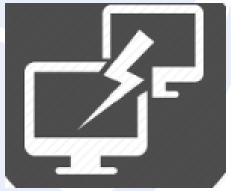


Continue collaboration with broadband forum

G.RoF — PON support for mobile front/backhaul, Radio over fiber

High speed fibre-based in-premises transceivers (G.fin) for Fiber to the Room (FTTR)

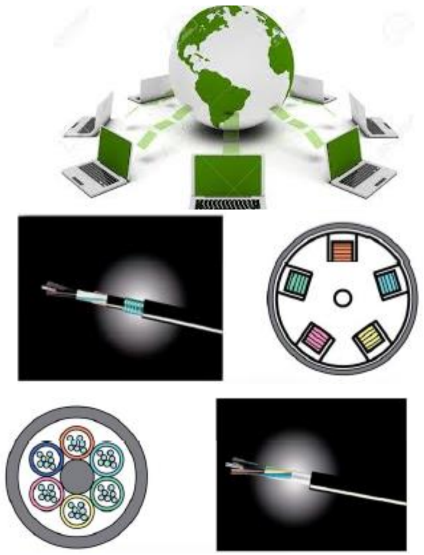
Free space optical home networking



Powerline communication (PLC)

G.Hn — G.hn and G.hn2 home networking over indoor phone, power, and coax wires >2 Gbps

WP2 – Optical Technologies



Optical Network Infrastructure

Optical Fibre Technologies and Cables for easy and environmentally friendly outside plants

L.pcc (Pre-connectorised cabling components)

100G and future higher-rate coherent multi-vendor interoperable interfaces

800G
B1T

Disaster Management issues

SMART submarine cables (G.SMART)

Space Division Multiplexing (SDM) for further high capacity

G.fso (Free Space Optics)

G.dfos (Distributed Fibre Optic Sensing)

Short-reach (OTN client) 200G and 400G interfaces reusing components developed for Ethernet applications

Note: G.SMART is now approved as G.9730.2

WP3 – Optical Transport Networks

Transport and synchronization supporting 5G mobile fronthaul and backhaul

G.83xx (metro transport network) for 5G optimized transport

Architecture and other Transport SDN Aspects

BEYOND
1 Tbit/s (B1T)

New "B1T" (Beyond 1 Tbit/s) OTN interfaces

Equipment & management specifications for OTN, Ethernet and MPLS-TP

Synchronization of packet Networks, MTN and future OTN networks, e.g., beyond 1 Tbit/s (B1T)

Network survivability (protection and restoration)

Management aspects of control and transport planes

Core Information model enhancement for management of synchronization and optical media

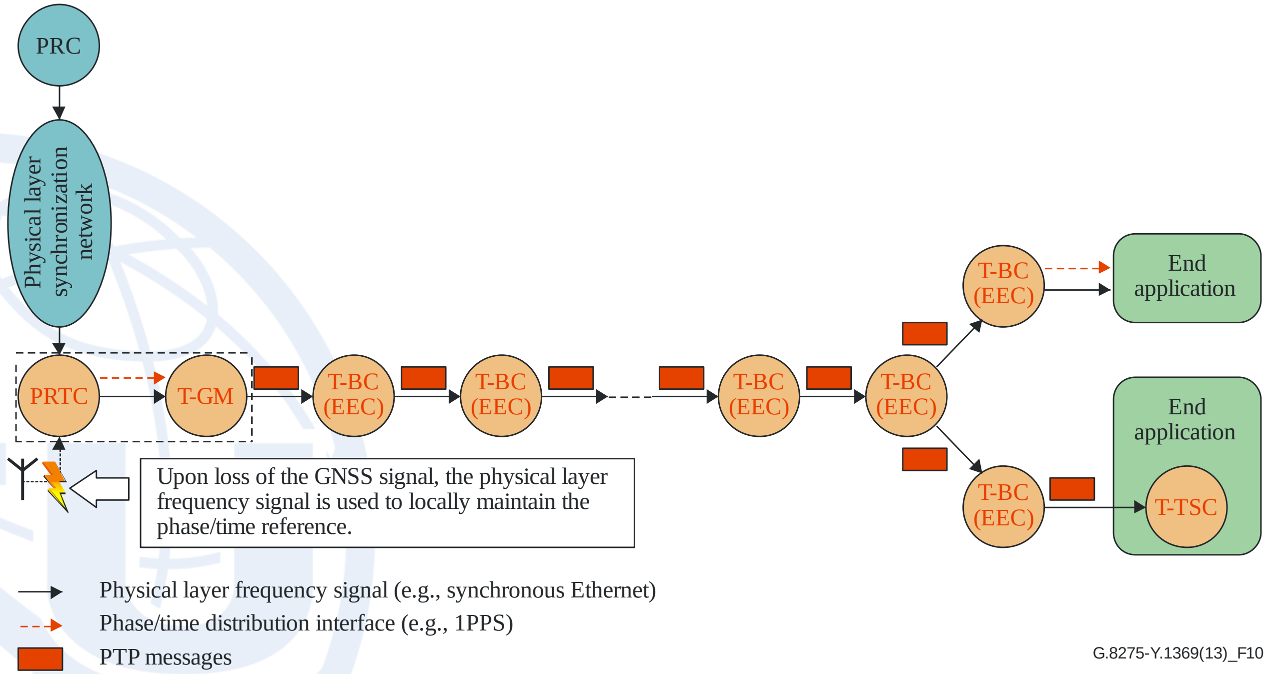
List of Questions (2025-28 Study Period)

