Stefano Ruffini, ITU-T Q13/15 Rapporteur I Strategic Technology Manager, Calnex Solution

Stefano Ruffini (stefano.ruffini@calnexsol.com) graduated in telecommunication engineering from the University of Rome La Sapienza. After a long experience at Ericsson, he is currently working as Strategic Technology Manager at Calnex Solution. Stefano is currently contributing to ITU-T SG15 Q13 (serving as Rapporteur), IEEE1588, and other relevant synchronization standardization bodies and forums.

He has published several international journal papers and delivered talks at various conferences. He is member of the Steering Group of the International Timing and Sync Forum and a member of the Steering Committee of the Workshop on Synchronization in Telecommunication Systems.

Silvana Rodrigues, ITU-T Q13/15 Associate Rapporteur, Senior Principal Engineer, Huawei

Silvana holds an Electronic and Electrical Engineering degree from University of Campinas, Brazil. She has been working on network synchronization and actively contributing to synchronization standards development for more than 15 years. She has been the secretary of IEEE 1588 Precision Time Protocol (PTP) Working Group since the beginning of the work of IEEE 1588 version 2. She is the editor of IEEE 801.1ASds And IEEE 802.1AS-2020-Rev and participates and contributes to several IEEE 802.1 TSN working groups.

She is currently the Associate Rapporteur and editor of several recommendations at ITU-T SG15 Q13 (the synchronization experts group).

ITU Workshop on “Evolution of Optical Networks for IMT2030 and Beyond”

Charles K. Kao Auditorium, Hong Kong Science and Technology Park (HKSTP)

20 November 2024, 15:00 - 18:00

Synchronization and Generation Definition (Resiliency, computing and IOT2030): Q13, role and future plans

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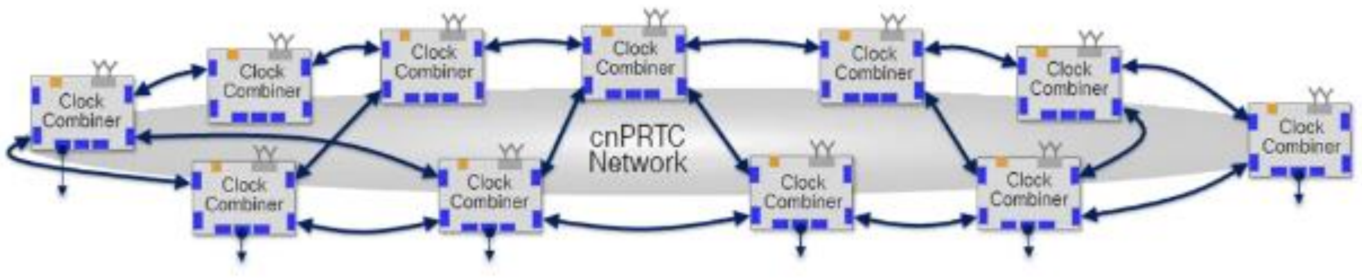
The need for increasing resiliency

- 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

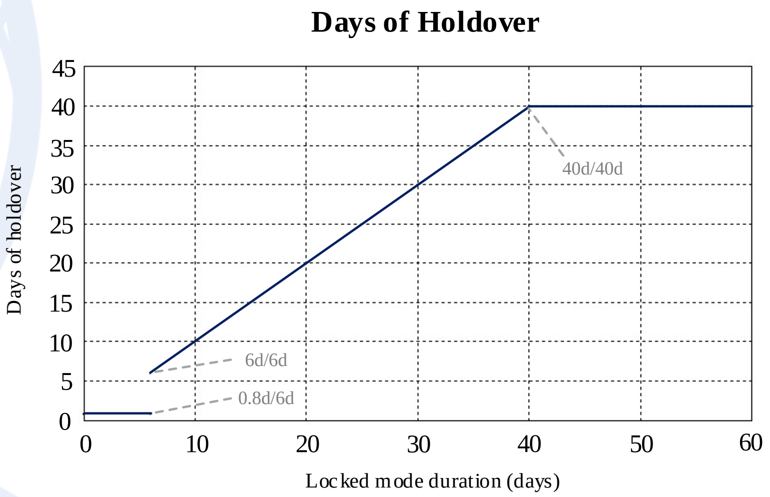
How to increase resilience in Sync?

