Calnex Solutions, Equinix Inc.

What is happening with synchronization in data centres ?

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- Introduction, incl. standards
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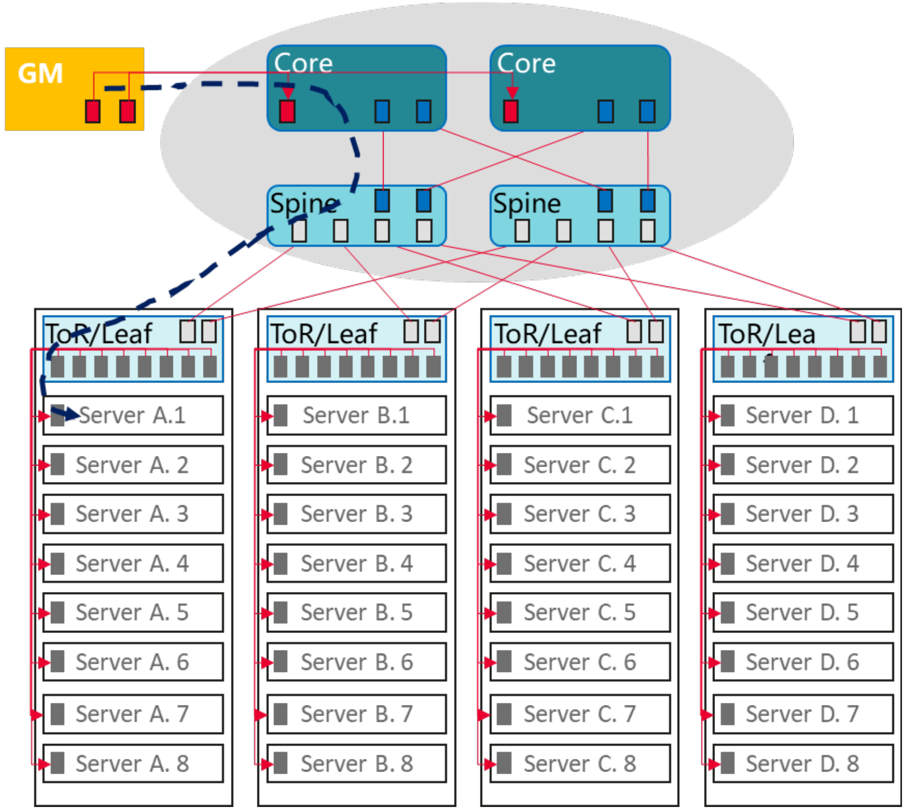
Why Synchronization in data centres

Enhanced Sync enables:

- Consistent operation between distributed data centres, minimizing latency.
- Event logging; Diagnosis and analysis of problems
- Improvements of the overall performance of Artificial Intelligence and Machine Learning (AI/ML), including reduction in power consumption
- Regulatory requirements (financial)
- Support telecom networks requirements



From ITU-T G Suppl.92

Sync solutions have been implemented by major data centre operators
Ongoing efforts to provide standardized solutions

How standards are addressing these needs

- ITU-T Q13, Analysis of Requirements and solutions in new Supplement G Suppl.92 (Synchronization in Datacentres) and optimized PTP profile (G.FTS-Lite) and clocks
- IEEE P3335, Standard on Timecard
- IEEE P1588.1, Standard on new simplified timing protocol (similar to PTP)
- OCP, timing related Workstreams in the Time Appliances Project (TAP); it has been working at an early version of a PTP profile for data centers. Examples from recent activities:
  - Unified Intelligent Architecture (Time Sync in AI Data Pipelines)
  - Instrumentation and Measurement (test guide)