Question Number	Question title
1/15	Coordination of Access and Home Network Transport Standards
2/15	Optical systems for fibre access networks (merging part of Q1/15)
3/15	Technologies for in-premises networking and related access applications (merging part of Q1/15)
4/15	Broadband access over metallic conductors
5/15	Characteristics and test methods of optical fibres and cables, and installation guidance
6/15	Characteristics of optical components, subsystems and systems for optical transport networks
7/15	Connectivity, Operation and Maintenance of optical physical infrastructures
8/15	Characteristics of optical fibre submarine cable systems
10/15	Interfaces, interworking, OAM, protection and equipment specifications for packet-based transport networks
11/15	Signal structures, interfaces, equipment functions, protection and interworking for optical transport networks
12/15	Transport network architectures
13/15	**Network synchronization and time distribution performance**
14/15	Management and control of transport systems and equipment

WP 3 (Questions 10/15 – 14/15)

Q13: Scope of the Question

- **Network synchronization and time distribution performance**
  - Active since the 90s (sync for SDH in SG18)
  - Networks Timing Needs (e.g., OTN, MTN)
  - 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 (IEEE 1588) profiles
  - Performance, Redundancy, Reliability, etc.
- Networks
  - Ethernet, IP-MPLS, OTN, xPON, MTN ...



Cooperating with other Questions in SG15

Q11: sync for/over OTN , MTN

Q14: Sync Management

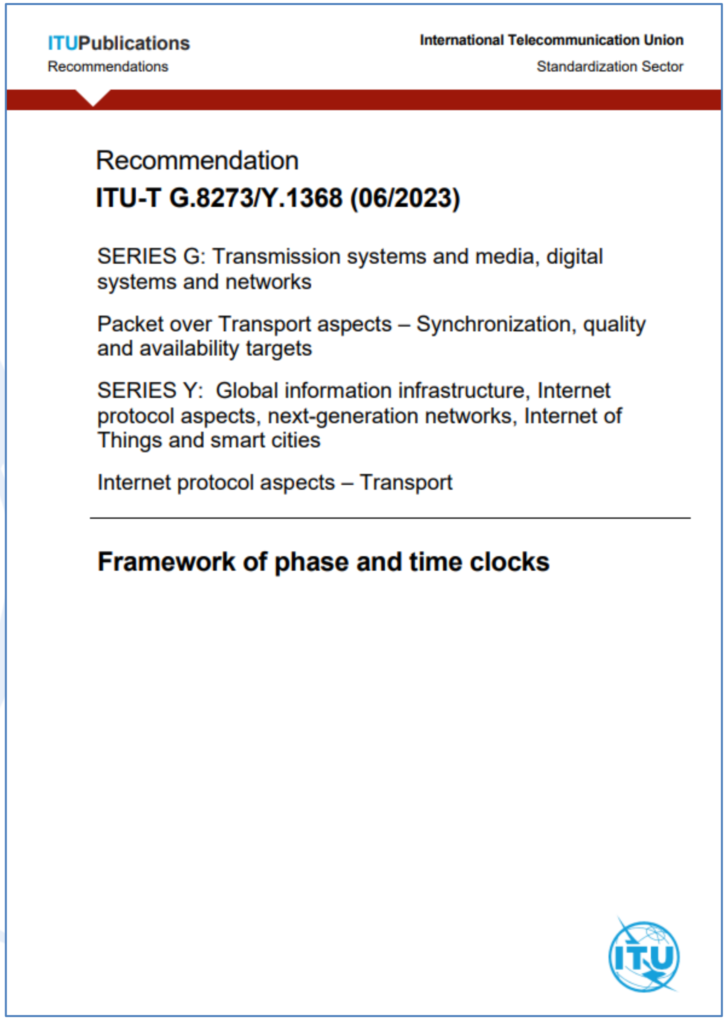
Q2, Q4: Sync in the access

Q6: sync over fibers

.. and SDOs (IEEE1588, 3GPP, O-RAN, etc.)

Outputs from Q13

- SDH and before packet timing:
  - G.803, G.810, G.811, G.812, G.813, G.823, G.824, G.825
- OTN: G.8251
- Enhanced Primary Reference Clocks: G.811.1
- Synchronization Layer Functions:
  - G.781, G.781.1
- Network requirements, Clocks, PTP Profiles
  - G.827x series (distribution of time synchronization)
  - G.826x series (distribution of frequency synchronization)
- Supplements :
  - G.Suppl65 (simulations on timing transport), G.Suppl68 (synchronization OAM requirements), G.Suppl83 (Full Timing Support Options)
  - New work item, G.Suppl.DCSync "Synchronization for Data Centres"
- Technical Report:
  - GSTR-GNSS (Use of GNSS in Telecom)
  - New work item, GSTR-OCN, "Optical clocks and their networking"


ITUPublications
Recommendations

International Telecommunication Union
Standardization Sector

Recommendation
ITU-T G.8273/Y.1368 (06/2023)

SERIES G: Transmission systems and media, digital systems and networks

Packet over Transport aspects – Synchronization, quality and availability targets

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet protocol aspects – Transport