- 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]

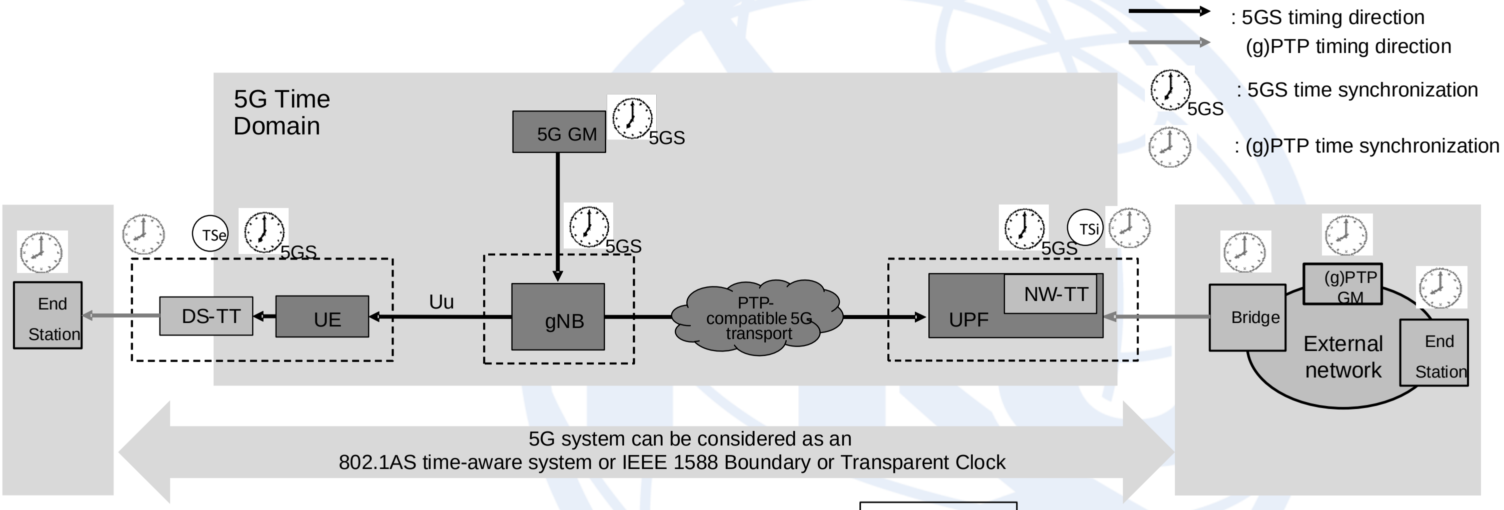
- “WD13-Resilience” to define Resilience Levels Appendix for G.8275

