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How to monitor sync in Data Centers
WSTS 2025

12-15 May 2025, Savannah

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Adam Paterson Head of Product Management, Calnex
Stefano Ruffini Strategic Technology Manager, Calnex

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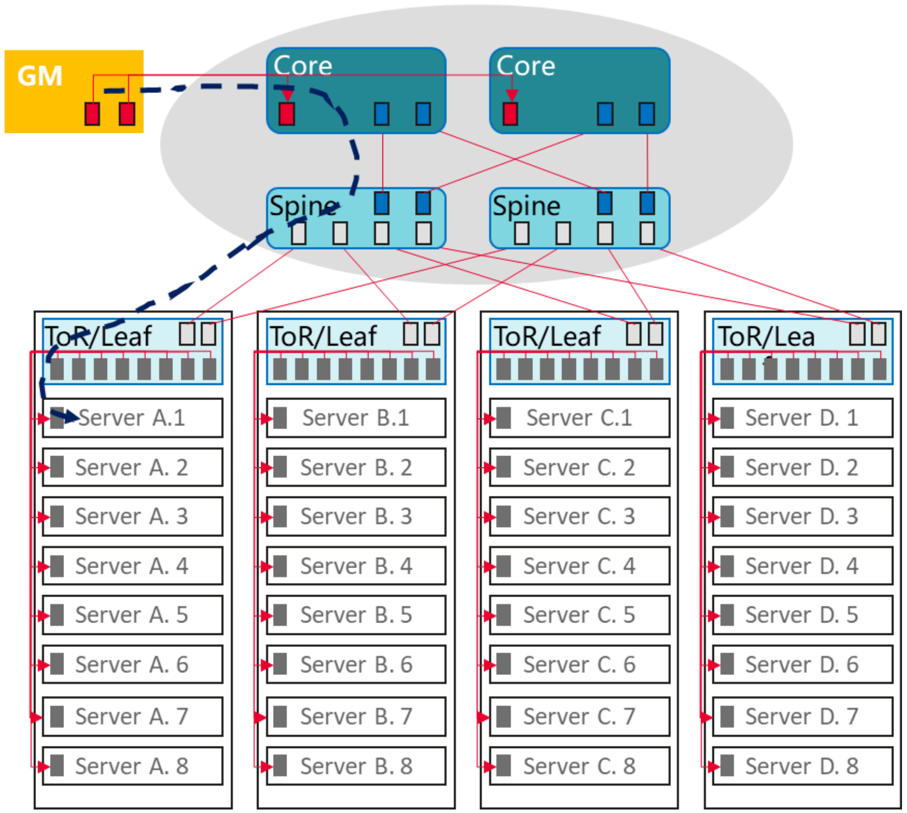
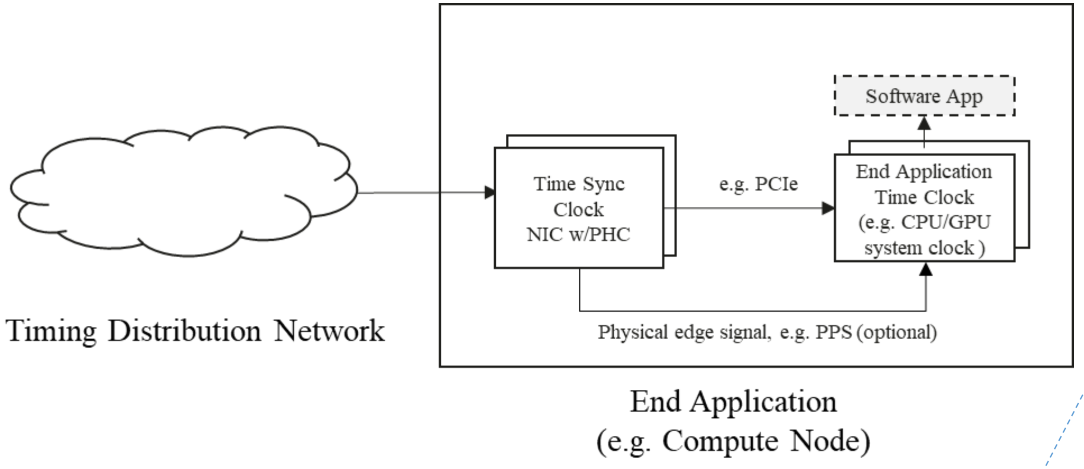
Synchronization in Data Centers

- Synchronization in Data Centers has received significant attention in the past few years, enabling:
  - Consistent operation between distributed datacentres, minimizing latency.
  - Event logging; Diagnosis and analysis of problems
  - Power consumption reduction
  - Improvements of the overall performance of Artificial Intelligence and Machine Learning (AI/ML).
- Sync solutions have been implemented by major datacentre operators

