Network timing

The basics of clock synchronization

OSCILLOQUARTZ
An ADVA Optical Networking Company

Cummunication networks need synchronization

Network synchronization is vital as it directly impacts the quality of service provided to end users. Synchronization is at the heart of any modern telecommunication network; it provides the rhythm at which it operates. In particular, radio access networks such as LTE-TDD and LTE-Advanced require frequency and tight phase synchronization in order to efficiently utilize the available radio spectrum and offer superior user experience.

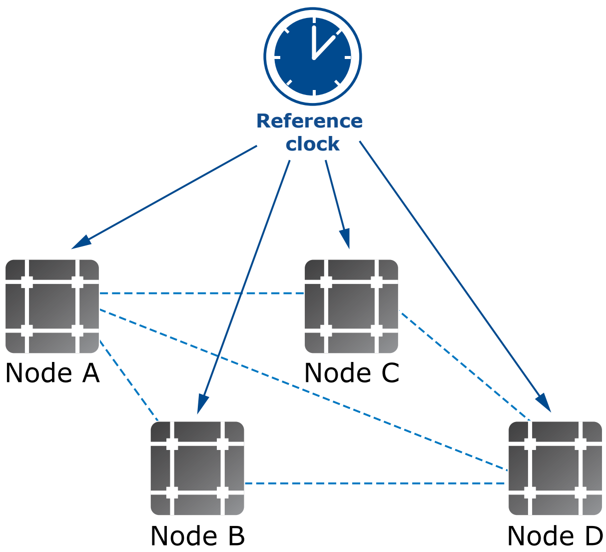
What is synchronization?

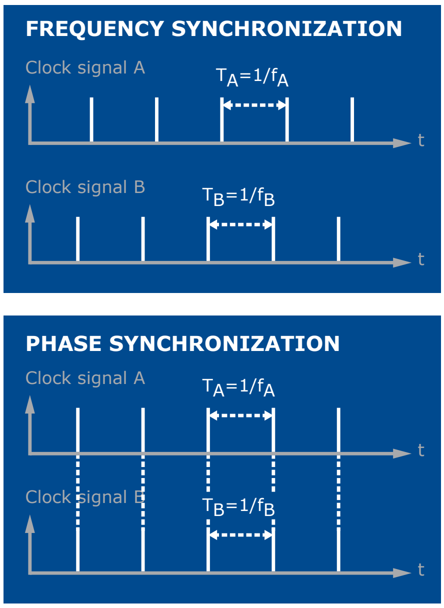
Network synchronization means the alignment of the frequency, phase and/or time clocks of all the nodes of a network by distributing a common frequency, phase or time reference.

The terms frequency and phase qualify what feature of a periodic timing signal is being aligned. The term time synchronization denotes the distribution of a common time scale.

Impact of poor synchronization

1. LTE-TDD: dropped calls
2. LTE-TDD: degraded specttral efficiency, loss of service
3. LTE-A MBSFN: video broadcast interruptions
4. LTE-A CoMP: lower bandwidth
5. LTE-A eICIC: increased interference between cells
6. LTE-A inter-site CA: capacity limitations





Poor synchronization harms business

Modern network synchronization solutions can provide reference timing signals of required quality to all types of telecommunication networks. Poor network synchronization often causes loss of data, which ultimately impacts the quality of service delivered over transport, switching, mobile and signaling networks. At best, insufficient synchronization causes degradation of the quality of experience; at worst, the entire communication network may go out of service. And that directly impacts business, leading to lower top-line and profitability.

Technical consequences

From a technical perspective, inaccurate synchronization of digital network infrastructure can cause a big increase in transmission error rates, which leads to poor quality of service or even service unavailability. Poor synchronization of radio base stations also leads to interference and inefficient use of radio spectrum resources.

That’s why precise and reliable network synchronization increases customer satisfaction, superior network availability, high throughput and efficient use of radio spectrum resources.