Mapping with Resiliency Levels

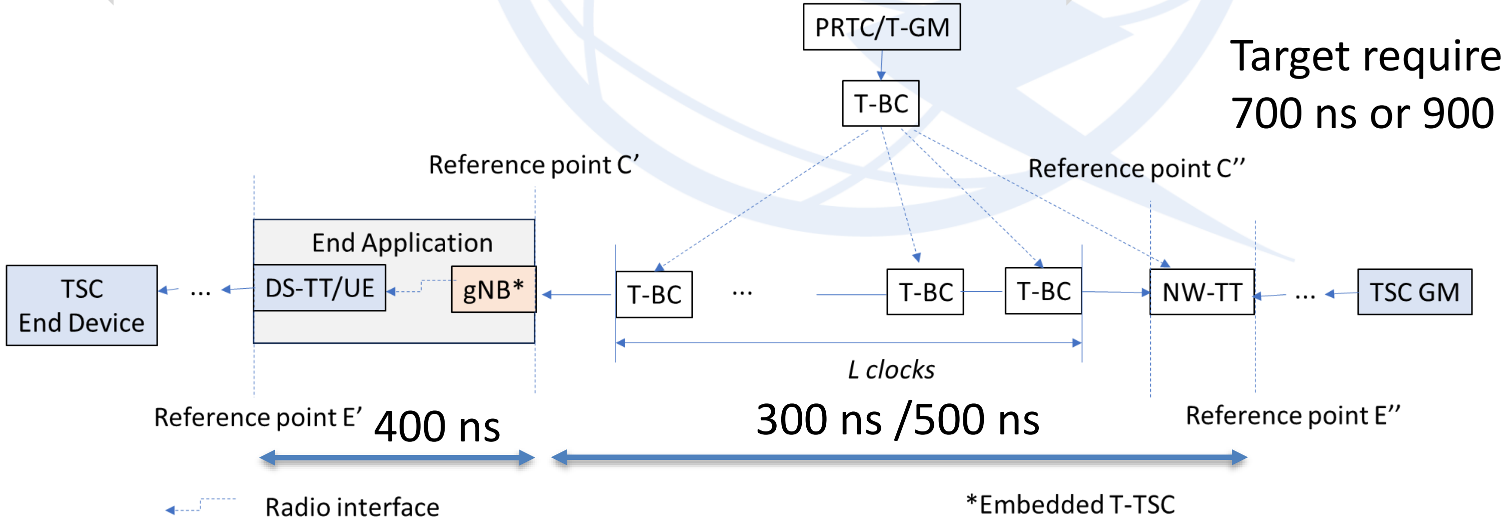
IEEE P1952 Resilience Level			Proposal	threat duration time	PRTC			ePRTC			cnPRTC	
					PRTC	PRTC with SyncE	PRTC with APTS	ePRTC	ePRTC with SyncE	ePRTC with UTC(k)	cnPRTC	cnPRTC with UTC(k)
1	**Detect** **Alert**	The ability to detect an adversity that might impact performance and generate an alert.	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

Related aspects: 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



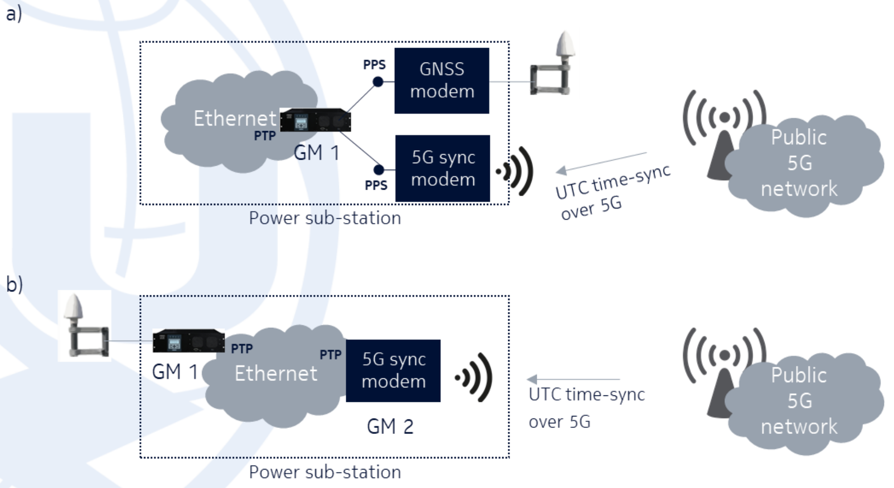
Target requirements for the 5G segment: 700 ns or 900 ns

