Q13/15, Evolution of Synchronization Technologies

Synchronization solutions to address new needs in terms of resiliency, and interworking with new applications (e.g., TSN)

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The need for increasing resiliency

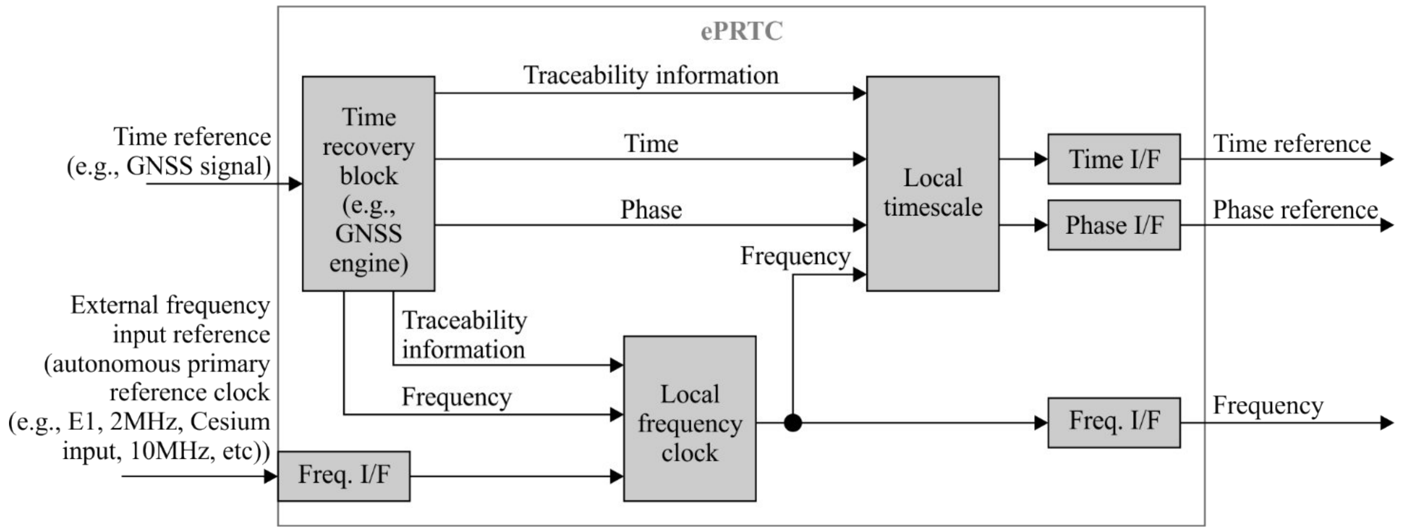
- Synchronization has become a fundamental function for various critical infrastructures (e.g., telecoms, power grid, transportation, financial services). The consequences of disruption of timing can be very serious.
- GNSS is one main technique used to deliver time sync, but its vulnerability raised 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 (e.g. ITSF, WSTS) and groups have started to address related solutions to increase resiliency to the timing solutions
  - E.g., IEEE P1952 defining technical requirements and expected behaviors for resilient "PNT UE"
- 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 Primary Reference Time Clocks 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

Recent updates: ePRTC enhancements

- Enhanced PRTC is specified in G.8272.1. It can be implemented as a combination of a local atomic clock and a GNSS receiver
- Target accuracy is 30 ns; Holdover characteristics recently improved
  - 100 ns over 40 days Holdover
  - Parametric specification (holdover time vs. learning period)
- ITU News: New ITU clock concept for more resilient synchronization networks - ITU