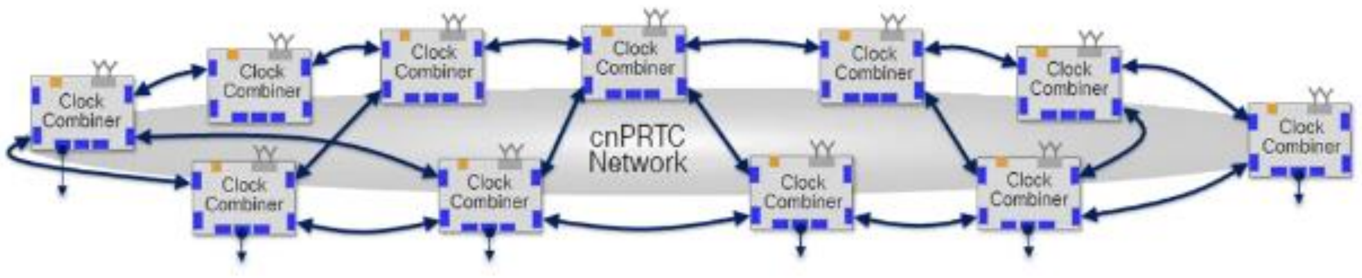
Framework of phase and time clocks

Recent challenge: The need for increasing resiliency

- Synchronization over the years has become a fundamental function for various critical infrastructures (e.g., telecoms, power grid, transportation, financial services). The consequences of disruption of timing can be very serious.
- GNSS is one main technique used to deliver time sync, but its vulnerability raised increasing concerns. Common causes of GNSS disruptions:
  - GNSS segment errors, Adjacent-band transmitters, GNSS spoofing, Environmental interference, GNSS jamming
- Other threats exist in timing (e.g., at packet layer).
- These topics have been debated over several years at the major sync events and groups have started to address related solutions to increase resiliency to the timing solutions in the standards (e.g., IEEE P1952)
- The need for redundancy and robustness in sync in telecom has always been a major requirement. Now even more.
  - Q13/15 continues to add resiliency to the sync solutions being defined

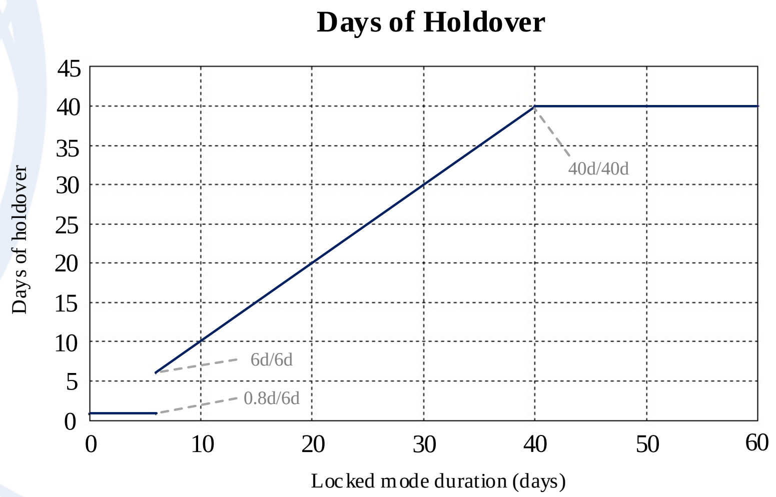
How to increase resilience in Sync?

- Architecture: Redundant PRTC / Grandmaster and Redundant paths
- Geographical distribution of GNSS Receivers, use of multiple constellations (GPS, Galileo, etc.)
- Increased Holdover: via physical layer support (SyncE), or enhanced PRTCs (ePRTC, cnPRTC)
- Increased monitoring solutions
- Protection at timing protocol



cnPRTC (Coherent PRTC):

PRTCs network at the highest core or regional network level to maintain network-wide ePRTC time accuracy, even during periods of GNSS loss



Enhanced PRTC specified in G.8272.1

[ITU News: New ITU clock concept for more resilient synchronization networks - ITU]

Mapping with Resiliency Levels

- "WD13-Resilience" to define Resilience Levels Appendix for G.8275
- The table maps clock variants to IEEE P1952 resilience levels.
  - It mainly addresses adversities related to GNSS interference (including jamming) and GNSS unavailability.