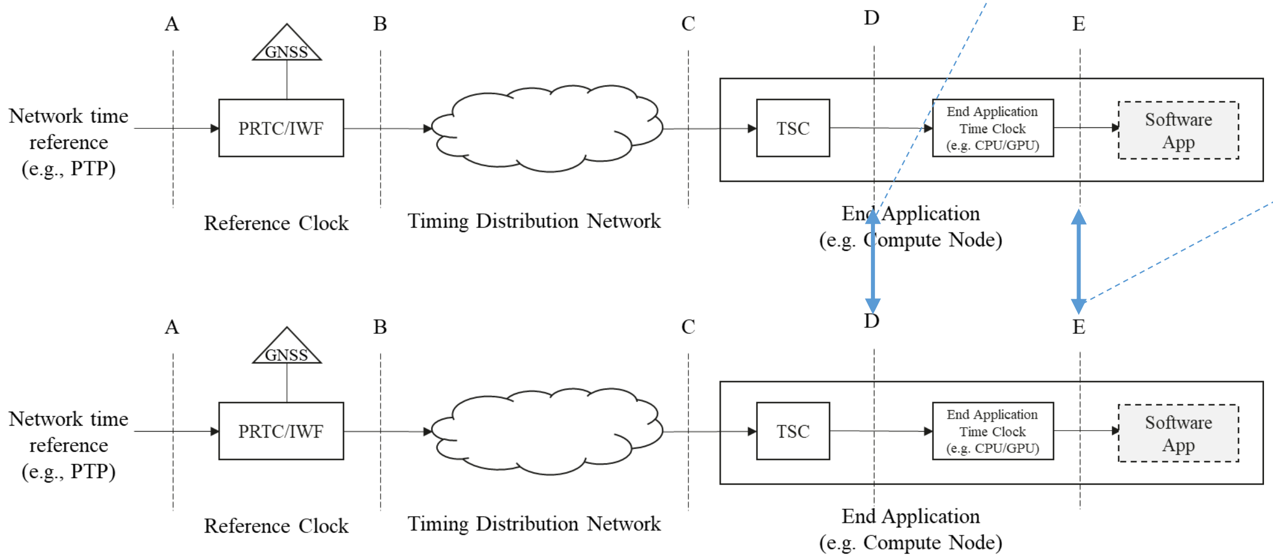


From draft ITU-T G Suppl.DCSync (March 2025)

ITU-T Work Item on Synchronization in Data Centers



Accuracy Class	Relative Time error requirements between Time Sync Clocks	Typical applications (for information)
1	5µsec	Distributed databases, applications profiling
2	1µsec	High-Frequency Telemetry, Multi-node performance analysis tools
3	200nsec	Congestion control based on one way delay, Time synchronized collective communication



Accuracy Class of End Application Time Clocks compared to Time Sync Clocks	Additional Time Error requirements for End Application Time Clocks vs Time Sync Clocks	Notes
A	2µsec	Typically, without PTM
B	200nsec	Typically, with PTM
C	50ns	Typically, with physical edge clock signal (e.g. PPS between clocks if available).

From draft ITU-T G Suppl.DCSync (March 2025)

PTP-based solutions for Data Centers

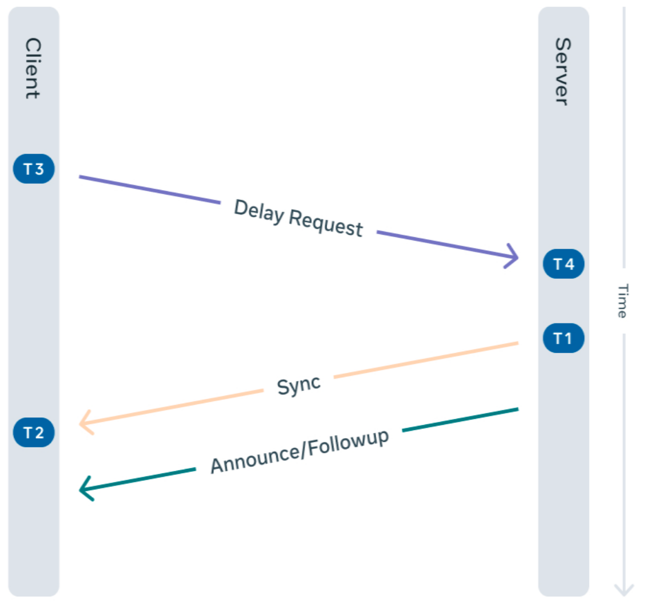
Data Centers may need to use different PTP profiles to address different use cases and network topologies:

- PTP based on Ethernet local link multicast communication
  - ITU-T G.8275.1 profile can be used as a baseline.
- PTP based on IP unicast communication
  - IEEE IM/ST/PNCS Working Group is developing IEEE P1588.1
  - This is client-server PTP (CSPTP), IP unicast, with full timing support from the network via transparent clocks.
  - Simple PTP is an alternative until P1588.1 is released

To ensure the highest accuracy of time delivery, the PTP profile for data centers should support full PTP timing support from the network.