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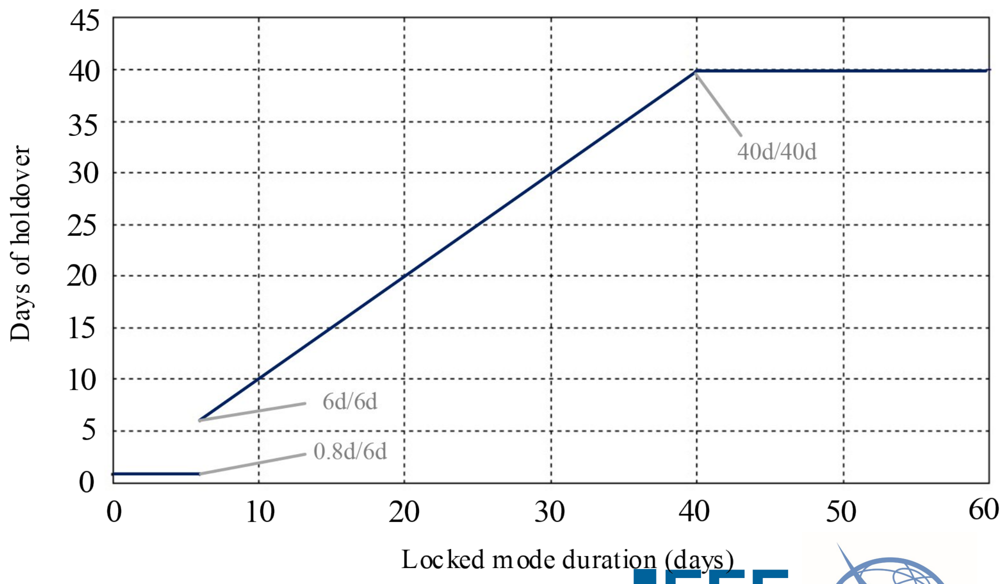
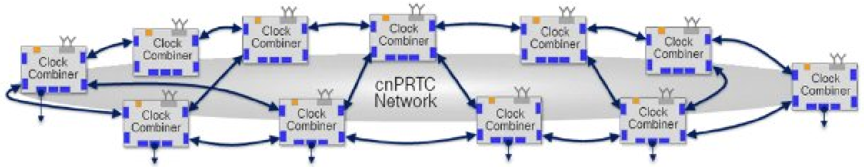
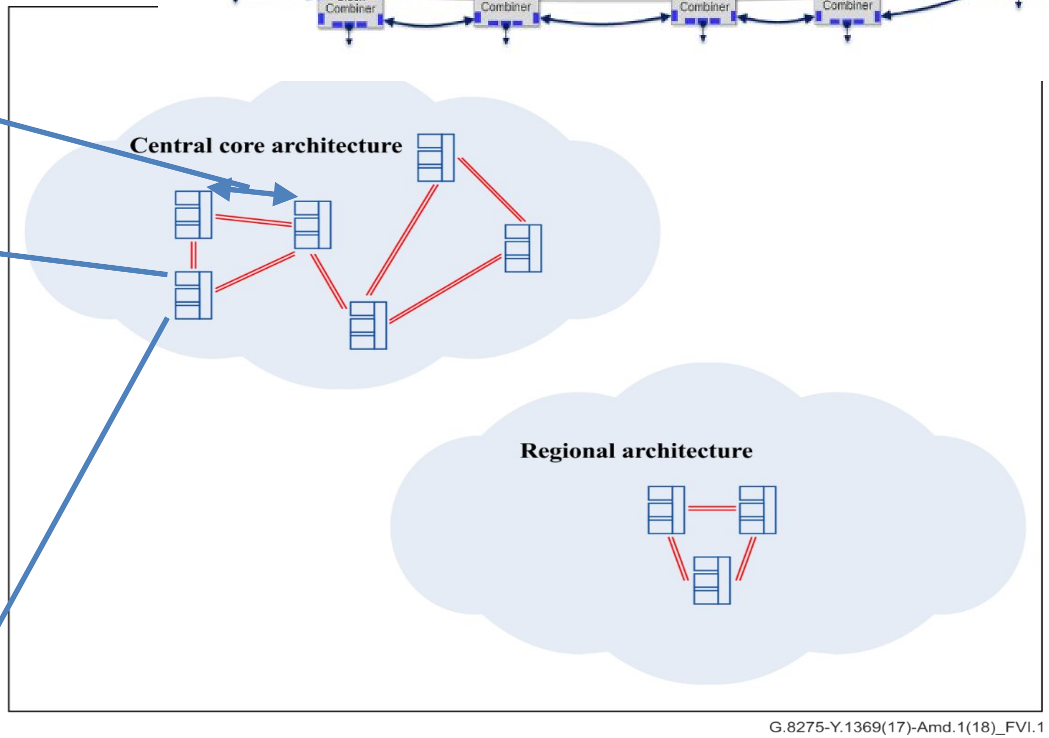