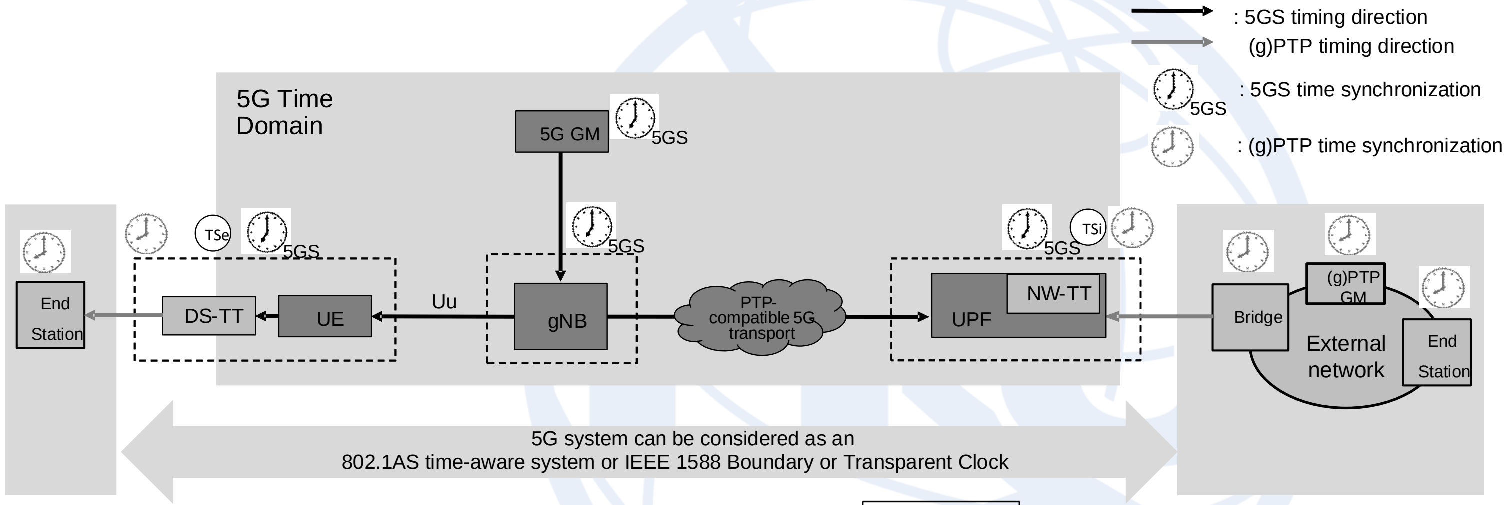
Information based on P1952 draft				View on ITU-T specified Primary clock options									
IEEE P1952 Resilience Level related information				~~threat~~ Adversity duration time	PRTC			ePRTC-A			cnPRTC		Comments
					PRTC	PRTC with SyncE	PRTC with UTC(k)	ePRTC	ePRTC with SyncE	ePRTC with UTC(k)	cnPRTC	cnPRTC with UTC(k)	
					1	2	3	4	5	6	7	8	
1	Detect	The ability to detect an adversity that might impact performance and generate an alert.	With the available on-board resources of the specific primary clock variants, resilience level 1 should be met without restrictions.		x	x	x	x	x	x	x	x	Internal supervison of sources (e. g. GNSS, PRC frequency, etc.)
	Alert												all ITU-T clock-internal measurement functions, raising events and alarms via TMN
2	Recover	The ability to automatically recover and operate normally after an adversity.	Resilience level 2 should be met without restrictions.		x	x	x	x	x	x	x	x	all ITU-T clocks do recover after the thread is over
3	Resist	The ability to operate during an adversity, perhaps with reduced performance, but still within specifications, for a specified length of time.	It is proposed to consider the maximal lenght of time for fulfillment of resilience level 3.	<= 1 day	x	x	x	x	x	x	x	x	Holdover based on own oscillator
				1 - 40 days (ePRC-A based)	-	based on remote ePRC via SyncE	based on external UTC(k)	x	based on remote ePRC via SyncE	based on external UTC(k)	x	based on external UTC(k)	As UTC(k) is out of the ITU-T clock domain, an agreement with UTC(k) provider is needed
				up to 1 year 1)	-			-			x		
4	With-stand	Withstand: The ability to operate during an adversity, perhaps with reduced performance, but still within specifications, ~~indefinitely~~ w/o a finite time interval	A ~~indefinitely~~ withstand w/o a finite time interval can be guarantied with usage of external UTC(k) only.		-	-	x	-	-	x	x 2)	x	
5	Verify	The ability to determine that information from a PNT source is accurate.			-	-	-	-	-	-	-	x	

1) This value is for information only, it depends on the number of involved ePRC clocks

2) Adversity is regional GNSS unavailability, minimum one cnPRTC clock combiner location with active GNSS

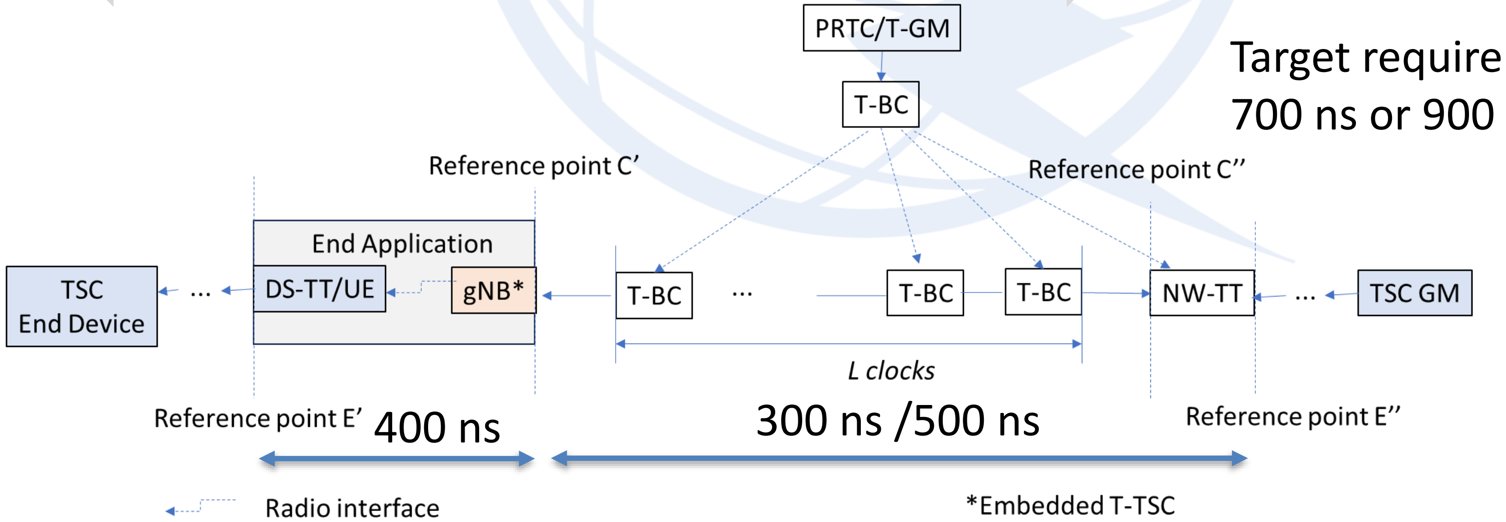
Recent Results: Timing delivery over 5GS