- In case of unicast, full timing support with transparent clocks may still generate some error (but limited by the longest distance, e.g., could be controlled within 10 us)

SPTP exchange



Why monitor sync performance?

The fundamental reasons for monitoring sync:

- Prevent-Minimize service impact
- Fast Fault localization and recovery

Specific aspects in Data Center applications:

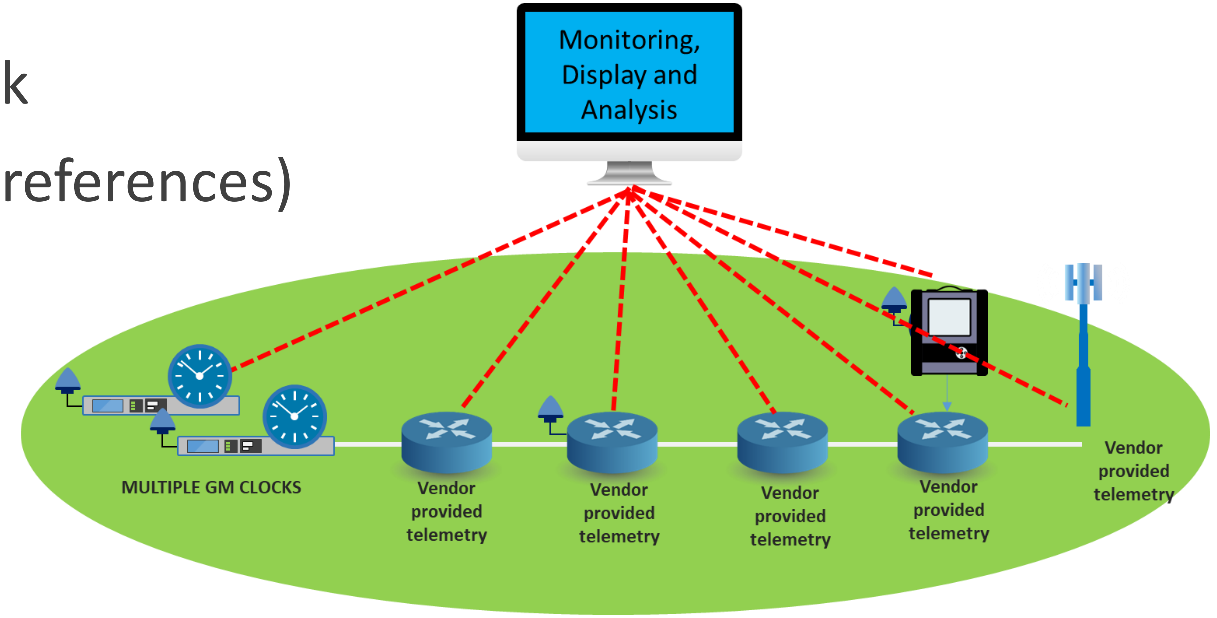
- There can be periods when sync is not accurate but is acceptable, but it is important to be aware if this impacts decisions in the system
- Regulatory implications (e.g., hosting Financial applications: MiFID II requirements)

Options to monitor sync performance

- Local reference (feasible in a limited number of sites)
- Data collected from the network elements
  - Configuration info
  - Measurements with respect to local clock
  - Relative measurement (e.g., vs. back-up references)

Current Issues

- Proprietary data collection
- #Points to monitor
- Analysis and interpretation of the data