Synchronization of PDH networks

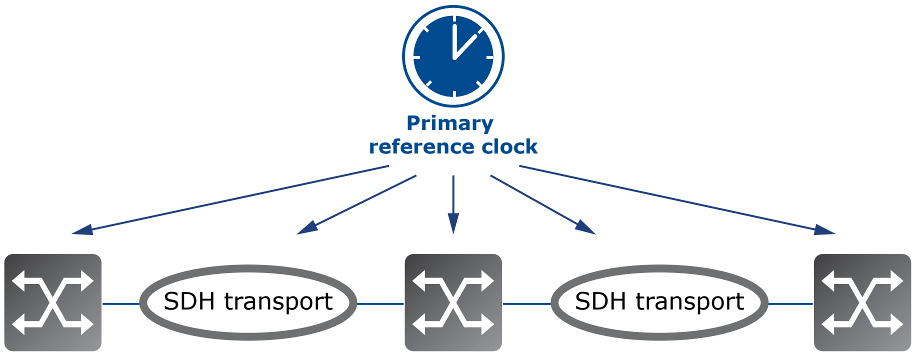
Plesiochronous digital hierarchy (PDH) transport networks only require synchronization of clients such as primary rate multiplexers, digital cross connect and exchanges. The PDH transport network itself is designed to work in plesiochronous mode and does not require synchronization. To transport timing between network elements requiring synchronization, operators generally use conventional 2Mbit/s signals transported across the network.

Primary rate multiplexers and cross-connecting devices are synchronized to a single primary reference clock (PRC), compliant with ITU-T Recommendation G.811. Synchronization supply units (SSUs) are deployed to minimize the detrimental effects of losing traceability to the PRC due to link and equipment failures. Working in holdover mode, the SSUs are able to deliver a synchronization signal close to PRC quality for several days.

Synchronization of SDH networks

In contrast to PDH networks, Synchronous Digital Hierarchy (SDH) networks require frequency synchronization of all network elements. Lack of precise synchronization leads to generation of pointer adjustments on STM-n aggregation signals, as well as jitter and wander on client signals. All cross-connecting, multiplexing and de-multiplexing operations require strict synchronism of all STM-n signals and synchronization to a single PRC also compliant with ITU-T Recommendation G.811.

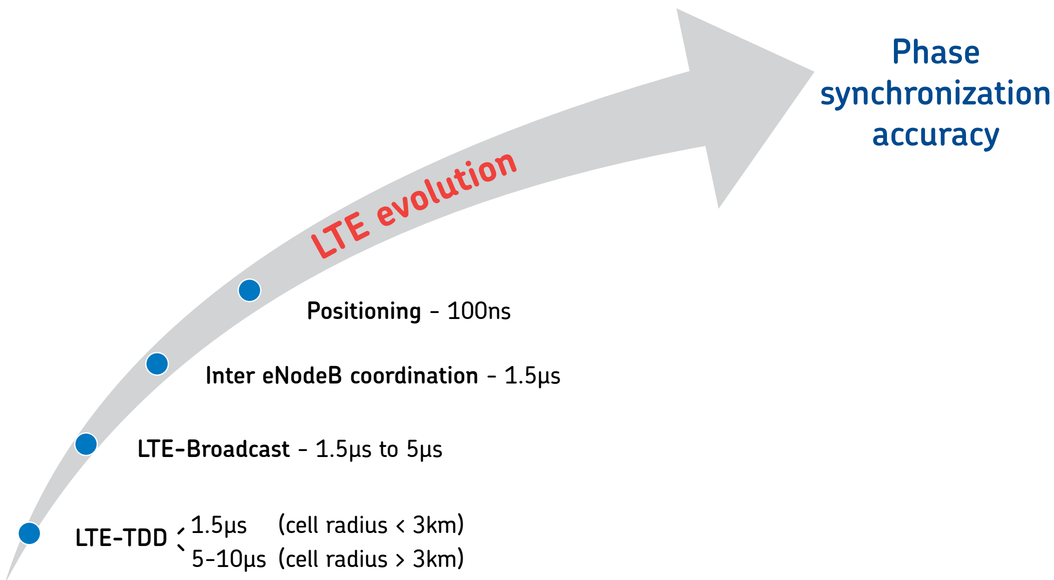
SSUs are in certain locations according to design rules specified by ITU-T Recommendation G.803. In addition to providing holdover protection in case of link and equipment failures, the SSUs act as highly efficient filters preventing excessive accumulation of jitter and wander.



SDH network synchronization

Radio access network synchronization

The needs of mobile networks in general and radio access networks (RAN) in particular are driving most of the current synchronization-related efforts in standards bodies. Each RAN technology has different frequency and phase synchronization requirements for both the radio interface and the backhaul network. Frequency synchronization is a strict requirement for all technologies, whereas phase alignment becomes mandatory for more recent technologies and services.