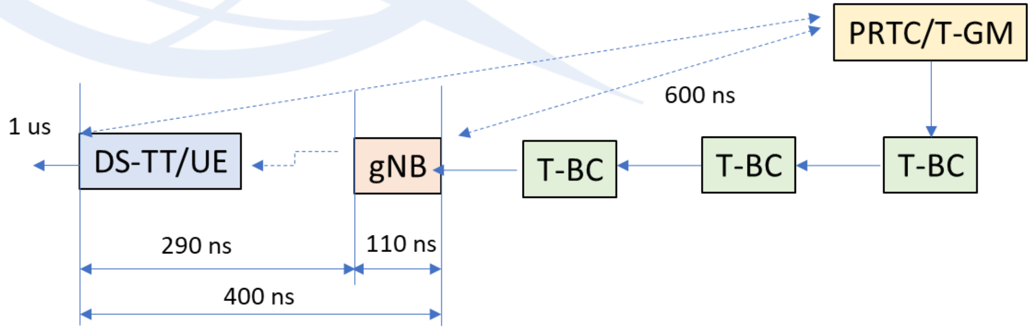
Related aspects: Timing Resiliency in 5G (G.8271/.1)

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)

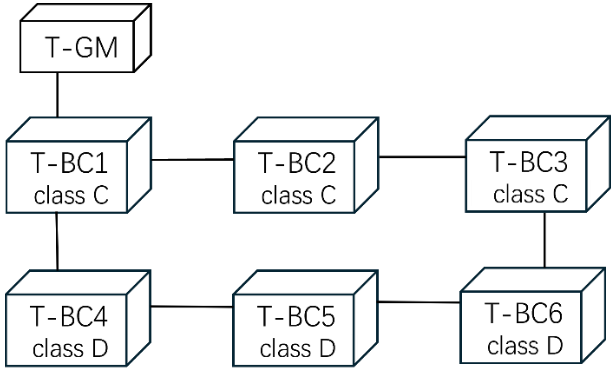




Related aspects: G Suppl-83, Enhanced Accuracy Metrics TLV

- 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	$\max\|TE\|_{T-GM}$	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.	

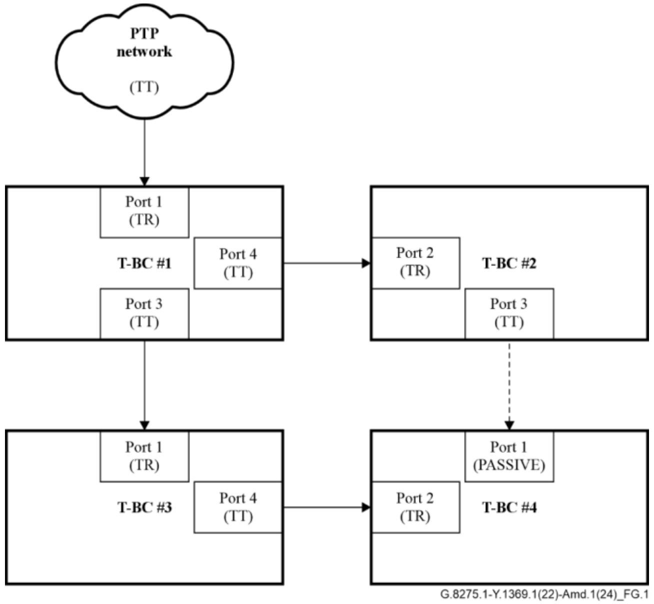
NOTE 1: $dTE_i^{\ 2}$ value is for further study.