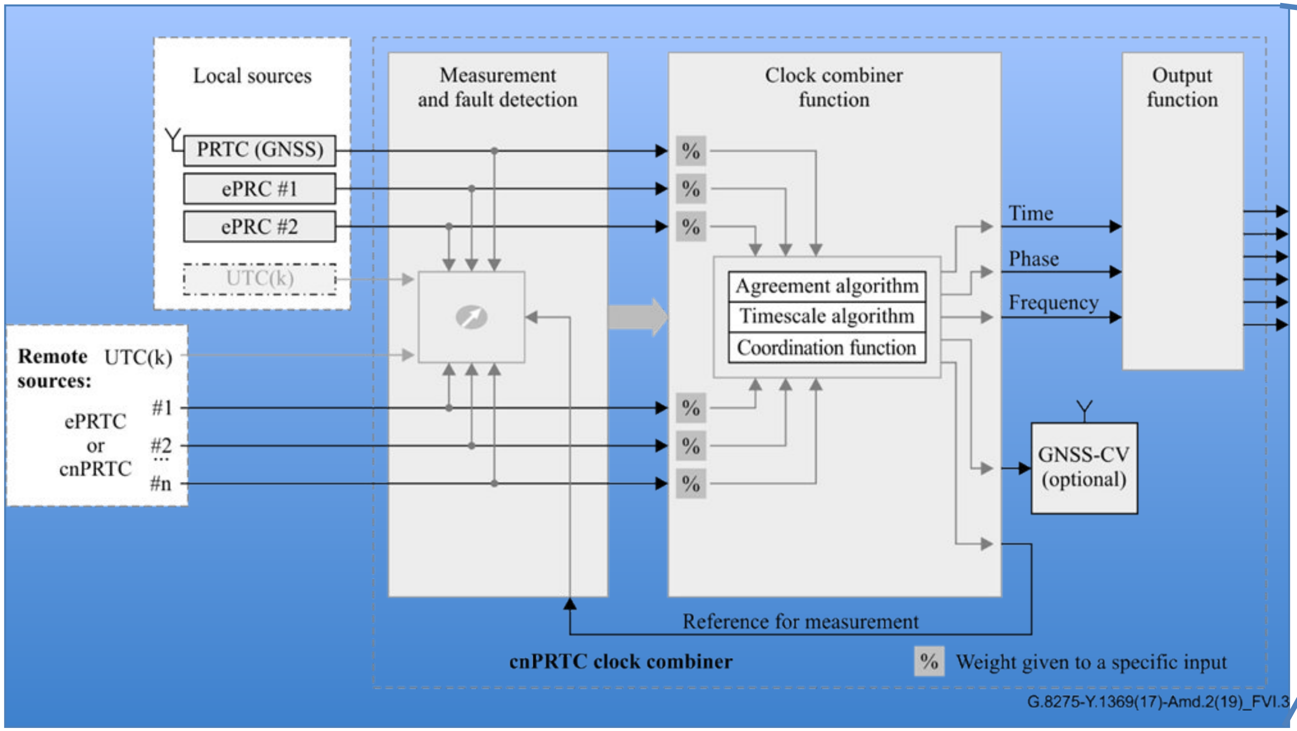
Recent updates: cnPRTC

- 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
- Clock Recommendation (G.8272.2)
- Network Requirements
- Methods (high accuracy profile?)



High-accuracy time transfer class	Maximum absolute time error – max|TE_L| (ns)
A	5 ns
B	1 ns