ITU-T G Suppl.92: Synchronization in Datacentres

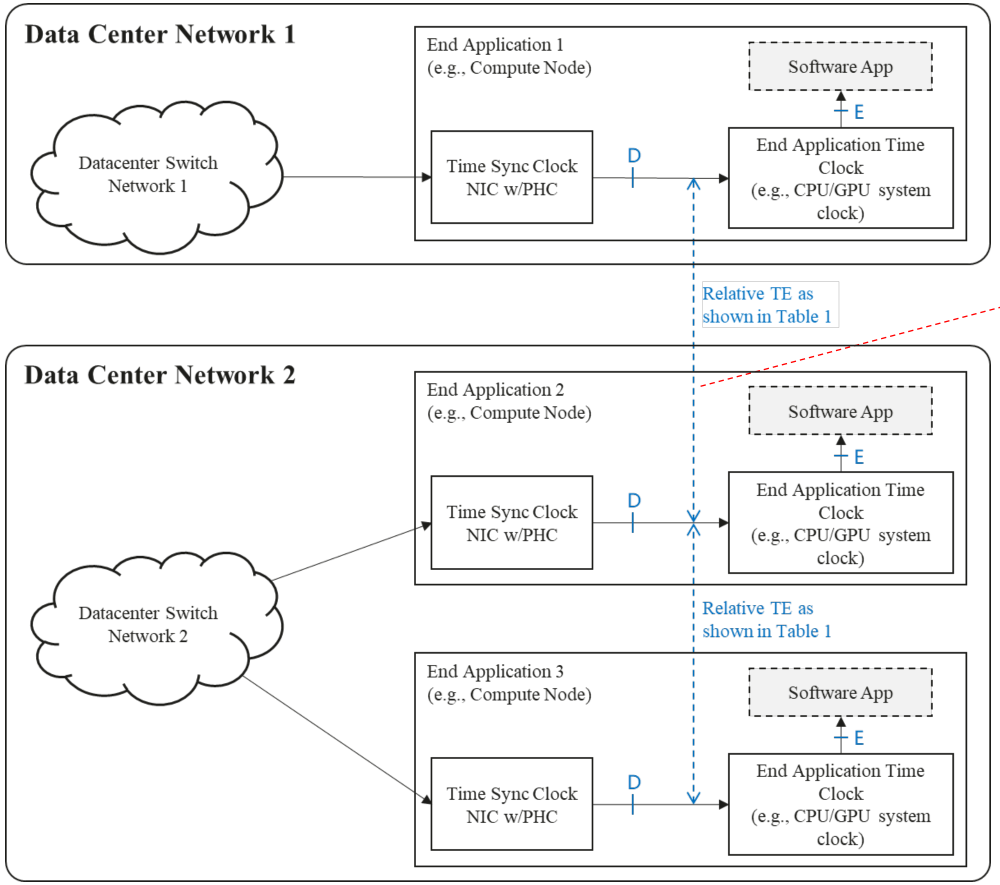
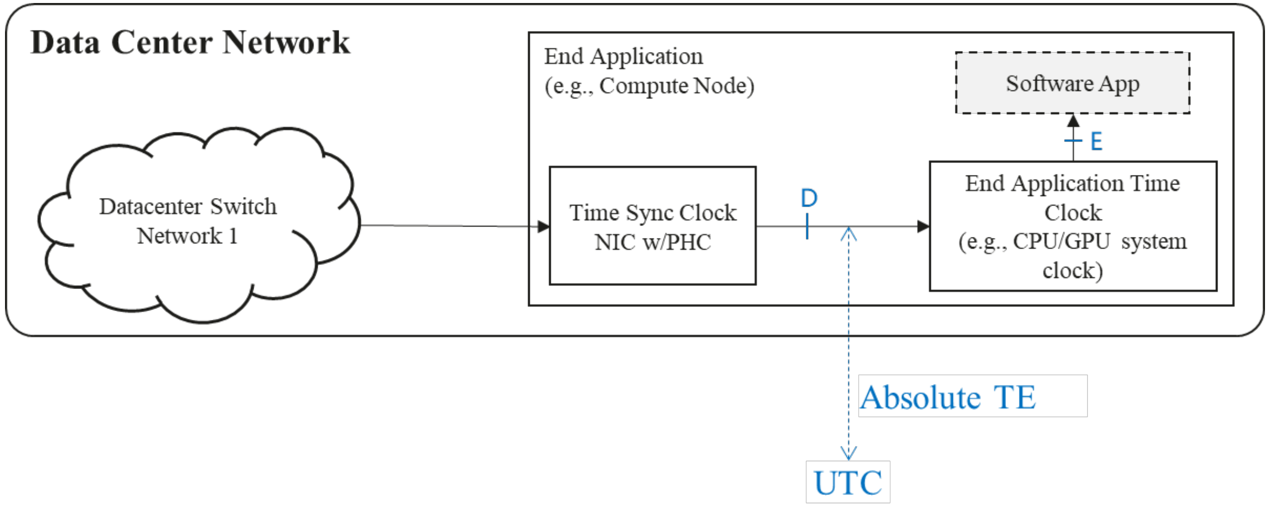