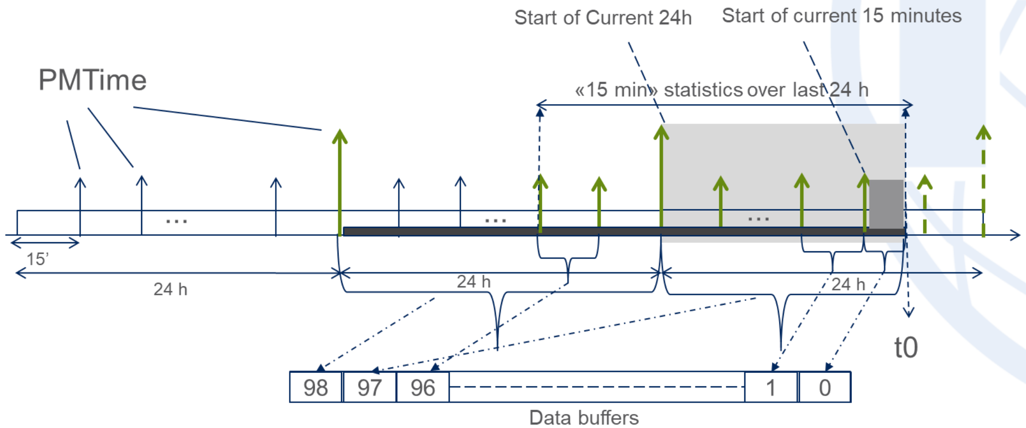
NOTE 2: Number of media/links between T-GM and PTP Instance updating metrics is N+1, where N is number of T-BC/T-TC in between.

- 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.

Related aspects: 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





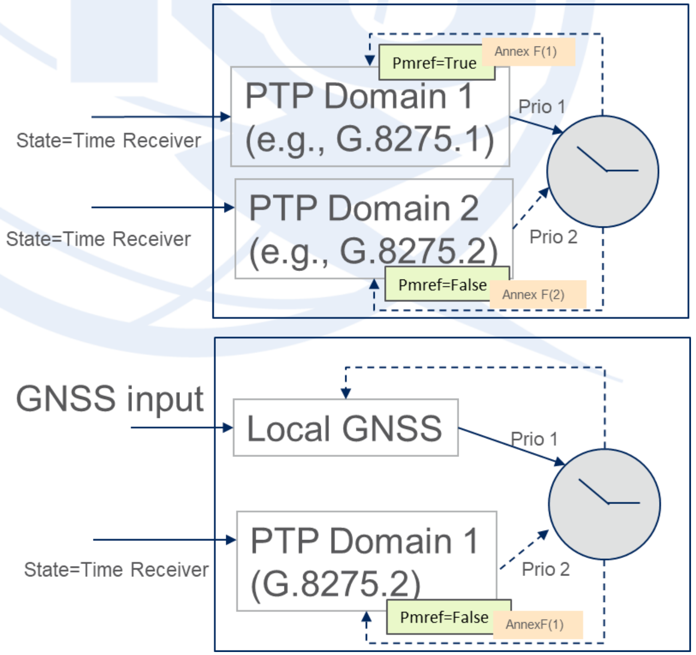
PMTime: start of the 15minutes / 24h periods

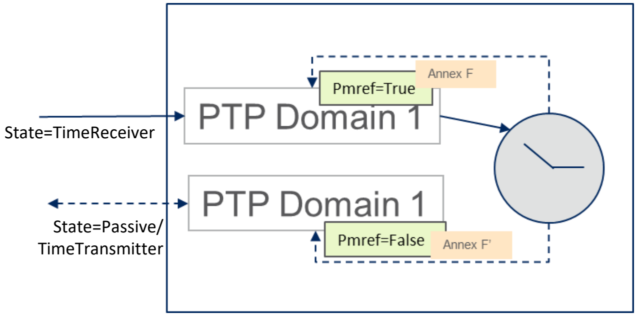
Data used for the statistics stored in the buffer