Synchronization delivery

Global Navigation Satellite System (GNSS) receivers can be deployed at cell site locations to provide an accurate clock signal locally, fulfilling frequency, phase and time synchronization requirements of all radio access network technologies. GNSSs platforms such us GPS (North America), GLONASS (Russia), GALILEO (Europe) and BEIDOU (China), provide global coverage and facilitate phase synchronization within +/-100ns of Coordinated Universal Time (UTC). However sync delivery solutions based only on GNSS receivers may not be sufficient.

Synchronous Ethernet (SyncE)

Frequency synchronization can be distributed over Synchronous Ethernet networks from a central PRC to the cell sites. Synchronous Ethernet differs from ordinary Ethernet solely by the fact that the physical line signal's timing is traceable to the PRC. SSUs are deployed for the same reasons and according to the same network design rules as in SDH (ITU-T Recommendation G.803).

Packet-based synchronization

IEEE 1588v2 Precision Time Protocol (PTP) is considered to be the most efficient synchronization solution operating over the top of the underlying packet network infrastructure. It fulfills all synchronization requirements in terms of frequency, phase and time alignment. Designed as a master/slave application, it can provide very accurate synchronization, down to a few hundred nanoseconds. Packet deviation variation (PDV) and packet delay asymmetry must be controlled within defined limits.

Telecom profile for frequency delivery

The Telecom Profile defined by ITU-T Recommendation G.8265.1 is designed to operate across PTP-unaware packet networks. Utilizing IP unicast, frequency synchronization information can be recovered by a slave situated far from a central distribution entity termed a grandmaster. Limits on PDV have to be guaranteed.

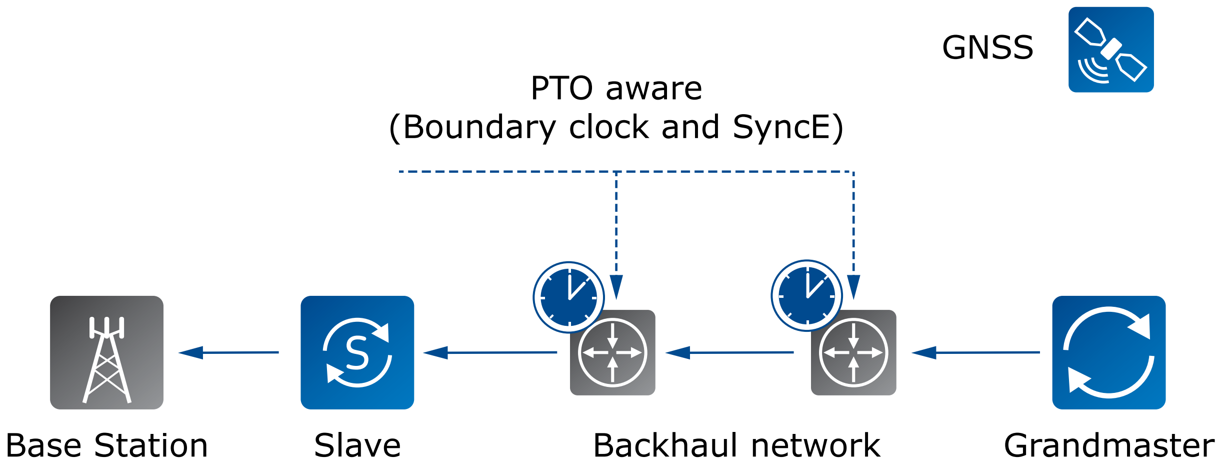
"GNSS everywhere" challenges

1. Antennas need to have line-of-sight to multiple satellites
2. Signal is easy to jam, both maliciously and inadvertently
3. Weather conditions and reflections from tall buildings cause interference
4. Deployment and maintenance cost in urban areas are high
5. No adequate solution achieves 72-hour holdover at +/-1.1µs in case of outage

Profile for frequency and phase delivery

To apply the profiles defined by ITU-T Recommendation G.8275.1 or G.8275.2, a centrally located grandmaster initiates PTP flows over the top of a fully (G.8275.1) or partially (G.8275.2) PTP-aware network.

For frequency and phase information recovery with guaranteed performance, G.8275.1 specifies that all network elements need to support SyncE and transparent/boundary clock functionality. Implementing this technique on top of existing legacy networks is complicated and costly. G.8275.2 significantly relaxes this requirement by mandating partial awareness only. Limits on PDV and packet delay asymmetry have to be guaranteed.



Centralized grandmaster

In most telecommunication networks operated today, grandmaster (GM) clocks are deployed at central network locations such as core sites where backbone network links terminate or elements of the mobile core reside. Each grandmaster is dimensioned to serve a large number of remote clients and forwards PTP-coded synchronization information to slave clocks integrated into or situated next to client equipment at the edge of the network.