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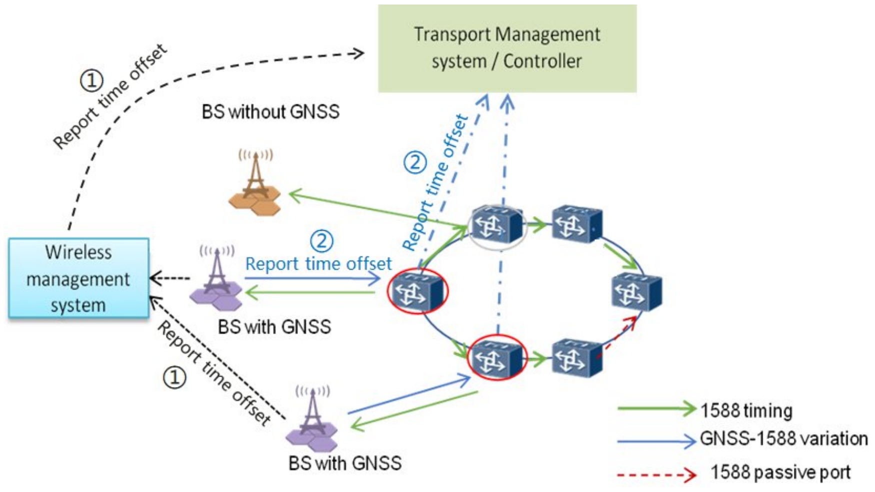
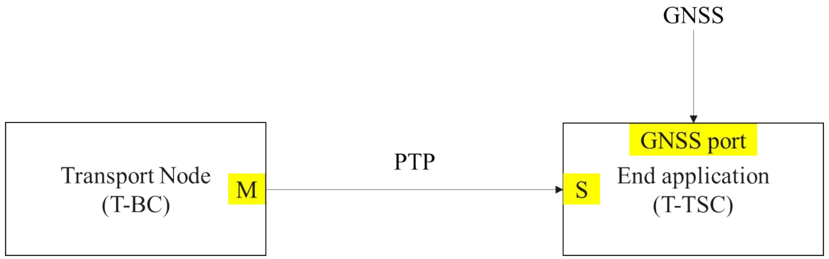
Mapping with Resiliency Levels (G.8275)

IEEE P1952 Resilience Level			Proposal	threat duration time	PRTC			ePRTC			cnPRTC	
					PRTC	PRTC with SyncE	PRTC with APTS	ePRTC	ePRTC with SyncE	ePRTC with UTC(k)	cnPRTC	cnPRTC with UTC(k)
1	Detect Alert	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
2	Recover	The ability to automatically recover and operate normally after an adversity.	With the available on-board resources of the specific primary clock variants, resilience level 2 should be met without restrictions.		x	x	x	x	x	x	x	x
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 maximul lenght of time for fulfillment of resilience level 3.	<< 1 day	x	x	x	x	x	x	x	x
				1 - 40 days	-	based on SyncE	based on PTS	x	x	x	x	x
				> 40 days	-			-	based on PRC via SyncE	x	(x)	x
4	With-stand	Withstand: The ability to operate during an adversity, perhaps with reduced performance, but still within specifications, **indefinitely**.	A indefinitely withstand can be guarantied with usage of external UTC(k) only.		-	-	-	-	-	-	-	x
5	Verify	The ability to determine that information from a PNT source is accurate.	A indefinitely withstand can be guarantied with usage of external UTC(k) only.		-	-	-	-	-	-	-	x

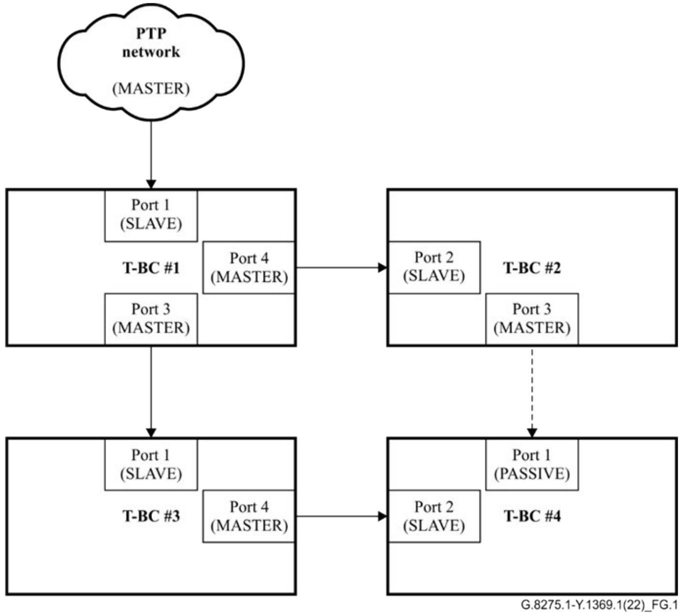
Recent updates: PTP Profiles enhancements