Data used for the current 24h value

Data used for the current 15 minutes value

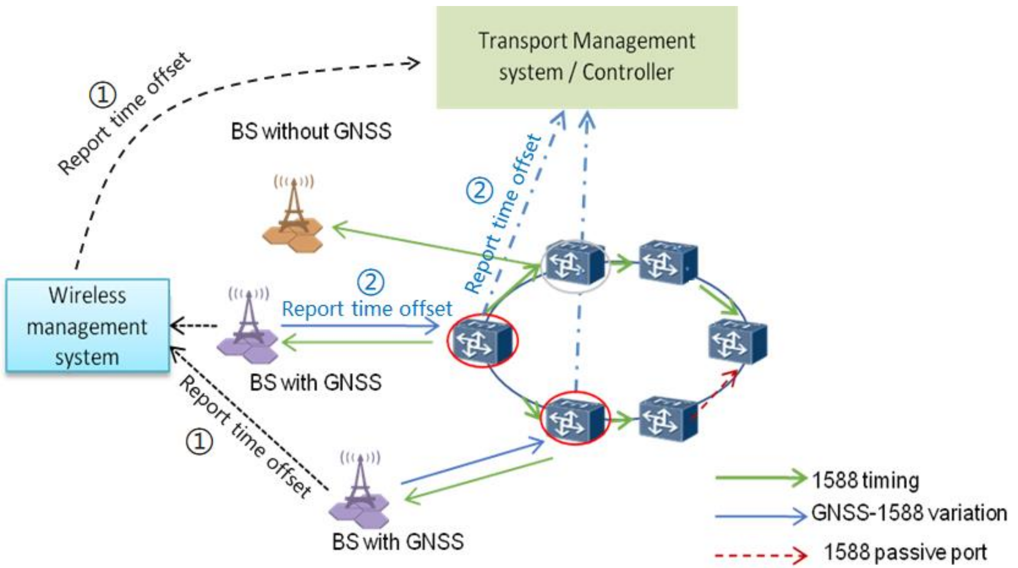
t0 Indication of current time when accessing the PM data



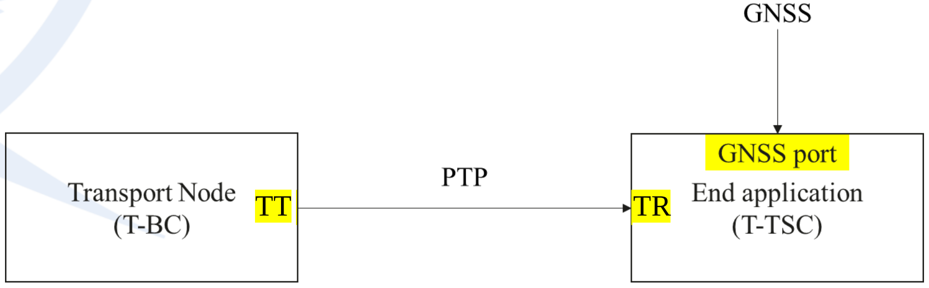


Related aspects: TLV carrying GNSS-PTP time error (G.8275.1 Annex L)

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



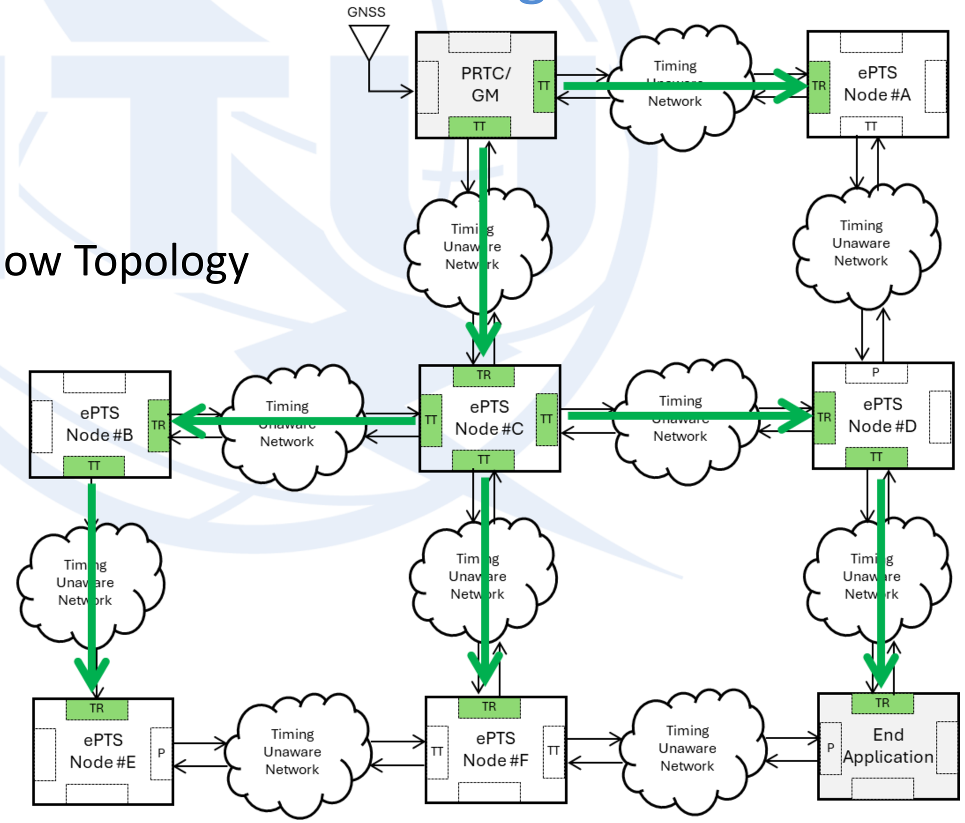
TLV fields		Octets
tlvType		2
lengthField		2
organizationId		3
organizationSubType		3
dataField	clockMode	1
	flags	1
	ptpGrandmasterID	8
	offsetFromPtpToLTR	8
	messageInterval	2
	Reserved	24