Following this approach, PTP frames are generally forwarded over multiple network hops before they reach their slave clock destination. A synchronization architecture built according to this principle is valid and efficient for frequency synchronization, because only PDV generated by the network needs to be limited.

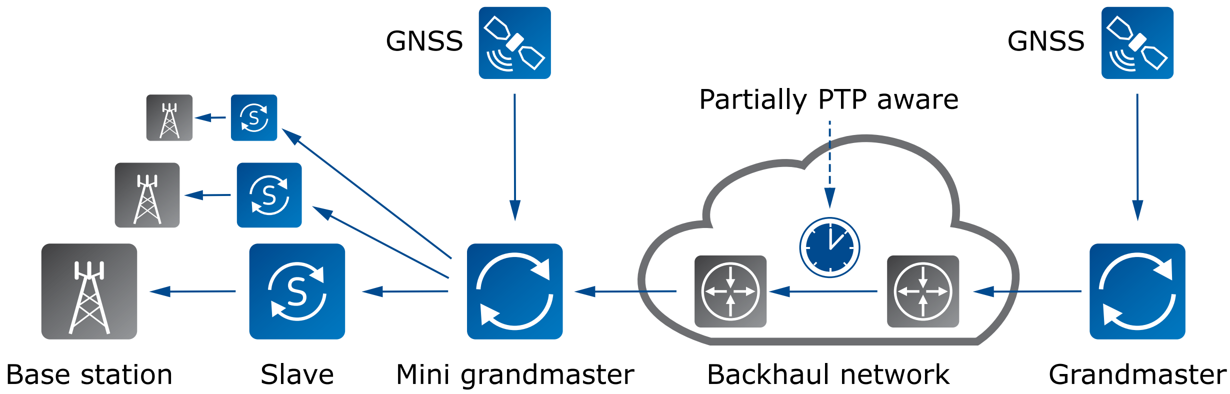
Deriving and assuring accurate phase synchronization at the network edge within the limits required by LTE-TDD and LTE-Advanced applications requires not just PDV, but also packet delay asymmetry to be constrained. In an architecture based on centralized grandmasters, the entire backhaul network needs to be PTP-aware and to perform boundary clock or transparent operation at each node – a stretch for most networks in service today.

A better approach: distributed mini-GM

The alternative approach focuses on the last mile and deploys cost-effective mini-grandmaster devices at the edge of the network, offering moderate grandmaster capacity and scalability sufficient for servicing a smaller number of slave clocks. Placing such devices at the first aggregation stage of a packet network enables PTP distribution to start closer to the cell site.

Involving a minimal number of hops between the mini-grandmaster and the slave clock has two elementary advantages. Firstly, it simplifies the maintenance of the integrity of the PTP timing reference. Secondly it reduces cost by avoiding the need to add PTP-awareness to the entire network.

The distributed mini-grandmaster approach also provides significantly better scalability of the timing domain and reduces cost compared to installing GNSS receivers at every cell site. These are important considerations in the context of large-scale rollouts of public access small cell networks.



A distributed grandmaster approach simplifies maintenance, provides better scalability and reduces overall cost

Assisted partial timing support

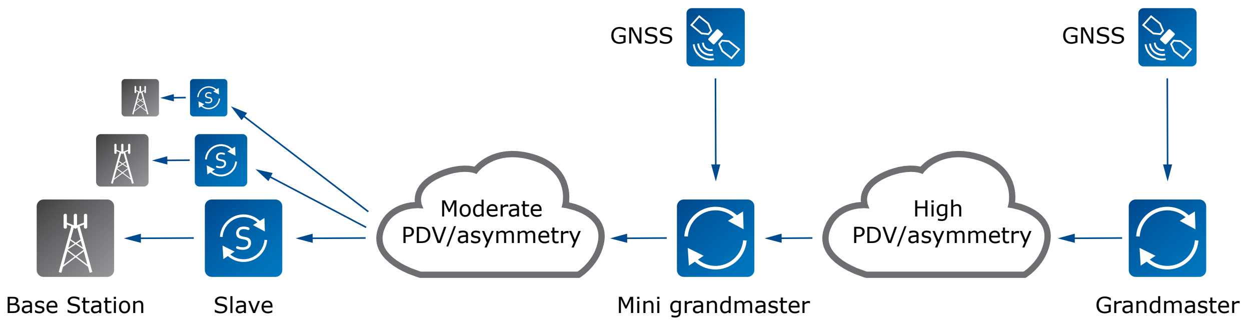
Assisted partial timing support (APTS) was developed as a new concept integrating the benefits of both GNSS receiver and IEEE 1588v2 PTP technology. The idea behind the combination of both technologies is the use of GNSS as the primary time reference for feeding the mini-grandmaster deployed at locations where the first packet network aggregation layer is situated, complemented by network-based timing available from a grandmaster in the network core. This combination has the benefit of assisting and maintaining the time base during holdover periods when tracking the GNSS signal is not possible. APTS is specified by ITU-T Recommendation G.8275.2.