- Impact from integration of 5GS (5G System) with Industrial Automation application ("TSN")
- New HRM and budgeting examples in G.8271.1 agreed at the July 2024 SG15 Plenary



From 3GPP TS 23.501

Target requirements for the 5G segment: 700 ns or 900 ns



Recent Results: Timing Resiliency in 5G (G.8271/.1)

Table 1 – Time and phase requirement classes, from G.8271

Class level of accuracy	Time error requirements (Note 1)	Typical applications (for information)
1	500 ms	Billing, alarms.
2	100 – 500 µs	IP delay monitoring. Synchronization signal block (SSB)-measurement timing configuration (SMTC) window.
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). New radio (NR) intra-band non-contiguous and inter-band carrier aggregation, with or without multiple input multiple output (MIMO) or transmit (TX) diversity.
5	**1 µs**	WiMAX-TDD (some configurations). **Timing services over 5GS (Note 5)**
6	x ns (Note 4)	Various applications, including location based services and some coordination features. (Note 3)

NOTE 1 – The requirement is expressed in terms of time error with respect to a common reference. Some of the original requirements were expressed in terms of relative time error.

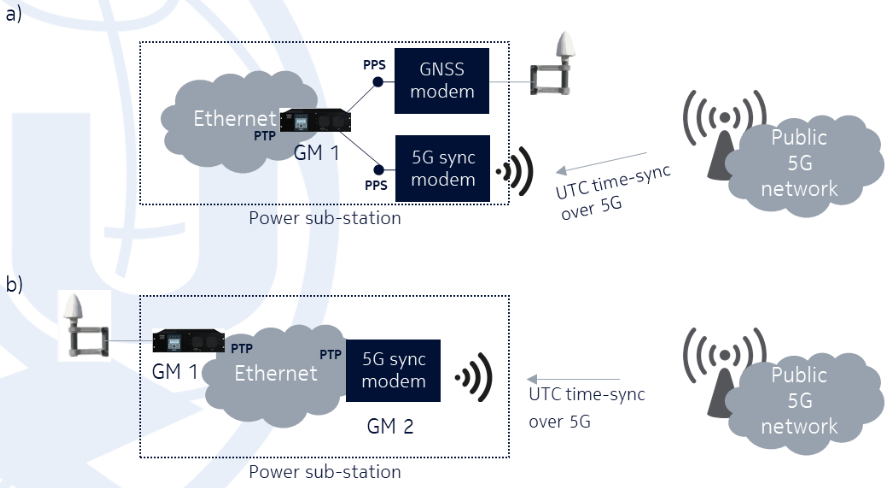
NOTE 2 – FR1: 410 MHz – 7.125 GHz; FR2: 24.25 – 52.6 GHz

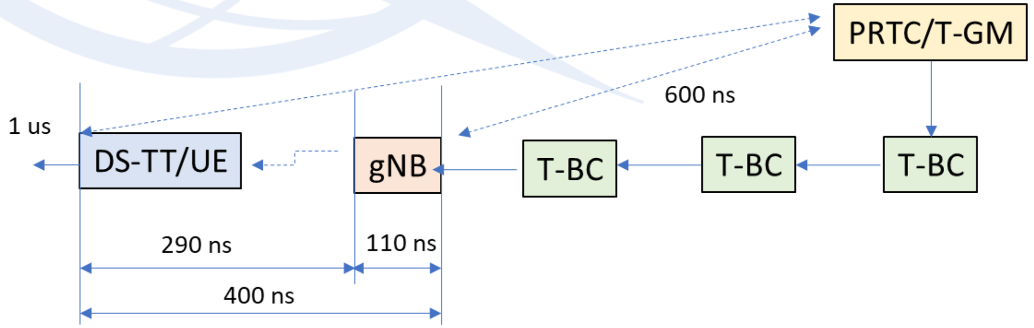
NOTE 3 – The performance requirements of some of these features are under study. For information purposes only, values between 500 ns and 1.5 µs have been mentioned for some features. Depending on the final specifications developed by 3GPP, these applications may be handled in a different level of accuracy.

NOTE 4 – For the value x, refer to Table 2 and Table II.2 of Appendix II.

NOTE 5 – Example of timing services are provided in Table 5.6.2-1 of 3GPP TS 22.104 (e.g., Smartgrid)

- 3GPP solution for timing carried over 5GS ("5G Timing Resiliency")
  - Examples added in G.8271.1 Appendix V based on new network limits (max|TE|< 600 ns)

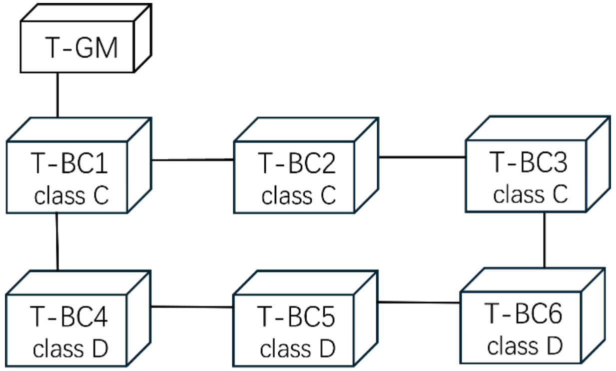




Recent Results: G Suppl-83, Enhanced Accuracy Metrics TLV

- TLV to collect estimate of the accumulated TE; It provides a common format that can be used to propagate information on the characteristics of the network.