Table 1 - From ITU-T G Suppl.92 last draft (modified in March 2026)

Accuracy Class at Time Sync Clock	rTE between Time Sync Clocks	Typical applications
1	5µsec	Distributed databases
2	1µsec	High-Frequency Telemetry, Applications profiling via multi-node performance analysis tools
3	200nsec	Congestion control based on one way delay Time synchronized collective communication

The Absolute TE req’t at Time Sync Clock output is half the rTE req’t shown in Table 1

ITU-T G Suppl.92: Synchronization in Datacentres



Accuracy Class: End Application Time Clock vs. Time Sync Clock	TE req's: End Application Time Clock vs. Time Sync Clock (from ref. point D to E)	Implementation Notes
A	2µsec	Typically, without PTM
B	200nsec	Typically, with PTM
C	50ns	Typically, physical clock signal (e.g. PPS OUT of Time Sync Clock, IN to End Application Time Clocks)

PTM: Precision Time Measurement

OCP/TAP Test Guide

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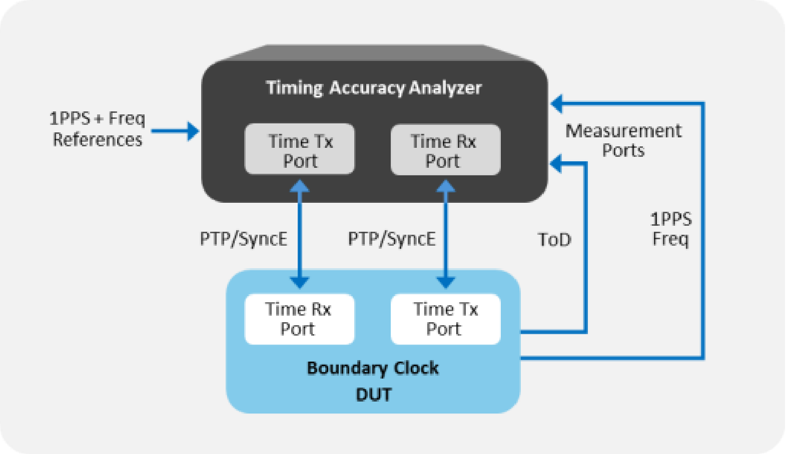
- Methods for verifying clock accuracy to predefined limits that can be applied to clocks used for datacentre applications.
- This version focuses on time receivers, boundary clocks, and transparent clocks. Grandmasters may be included in the future.
- The performance metrics refer to ITU-T recommendations:
    - they can be considered consistent with some of the most stringent classes of requirements also applicable in datacentres