Precise and accurate clock behavior during holdover periods longer than 72 hours is consequently assured while significantly reducing the challenge of network operations. Incidents such as bad weather conditions and GNSS signal jamming can be isolated and have no influence on the performance of the mobile network performance.

Auto-calibration

Using the combination of GNSS and network-based time sources also enables auto-calibration of the IEEE 1588v2 PTP recovery algorithm. Auto-calibration is used to actively compensate for dynamic network asymmetries and to monitor whether the clock signal recovered from the central grandmaster is suitable for service.

Auto-calibration in APTS substantially relaxes the requirement to deploy PTP-aware network elements along the entire communication path from the core to the edge of the network. It therefore provides a means to enhance the stability and precision of timing distribution while minimizing the cost.



An advanced mini grandmaster maintains a precise and accurate time base during holdover periods longer than 72h

Synchronization assurance

The Oscilloquartz portfolio of IEEE 1588v2 PTP access grandmasters has the unique capability of monitoring synchronization quality while operating in service. The powerful Syncjack™ performance monitoring suite includes various tools to test the accuracy and performance of clock signals and the usability of networks. What's more the FSP Sync Manager complements the widely-deployed FSP Network Manager with powerful synchronization network analysis and display tools.

Clock accuracy

This measures the frequency or phase accuracy and stability of physical-layer timing signals relative to a synchronization reference, which can be internal, external, recovered or originating from a GNSS signal.

Clock analysis

This has the following use cases:

- To measure the frequency or phase quality of a PTP packet timing signal directly at a master or a slave port, in order to evaluate the quality of the associated PTP master or slave clock under testing
- To give a measure of the performance potential of a PTP packet flow which was transported over a network by estimating the frequency or phase quality of the timing that a PTP slave clock would recover from the PTP packet flow under testing
- To monitor the state of the OSA internal PTP slave clock and estimate the quality of the internal timing recovery function without using a synchronization reference

TIE, TE and MTIE measurements are based on time stamps embedded in the PTP packets, which are compared against a synchronization reference signal (typically GNSS). Additionally, performance scores provide an easy interpretation of the results.