Example: misconfiguration

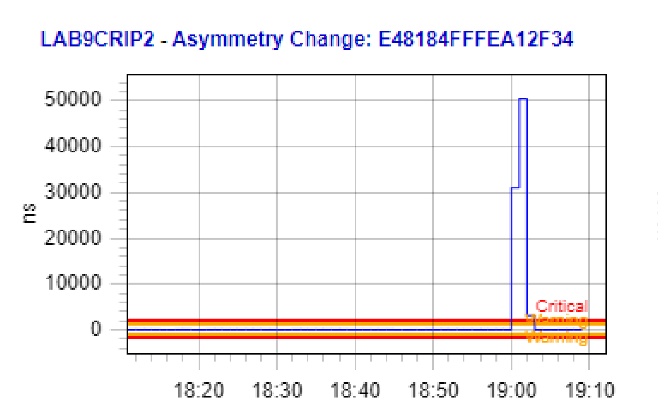
LAB9CRIP2

Last Updated: Oct 15, 2024 7:00:36 PM

Ok | Critical | Warning | Unknown | Ignored | Not Polled

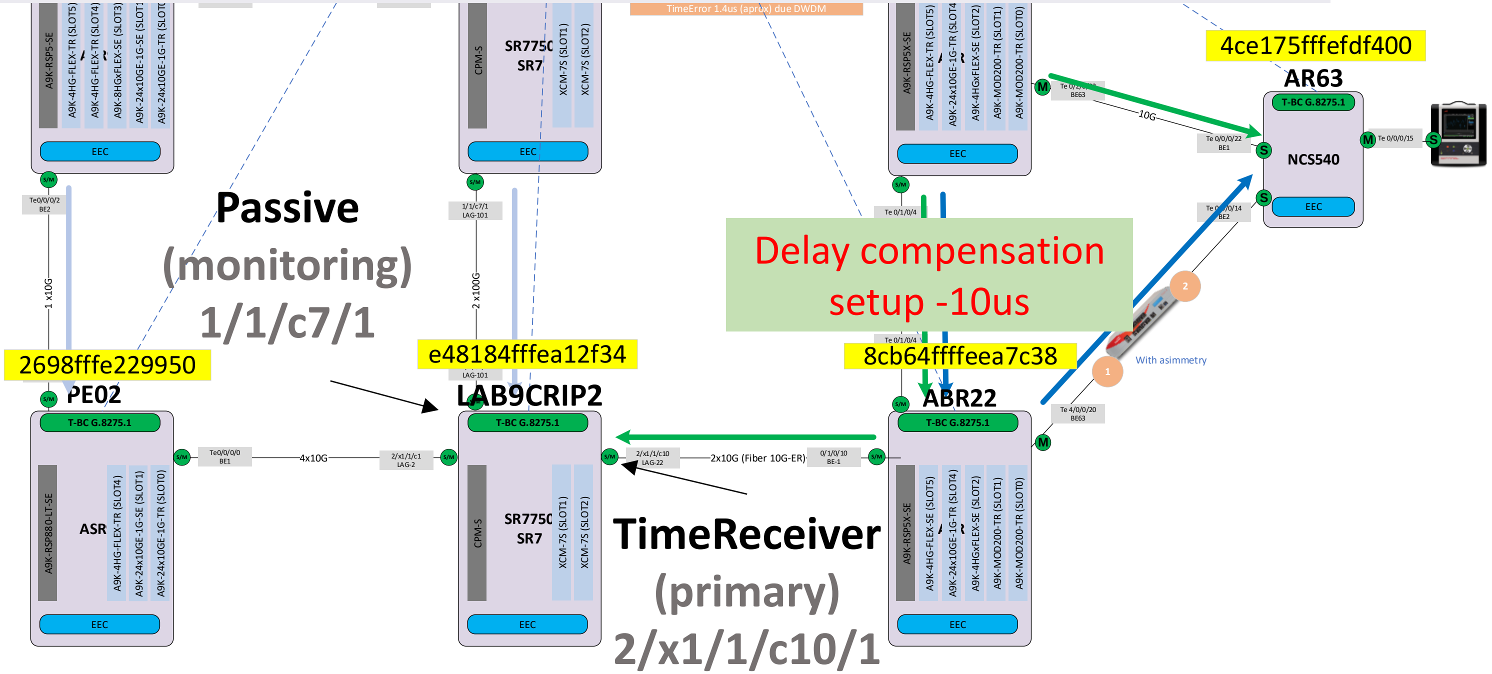
Sync Explorer | Graphing

1 item Critical, 1 item Warning. Asymmetry change, Time Recovery State: Acquiring. more...