Bits								Octets	TLV offset
7	6	5	4	3	2	1	0		
tlvType[1]								2	0
lengthField[2]								2	2
bcHopCount[3]								1	4
tcHopCount[4]								1	5
exclusionFlags (Boolean[0]–Boolean[7])[5]								1	6
EVSII	EMSII	EVDI	EMDI	EVTI	EMTI	EVGI	EMGI		
exclusionFlags (Boolean[8]–Boolean[16])[6]								1	7
Reserved						EVSMI	EMSMI		
maxGmInaccuracy[7]								8	8
varGmInaccuracy[7]								8	16
varDynamicInaccuracy[8]								8	24
maxStaticInstanceInaccuracy[8]								8	32
maxStaticMediumInaccuracy[8]								8	40
varStaticMediumInaccuracy[8]								8	48



Path Time Error Accumulation

maxGmInaccuracy	$\max\lvert TE\rvert_{T-GM}$	cTE
varGmInaccuracy	0	dTE
maxStaticInstanceInaccuracy	$\sum_{i=1}^{N} cTE_{T-BC/T-TC_i}$	
varDynamicInaccuracy	$\sum_{i=1}^{N} dTE_{T-BC/T-TC_i}^{2}$ NOTE 1.	
maxStaticMediumInaccuracy	0 if unknown, else $\sum_{i=1}^{N+1} cTE_{medium/link_i}$ NOTE 2.	
varStaticMediumInaccuracy	0 if unknown, else $\sum_{i=1}^{N+1} dTE_{medium/link_i}^{2}$ NOTE 1, 2.	

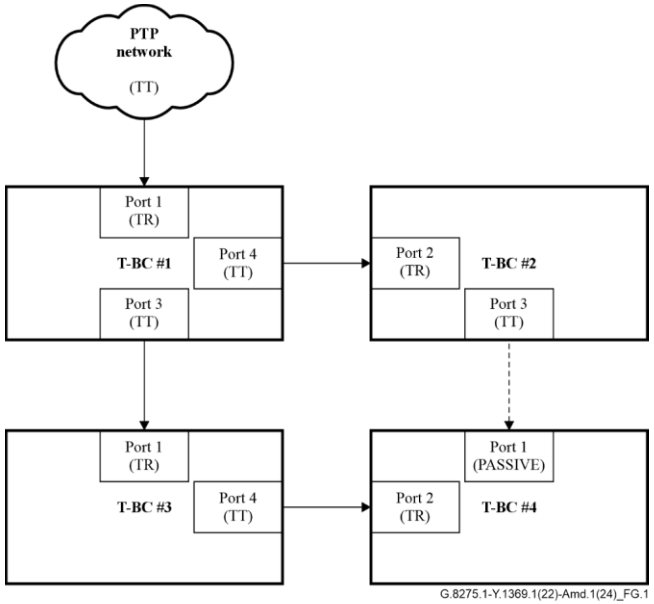
NOTE 1: dTE_i^2 value is for further study.

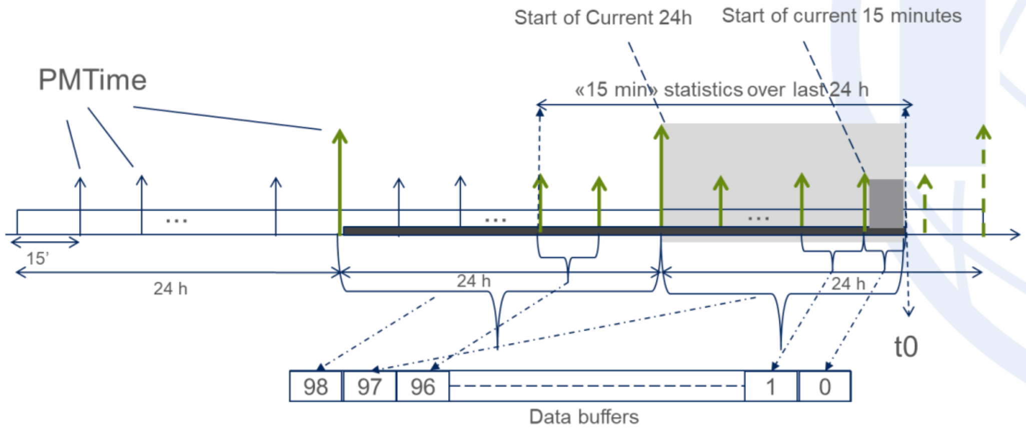
NOTE 2: Number of media/links between T-GM and PTP Instance updating metrics is N+1, where N is number of T-BC/T-TC in between.

- Next Steps:
  a new ABTCA may be defined based on positive results from simulations with modified ABTCAs making use of information from the Enhanced Accuracy Metrics TLV.

Recent Results: PTP Performance Monitoring Option in G.8275 Annex F

- Network and clock monitoring:
  - Support for IEEE 1588 standard Perf. Monitoring methodology (G.8275 Annex F) based on IEEE 1588 Annex J
  - When available measurements collected vs. a local GNSS receiver
  - Options recently added to address various use cases





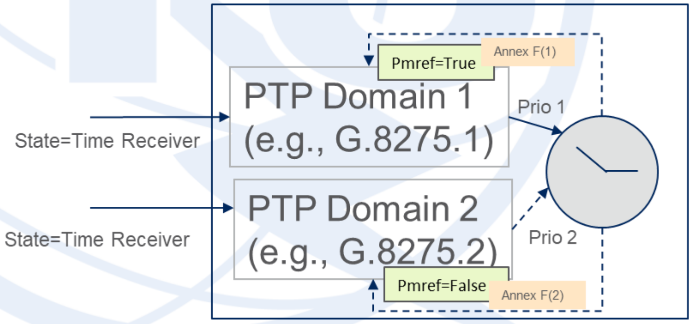
PMTime: start of the 15minutes / 24h periods