- New TLV to carry GNSS-PTP time error
- Use of the «Enhanced Accuracy metrics TLV» for estimating accumulated Time Error, with potential definition of a modified Alternate BMCA
- PTP Security:
  - ongoing discussions (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
- PTP Performance Monitoring Option

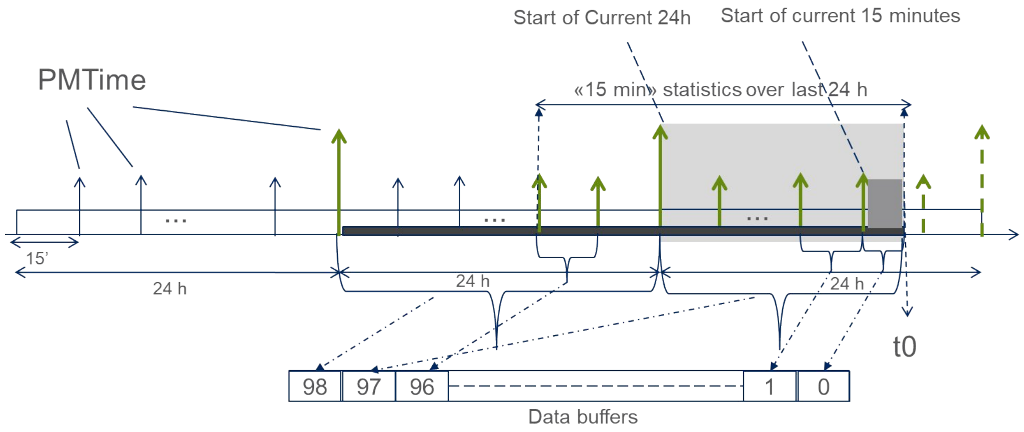




PTP Performance Monitoring Option in G.8275 Annex F



- 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



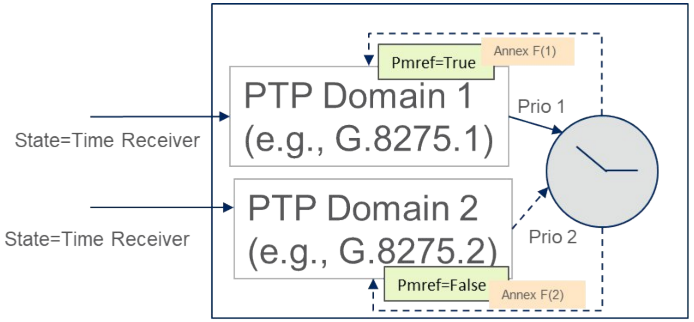
PMTime: start of the 15minutes / 24h periods

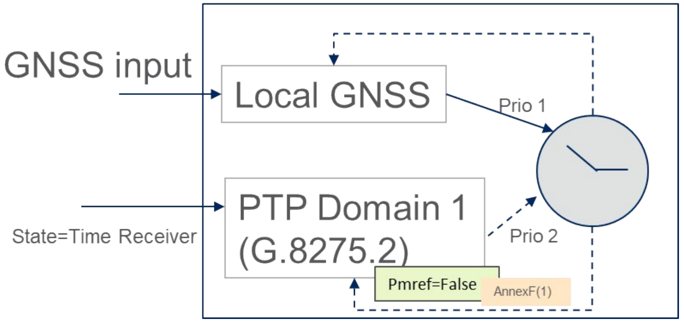
Data used for the statistics stored in the buffer