Misconfiguration of delay compensation setup has been activated in ABR22 TimeReceiver port @ 19:00

Sync Monitoring tool **detects asymmetry change**



from ITSF 2024 (tests with NOS)

Example: misconfiguration

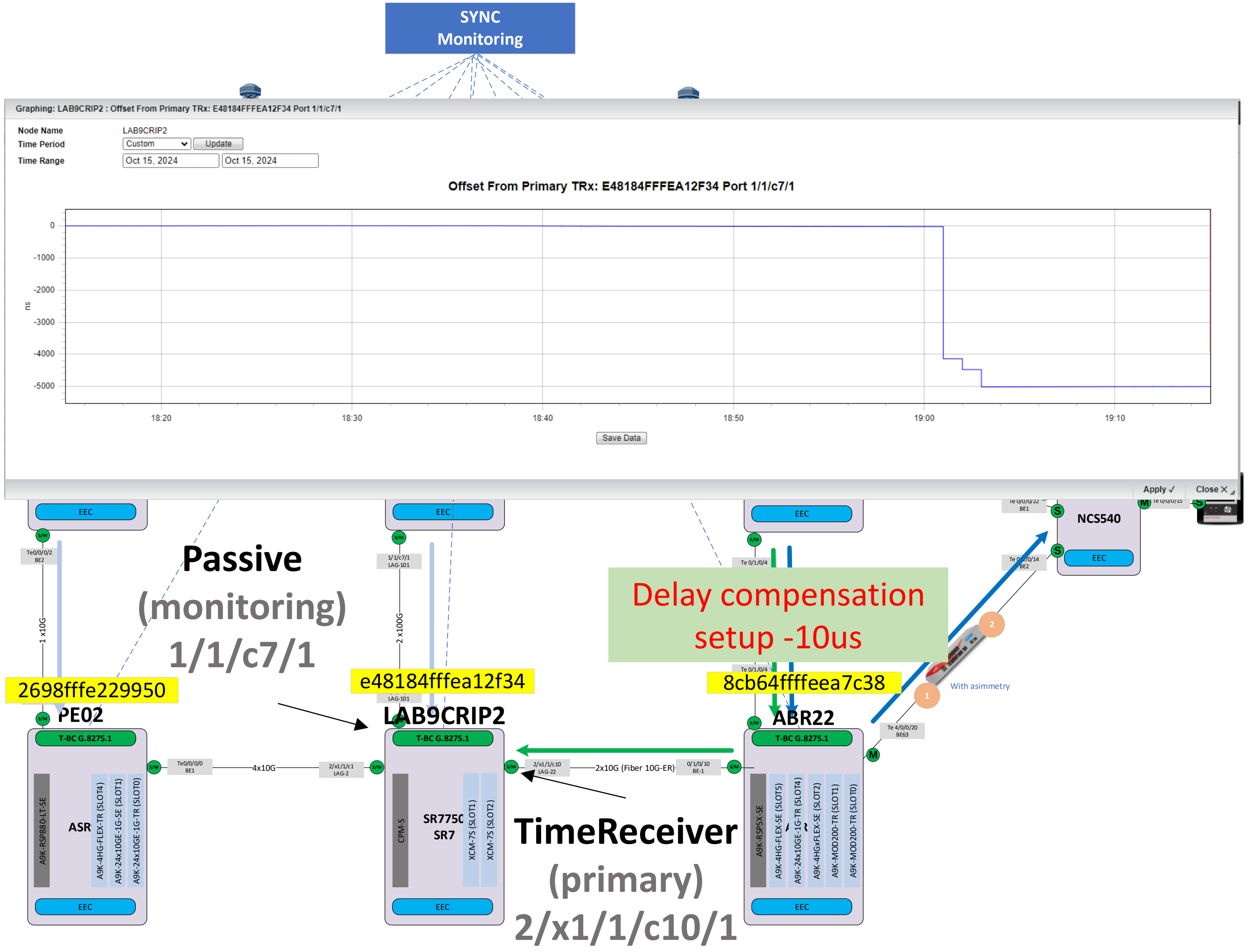
LAB9CRIP2 is synchronized through GM TP5K from ABR22 port 2/x1/1/c10/1… green path

LAB9CRIP2 has a passive port 1/1/c7/1 connected to LAB9CRIP1 using GM OSA… silver path

Misconfiguration of delay compensation setup has been activated in ABR22 TimeReceiver port @ 19:00

Sync Monitoring tool **detects asymmetry change**

While the misconfiguration persists, LAB9CRIP2 has the perception that the TimeReceiver and passive port have asymmetry.