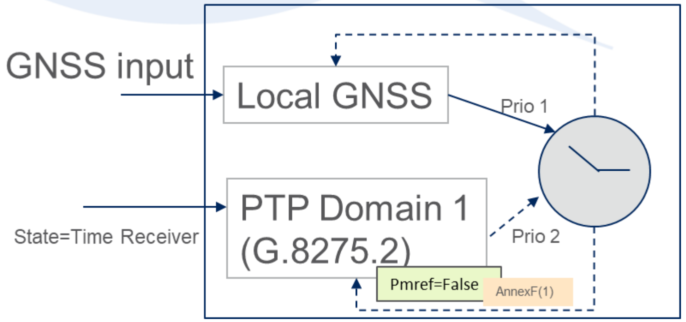
Data used for the statistics stored in the buffer

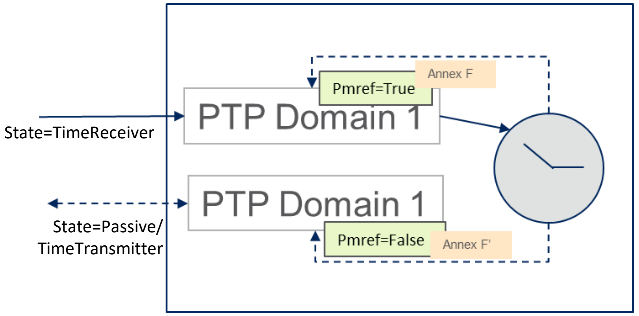
Data used for the current 24h value

Data used for the current 15 minutes value

t0 Indication of current time when accessing the PM data

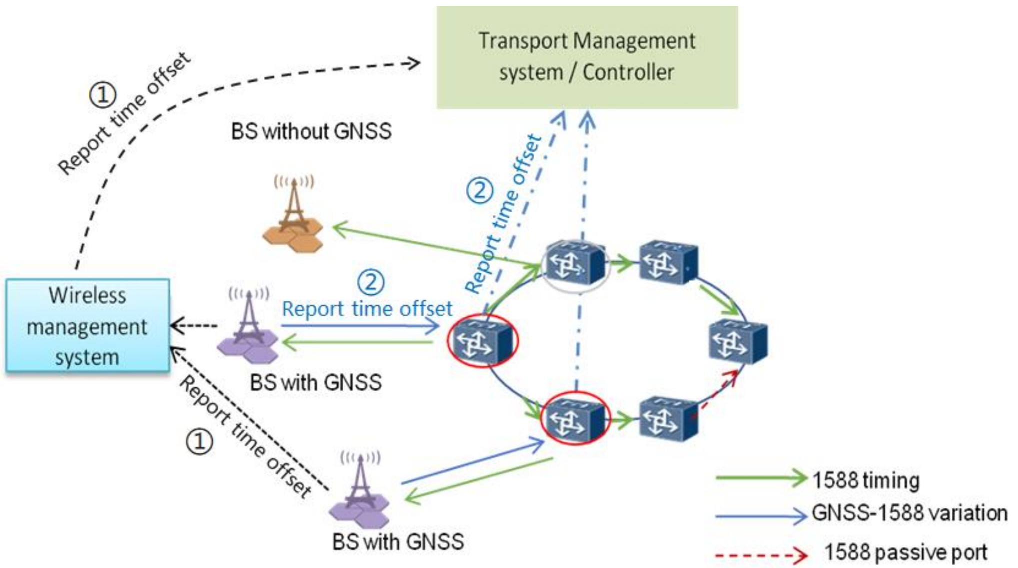




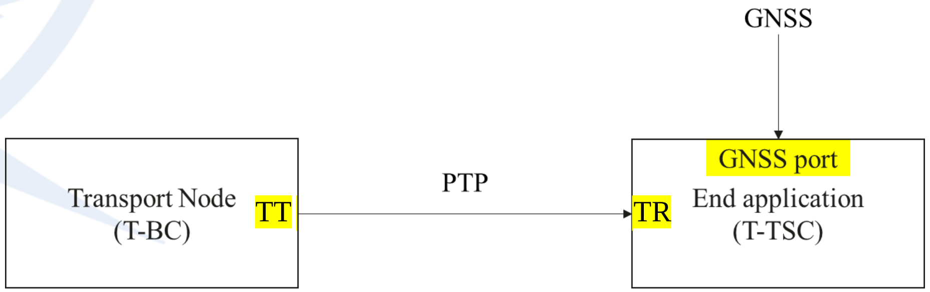


Recent Results: TLV carrying GNSS-PTP time error (G.8275.1 Annex L)