Reated aspects: PTP Profiles evolution

- 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

Example of ePTS Timing Flow Topology



From WD13-30R6 (Montreal July 2024)

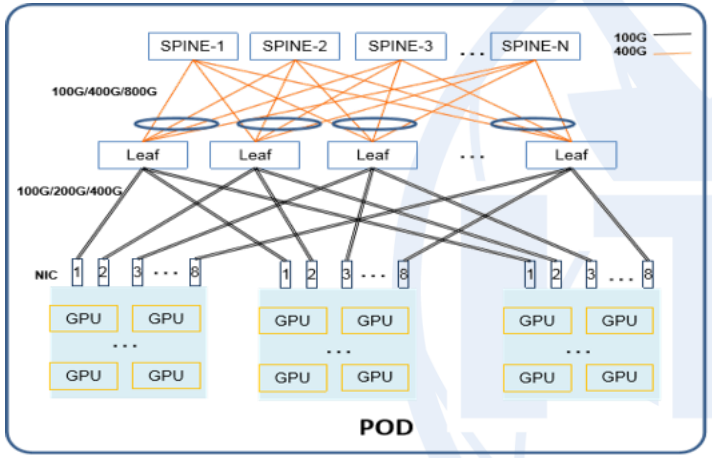
Other connected applications: Data Centres

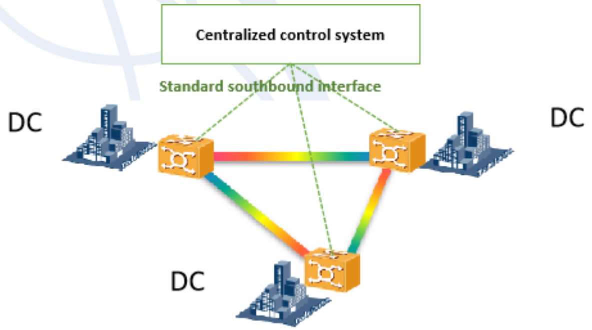
- Responding to request from Data centres operators (e.g., OCP Global Summit October 2023), a new work item on the extension of ITU-T defined sync frameworks and profiles for synchronization in data centres
- Focus on sync technologies and methodologies that Q13 has developed in cooperation with IEEE 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

Synchronization for Datacenters

- G Suppl.DCSync started at the SG15 plenary in July 2024

Example of topology for the data center network (DCN) and Data center interconnection (DCI).





- Some reasons for using accurate timing in data centers are as follows:
  - Permits consistent operation between distributed data centers, it minimizing latency.
  - Reduces power consumption
  - Improves overall performance of Artificial Intelligence and Machine Learning (AI/ML).

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))

Thank you !