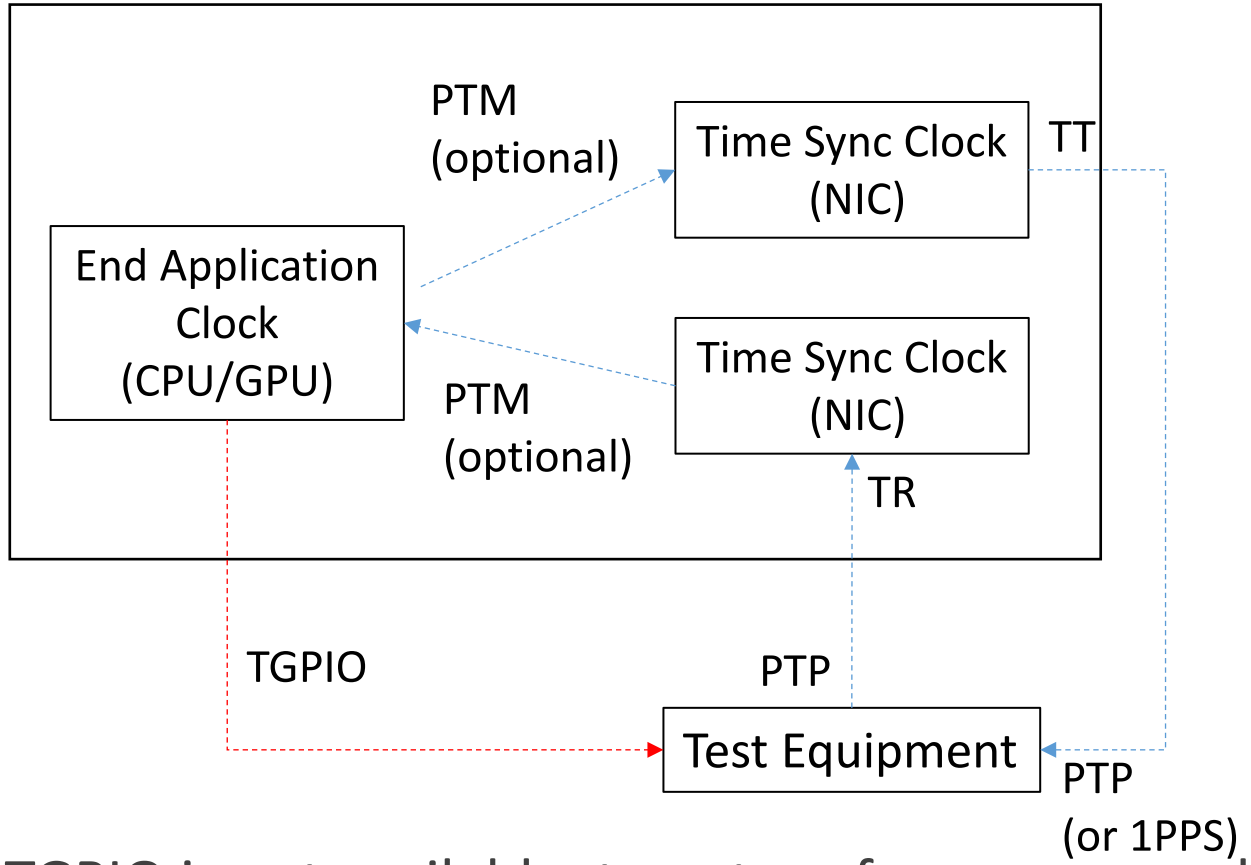
test-guide-for-data-center-timing-pdf

OPEN Compute Project

TEST GUIDE FOR DATA CENTER TIME RECEIVER, BOUNDARY CLOCK AND TRANSPARENT CLOCK TIME ERROR MEASUREMENT



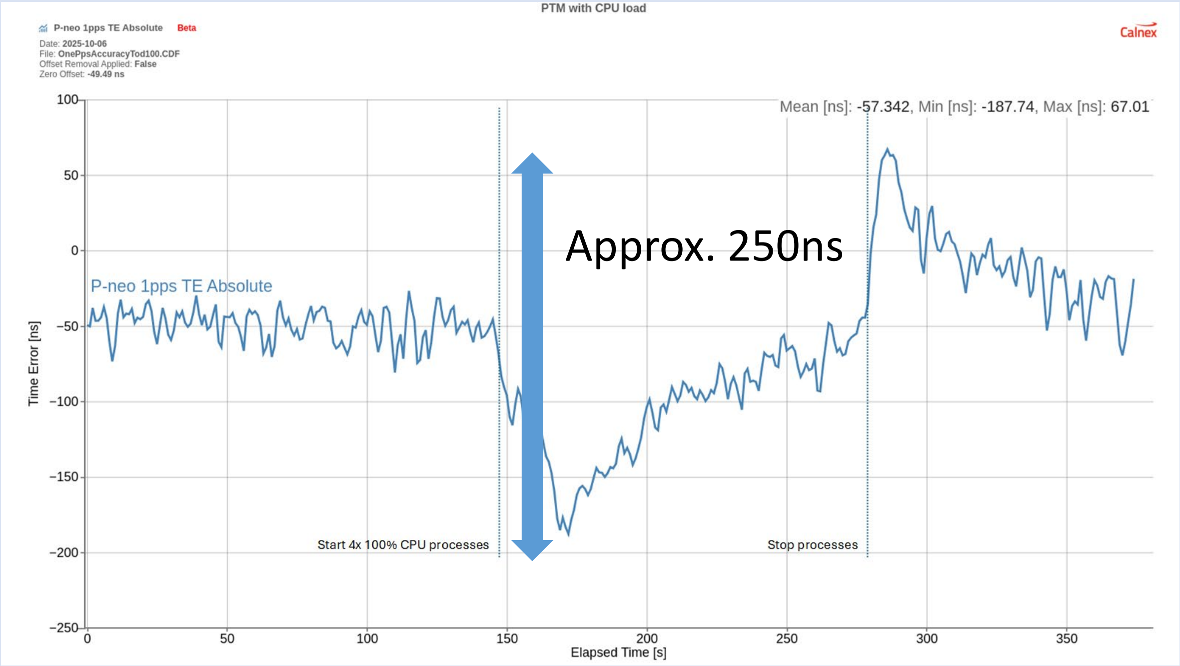
Testing the performance

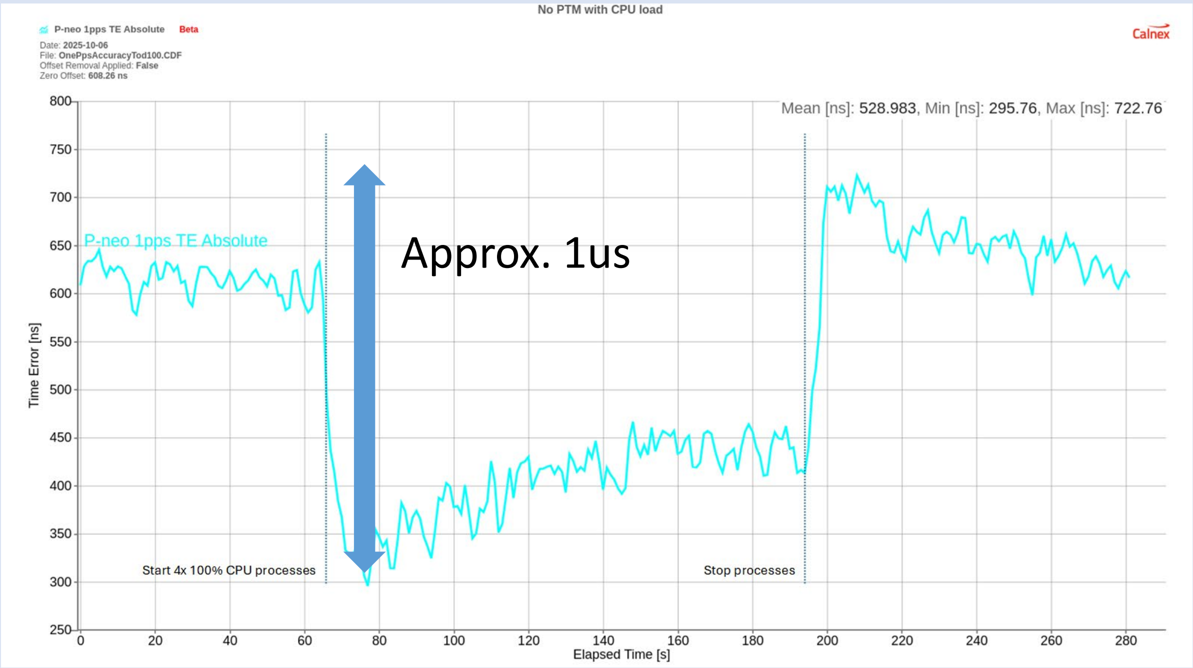


	Based on class B T-BC	
	Single T-BC	Pair of media converters
cTE (ns)	±20	±40
dTE_L MTIE (ns)	40	60
dTE_L TDEV (ns)	4	6
dTE_H (peak-to-peak, ns)	70	70
max|TE| (ns)	70	100

- If TGPIO is not available, target performance can be based on considerations made in G.8273.2 Appendix V (*Performance estimation for cascaded media converters acting as T-BCs and for T-BC chains*)
- Example: pair of class B clocks, with the addition of 200 ns (Table 2 from G.Suppl.92) :