- TLV can carry GNSS-PTP time error for use in the Transport Management System



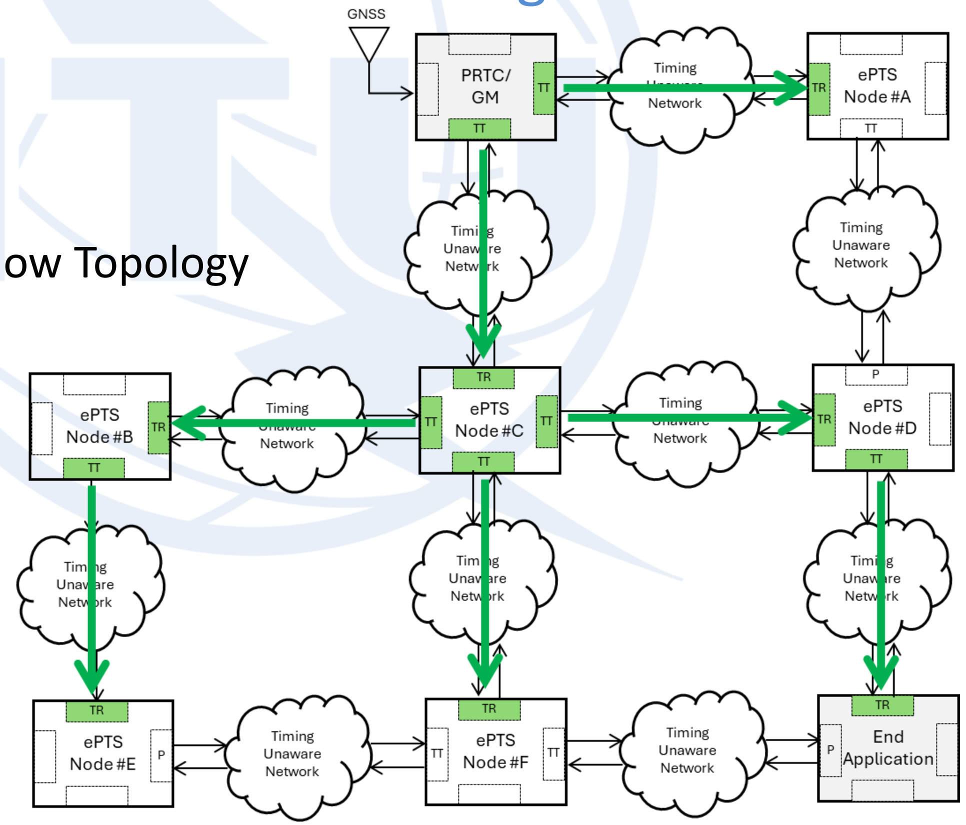
TLV fields		Octets
tlvType		2
lengthField		2
organizationId		3
organizationSubType		3
dataField	clockMode	1
	flags	1
	ptpGrandmasterID	8
	offsetFromPtpToLTR	8
	messageInterval	2
	Reserved	24



Ongoing Studies: PTP Profiles evolution

- PTP Security:
  - Analysis on various options (e.g., IEEE1588 Security TLV vs. MACsec)
- Enhanced Partial Timing Support ("ePTS")
  - Increased message rate (>128 packets per seconds)
  - Automatic asymmetry compensation via network management or local adjustments

Example of ePTS Timing Flow Topology



From WD13-30R6 (Montreal July 2024)

Other connected applications: Data Centres

- Timing has become an important aspect for data centres (e.g., to control power consumption)
- Responding to request from Data centres operators (e.g., OCP Global Summit October 2023), a new work item on the extension of ITU-T defined sync frameworks and profiles for synchronization in data centres
  - G.Suppl.DCSync (Synchronization for Data Centres)
- Focus on sync technologies and methodologies that Q13 has developed in cooperation with IEEE 1588 and other relevant SDOs, over the last 3 decades, to support data centres applications.
- Work done in cooperation with the main groups addressing related items, e.g., IEEE P3335, IEEE P1588, IEEE IC timing in data centres

Summary

- Synchronization continues to be a fundamental function as networks and applications evolve
- Q13/15 expertise and technologies can play a key role to address network evolution and new challenges :
  - Increased resiliency (security, sync monitoring, holdover, etc.)
  - Emerging needs in mobile networks (e.g., 5G evolution towards 6G)
  - Support connected applications (Industrial Automation, Datacenters, etc.)
  - New applications with particularly stringent timing requirements (e.g., quantum key distribution (QKD))
  - Investigate new technologies (e.g., new work item on optical clocks)

SG15 - Networks, technologies and infrastructures for transport, access and home (itu.int)
List of Questions and Rapporteurs (itu.int)

SG15 Meetings

- Past meetings in the 2022-2024 Study Period
  - Geneva, September 2022
  - Geneva, April 2023
  - Geneva, November 2023
  - Montreal, July 2024
- Future Meetings in the 2025-2028 Study Period
  - Geneva, March 2025
  - Dates/locations for 5 further meeting are to be confirmed
- Between Study Groups Meetings
  - Interim Meetings, Virtual Meetings, Correspondence activities, arranged by the Questions (Q13 usually meets face-to-face 4 times per year including the SG15 Plenary)

Getting involved in Q13

- Q13 meets periodically , generally face-to-face (3-4 times per year), with eMeetings as needed
- Meetings in 2025:
  - SG15 Plenary (Geneva, 17 - 28 March 2025)
  - Interim meeting at the European Commission – Joint Research Centre (Ispra - Italy, 9-13 June 2025)
  - SG15 Plenary (Geneva, October 2025, date to be confirmed)
- Where to find additional information (URL links):
  - SG15 Home Page: SG15 - Networks, technologies and infrastructures for transport, access and home (itu.int)
  - Q13/15 Terms of Reference: Text of the Question (itu.int)
  - How to become a member: Become a member- ITU/ UN Tech agency
  - Contacts:
    - Hiroshi Ota (hiroshi.ota@itu.int) SG15 Advisor
    - Stefano Ruffini (Stefano.Ruffini@calnexsol.com) Q13 Rapporteur
    - Silvana Rodrigues (silvana.rodrigues@huawei.com) Q13 Associate Rapporteur