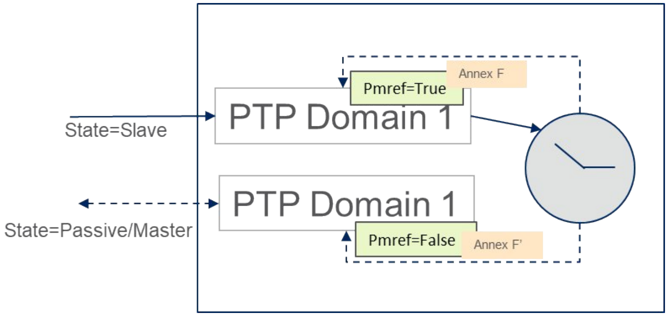
Data used for the current 24h value

Data used for the current 15 minutes value

t0 Indication of current time when accessing the PM data

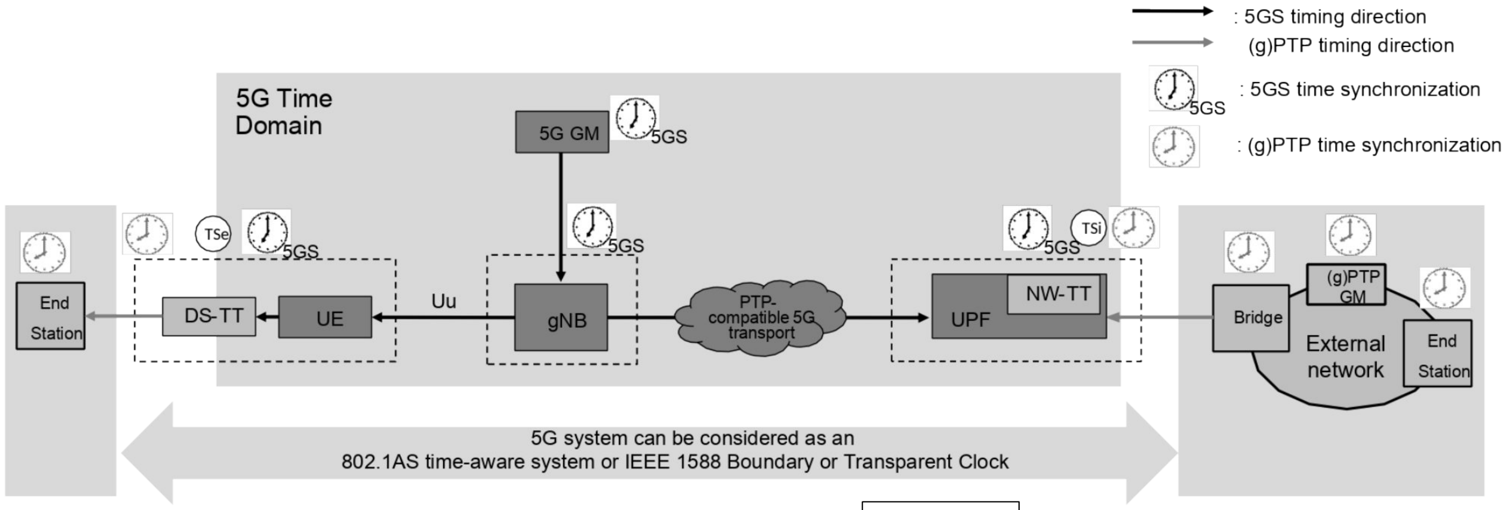




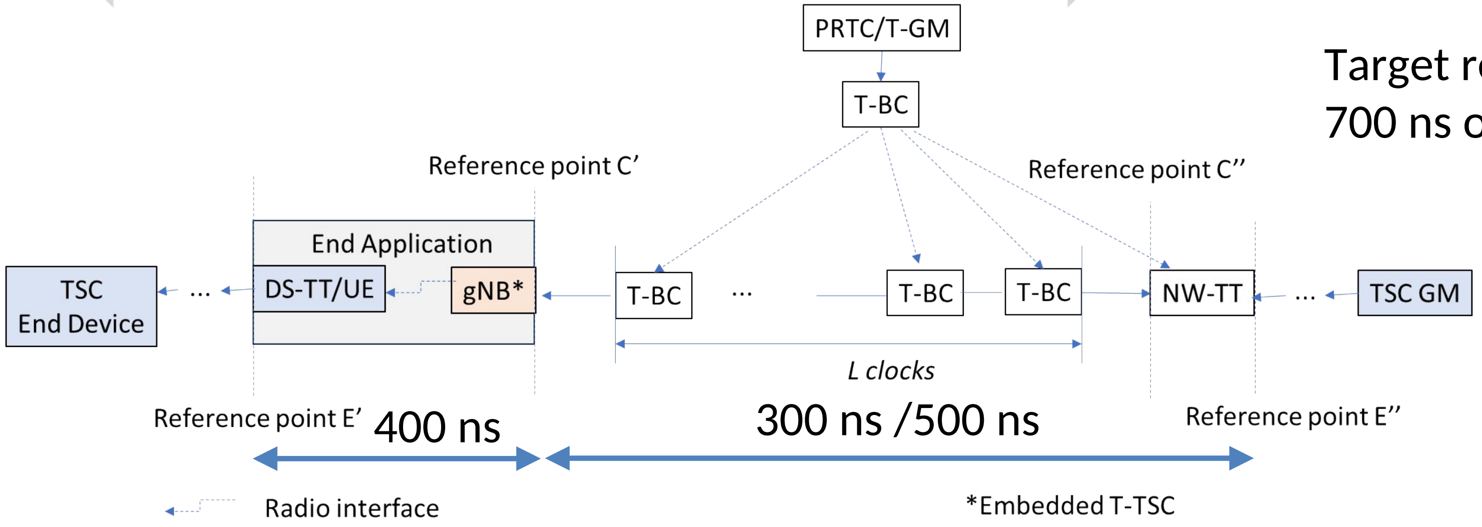


TSN Interworking: Timing delivery over 5GS

- 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

Timing Resiliency in 5G

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.

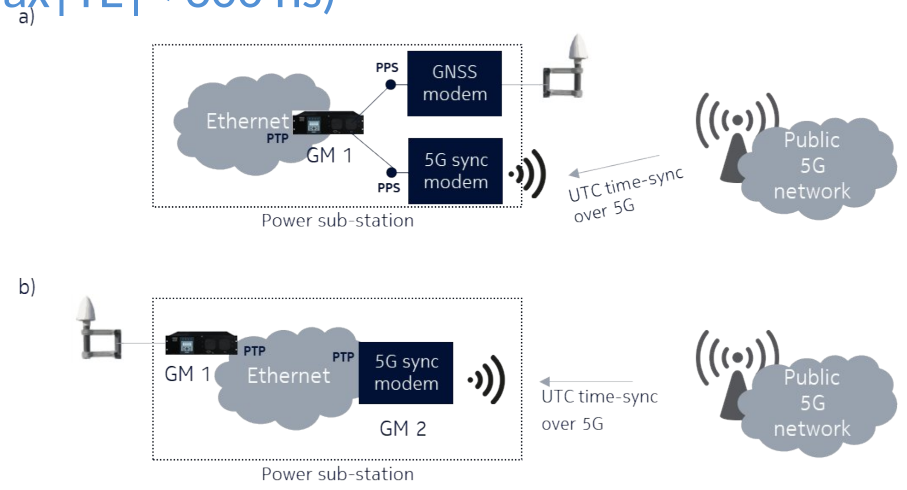
NOTE 2 – FR1: 410 MHz – 7.125 GHz; FR2: 24.25 – 52.6 GHz

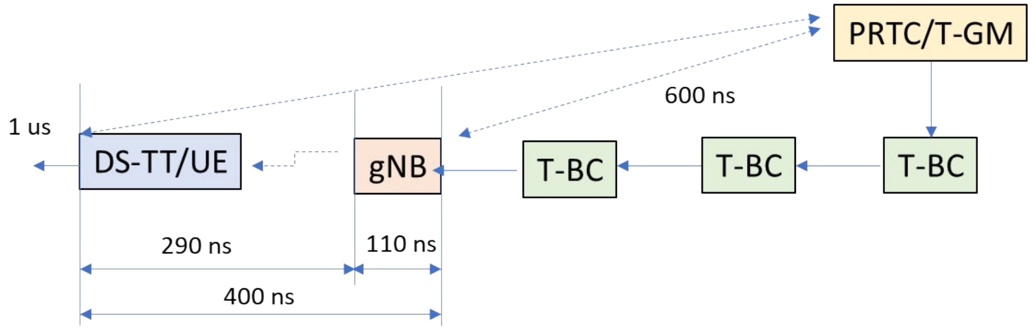
NOTE 3 – The performance requirements of some of these features are under study. For information purposes only, values between 500 ns and 1.5 µs have been mentioned for some features. Depending on the final specifications developed by 3GPP, these applications may be handled in a different level of accuracy.

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”)
  - Liaisons with 3GPP to study the impact on time sync architecture
  - Examples added in G.8271.1 Appendix V based on new network limits (max|TE|< 600 ns)





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 has been created at this SG15 Plenary
- 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.
- Plan to work in cooperation with all groups addressing related items, e.g., OCP/TAP, IEEE P3335, IEEE P1588, IEEE IC timing in data centres, etc.

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))

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