  - max|TE| = 20 ns + 20 ns + Sqrt (50^2 ns + 50^2 ns + 200^2 ns+200^2 ns) = 331 ns

Impact of Load: with and without PTM





With PTM:
phc2sys *is* impacted by changes of CPU load but manages to go back around its baseline when the CPU load is constant.

Without PTM:
Impact on time error is higher.
Even with constant CPU load, unable to recover to base line.

OCP/TAP: Unified Intelligent Architecure

- *A collaborative space for driving innovation and coherence across hybrid multi-cloud infrastructure, AI systems, distributed architectures, time-aware computing, and emerging domains such as quantum and beyond.*
- Project focused on demonstrating time synchronization impact on AI workloads.
- Reproducible testbed that can inform future OCP standards and reference designs for time-aware AI infrastructure

Examples impact on AI operation due to bad timing

EQUINIX Calnex OPEN Compute Project®

- Representative AI inference pipeline using commodity infrastructure and open-source components
- The postprocessing stage computes observability metrics:
  - Total tokens processed
  - Negative timing spans
  - Violation rate
- Impact of injected clock skew on causality failure under controlled conditions
- Before each experiment, all participating hosts are manually synchronized to a common time source (within sub-millisecond bounds).
- Clock skew is injected at the inference stage by offsetting application-level timestamps. The operating system clock is not modified. Skew values tested range from 0 ms to 10 ms.

Metrics analysed:

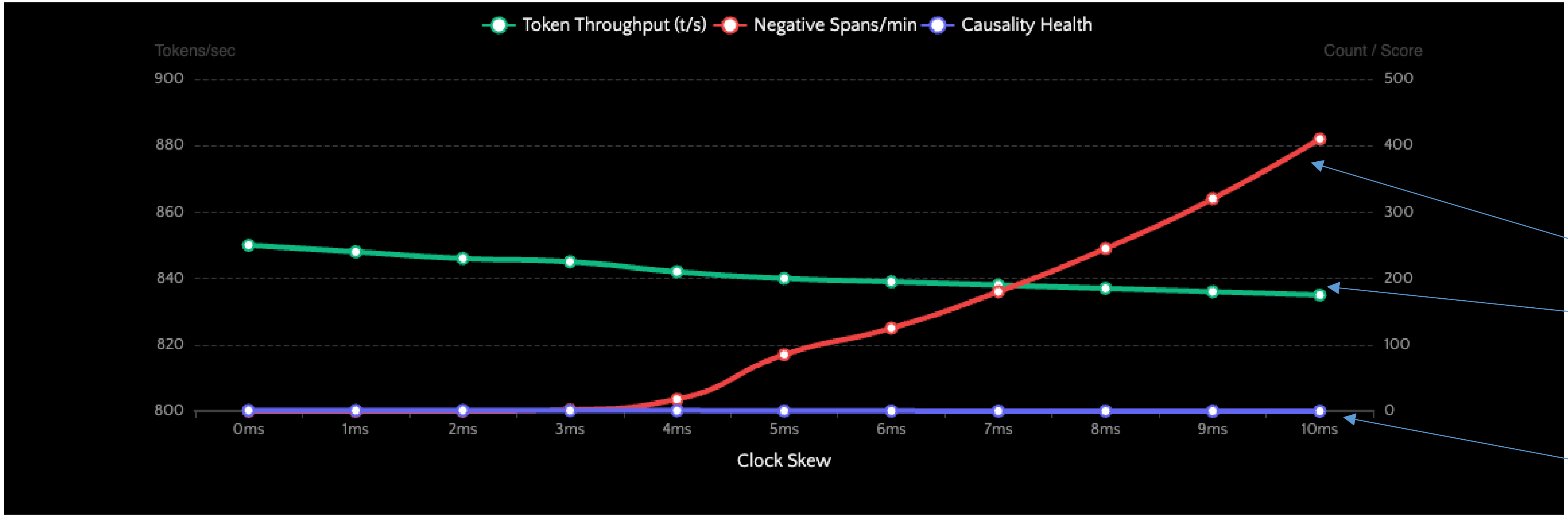
Negative timing spans: when timestamps imply impossible causal relationships, such as events being received before they were sent.

Causality health, defined as:

- 1 if no violations occur within a rolling 30-second window
- 0 otherwise

AI Inference Pipeline Flow

Impact on AI operations from bad timing



Negative Spans
Increases exponentially from 0 to 410/min. Clear signal of observability degradation.