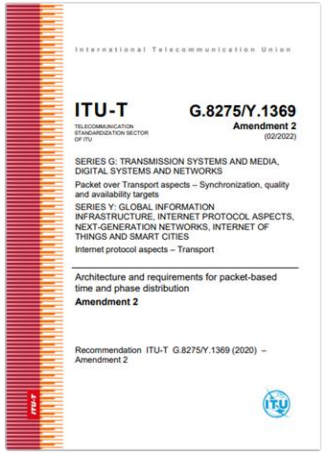


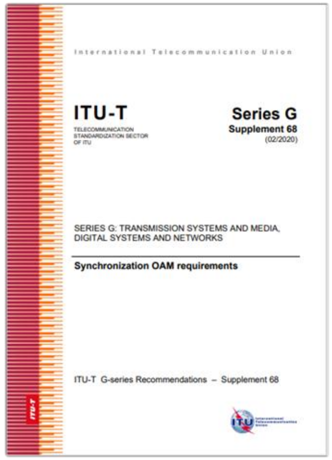
from ITSF 2024 (tests with NOS)

Standardization initiatives

Sync in Data Centers:

- IEEE1588.1 («CSPTP»)
- ITU-T Sync in data centers (G Suppl.DCSync)
- OCP TAP





Performance monitoring

- **IEEE P1588e** :
  - IEEE1588-2019 YANG and MIB data models
- **IEEE1588-2019 Annex J; ITU-T G.8275 Annex F**:
  - Standard Performance Monitoring parameters
- **ITU-T G.781** :
  - New Annex with SyncPHY dataset for use in YANG and MIB data models
- **ITU-T G.Supp68** :
  - High-level Sync management requirements
- **ITU-T G.7721.1**
  - YANG data models for SyncE and PTP
- **O-RAN (Xhaul Transport specification, Annex H):**
  - End-to-end monitoring (based on IEEE and ITU-T)

Telecom vs. Data Center

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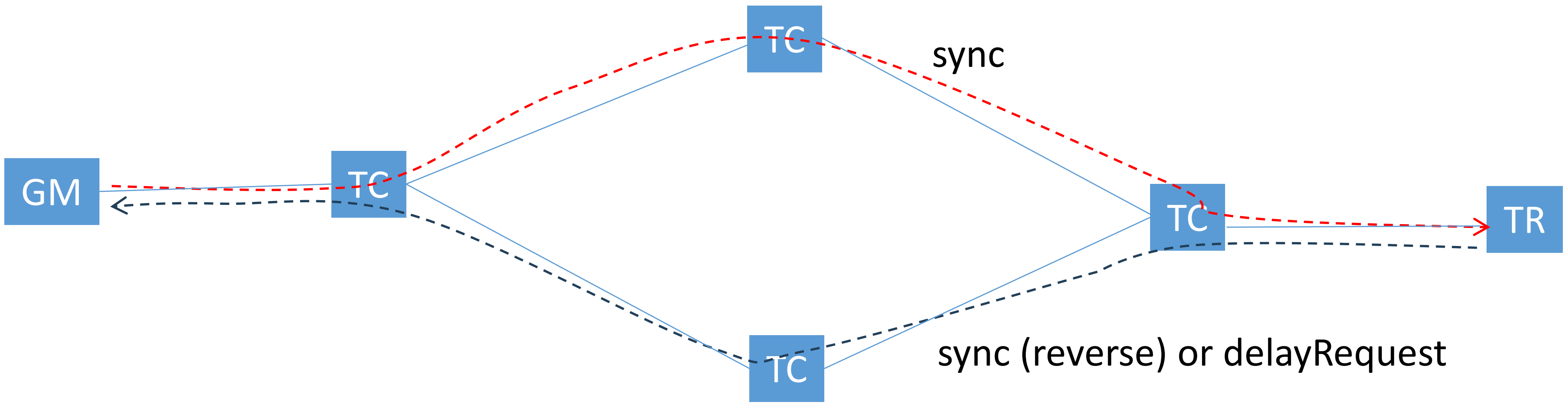
	Telecom	Data Center
Network characteristics	Generally geographically distributed network (limited number of clocks within the site)	Large network within the site, and need to synchronize also remote locations
FTS vs PTS; Multicast vs Unicast	Typically Full Timing Support (PTP over Ethernet, mcast) or Partial Timing Support (PTP over IP, unicast) as back up to local GNSS	Within the building: full timing support or partial timing support depending on target requirement; generally Unicast (PTP over IP)
BC vs TC	Mainly use of Telecom Boundary clocks: better control of the sync hierarchy, PTP flooding, scalability	Within the building: mainly Transparent clocks (simpler implementation of sync function in the network; easy time error monitoring); Issue: asymmetries due to different paths
Standardization	Standardized	Ongoing standardization

Challenges with use of TCs

- PTP over IP Unicast and Transparent clocks (1-step in this example) can create asymmetries
- Time Error depends on the size of the network. In-building, could be controlled to a few microseconds:
  - Additional delay in full timing support is only due to possible different length of fiber links and potential different number of links.
  - Within a building this is expected to be controlled within 1 Km (i.e., 5 us delay)