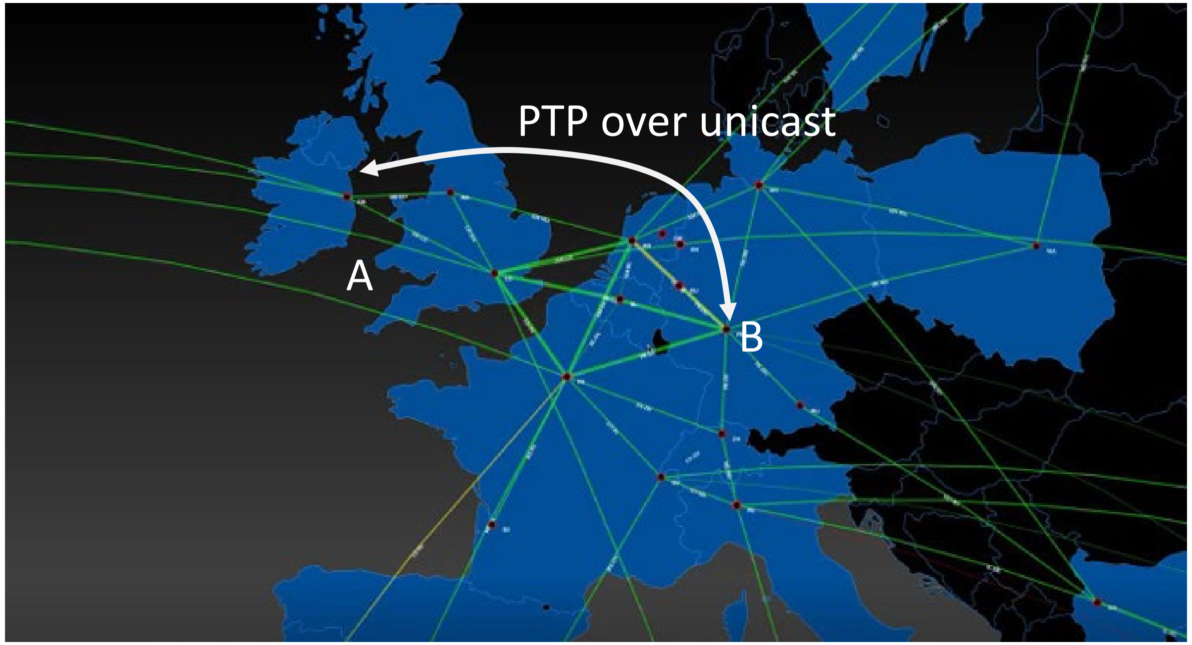
Token Throughput

Causality Health
Drops from 1.0 to 0.03. Observability becomes essentially unusable for debugging.

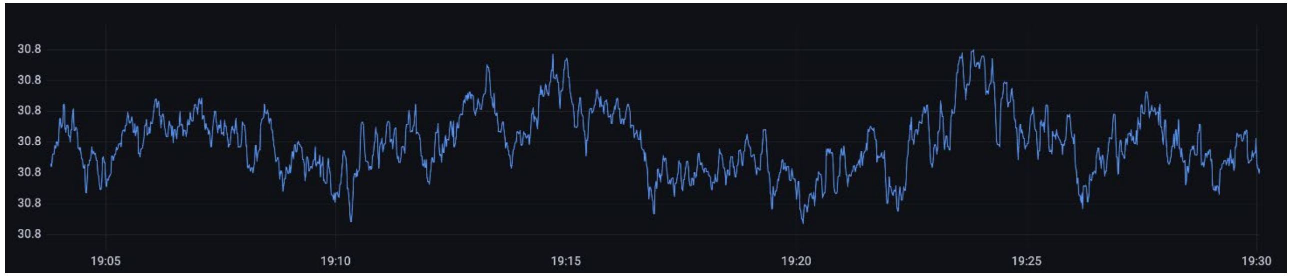
- Consistent behaviors across the experiments:
  - zero violations under zero skew
  - immediate and sustained violations once skew exceeds a small threshold
  - no impact on throughput or functional correctness, and persistence of violations independent of queueing
  - observability can fail after a threshold skew

Loss of causal trust can be detected explicitly at runtime, even though system behavior and throughput remain unchanged.

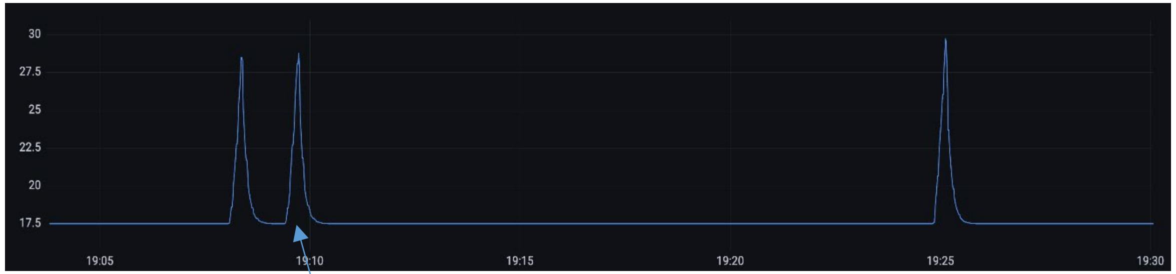
Network observability via PTP



Each server synchronized (e.g., via GNSS)
PTP is used between end points (A and B in this example)
To measure latency (mean path delay measurements)



Under normal conditions (no network rearrangement/ disruption)



Analysis of latency changes to indicate
Potential issues in the transport network

Conclusions

- Sync in Data centres is an area of increased interest; e.g.,
  - Synchronization and controlled latency are enabler to effective AI operation
  - Enabler of advanced network performance monitoring
- Data centre industry is relatively new to sync practices:
  - Need to define requirements, methodologies, solutions
  - Verification of the various technologies and scenarios is a key aspect
  - Important to verify performance also at the SW application layer

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