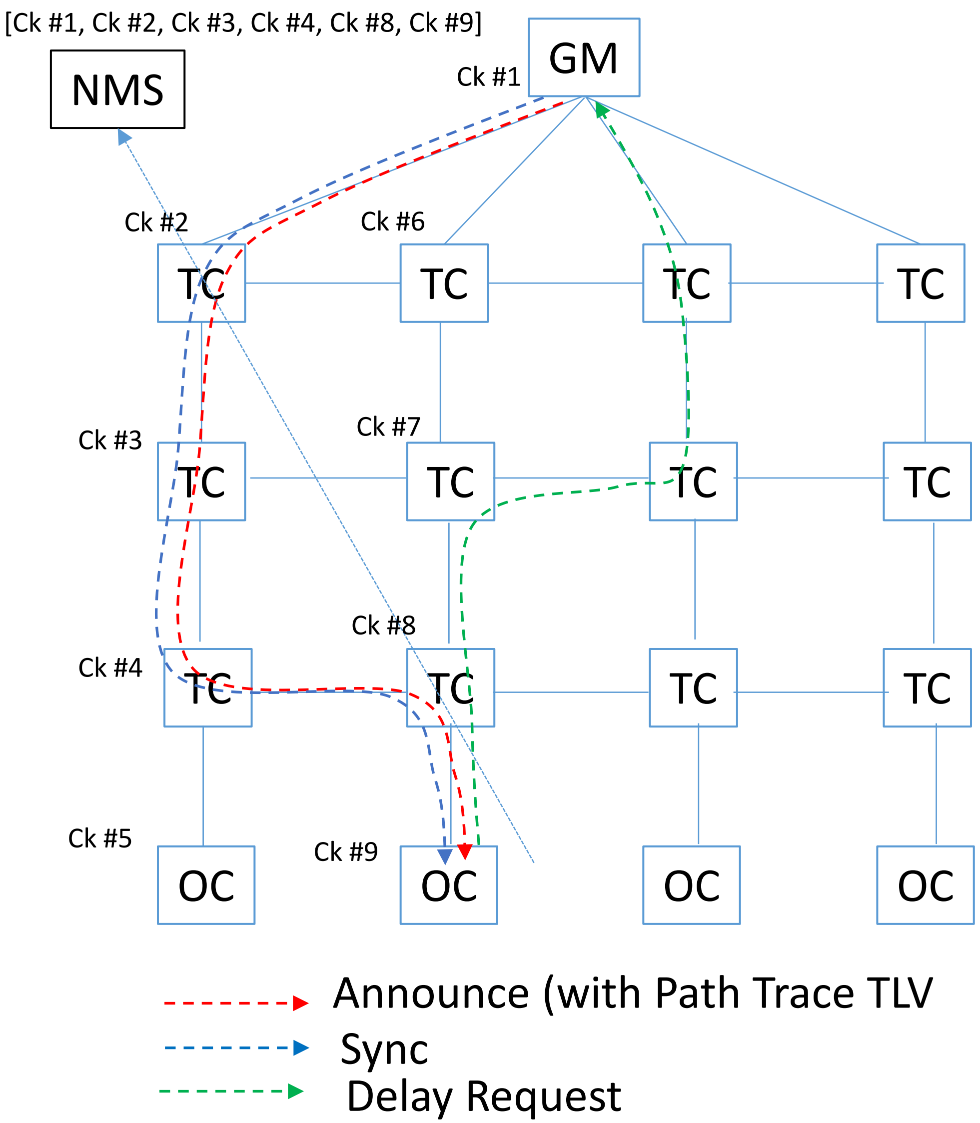
Options to monitor sync in datacentres

Limited or no use of BC creates some limitations for monitoring sync networks:

- Not possible to track the sync path
- Not possible to monitor performance and rearrangements happening along the path

IEEE 1588 «Path trace» (clause 16.2 of IEEE1588-2019) may be enabled in every TC to track the expected path of the sync messages :

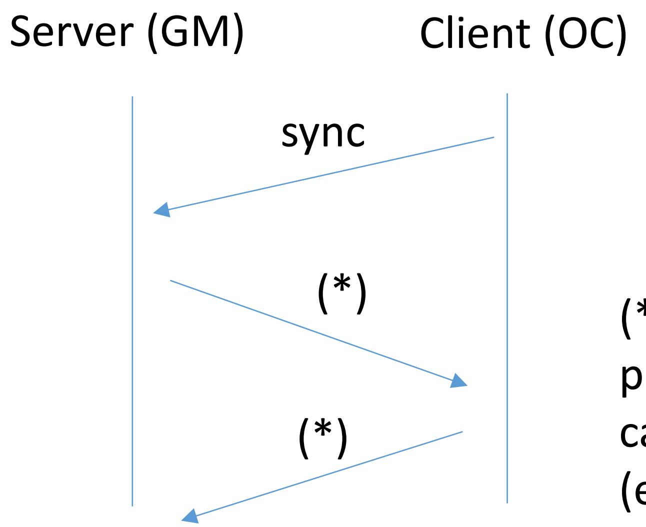
- Path Trace append the CkId of the PTP clock along the Announce message path
- Actual path of the reverse messages may be different as it depends on the routing tables)



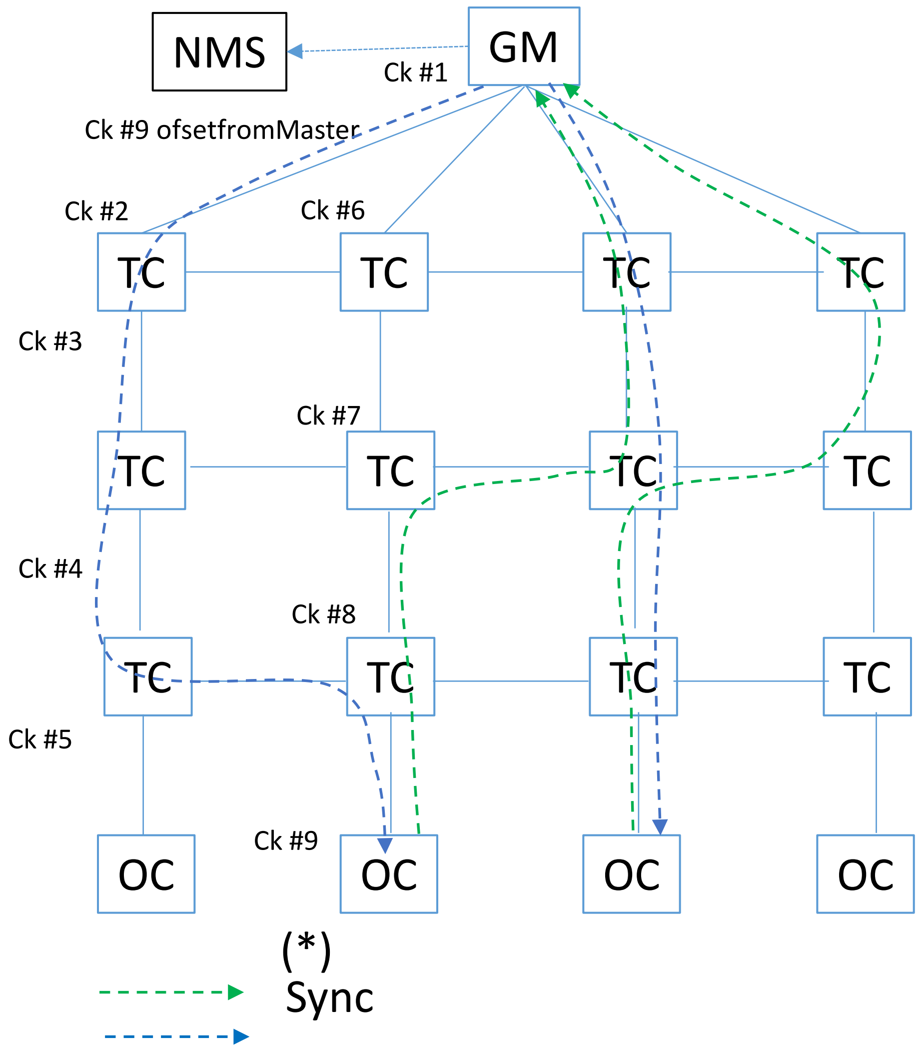
Options to monitor sync in Data Centers, cont.

Use of Unicast combined with TCs has benefits:

- Direct exchange of timestamps between server and client
- (Reverse) Sync available at the server that can monitor all the clients



(*) various options to provide 4 timestamps to the server to calculate the meanPathDelay (e.g., reverse sync, IEEE 1588.1, etc.)



Summary

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- Synchronization is increasingly important in datacentres for several reasons.
  - AI could lead to significant investments in synchronization.
- Effective monitoring of synchronization is essential for a resilient solution, even more so when there are regulatory requirements.
- Progress is being made on synchronization standards for Data Centers (e.g., ITU-T, IEEE), which may help establish standard monitoring practices.
  - Consistent analysis relies on standard formats.
  - The large volume of data necessitates efficient filtering and comparison methods.

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