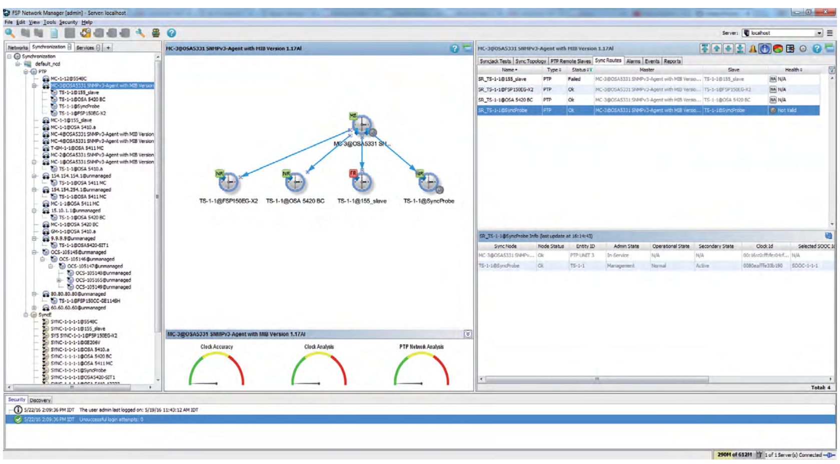
Active and passive probing

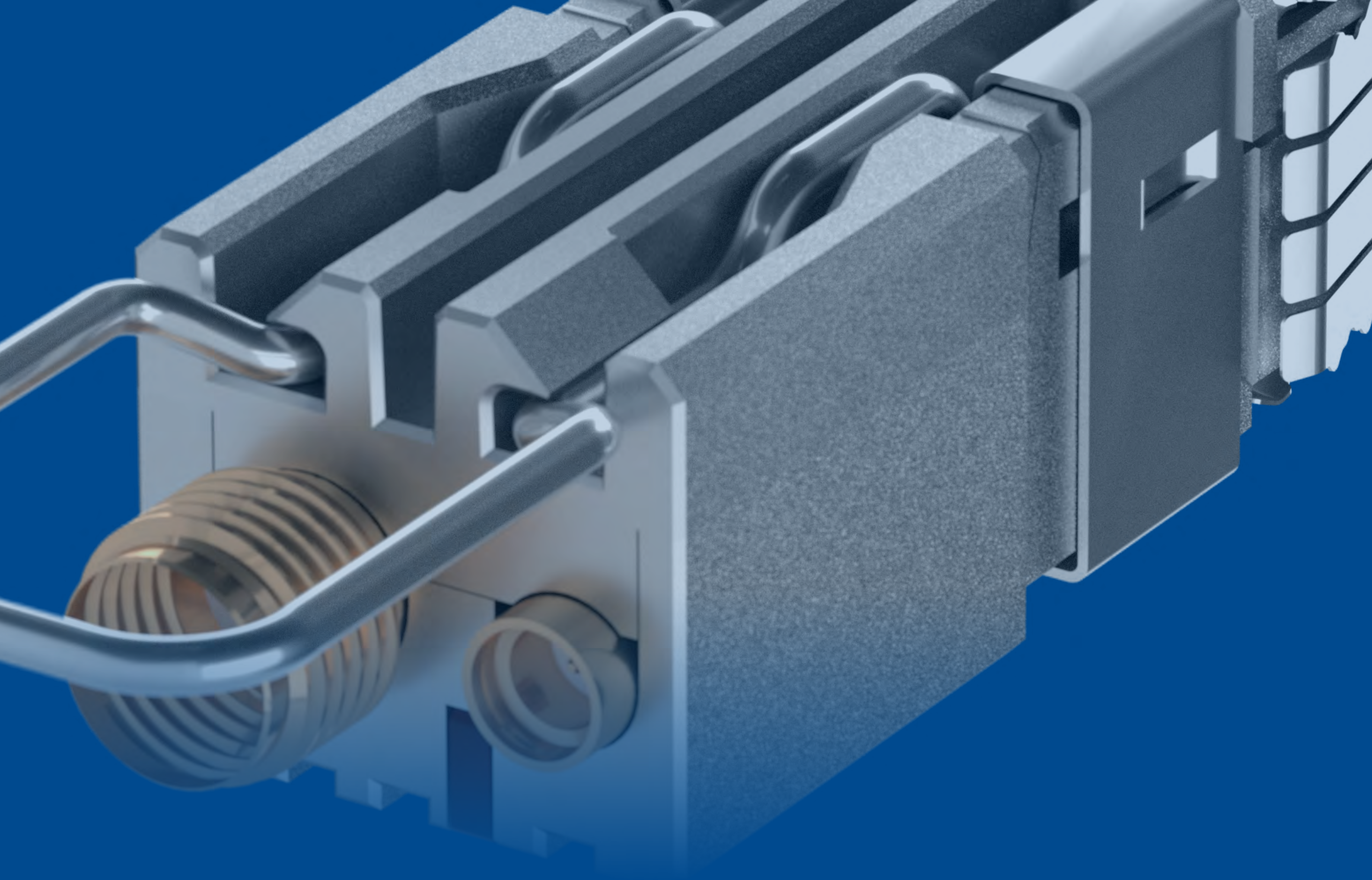
1. Specified in ITU-T Recommendation G.8273
2. Active technique: a probe device participates in the packet exchange and performs measurements at the same time as it transmits and receives the timing packets.
3. Passive technique: a probe device monitors packet exchanges over a communication link and acts as an observer.
4. Both options are supported in parallel.

PTP network analysis

This is used for analysis of the packet delays in the packet transport network. Since packet delay variation and packet delay asymmetry need to be constrained, their analysis provides information about the usability of the packet network for the transport of PTP. The results are based on time stamps embedded in the PTP packets, which are compared against a synchronization reference signal (typically GNSS). The results are presented in the form of various statistical functions.

Both active and passive modes are possible in clock and PTP network analysis.





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About ADVA Optical Networking

ADVA Optical Networking is a company founded on innovation and driven to help our customers succeed. For over two decades our technology has empowered networks across the globe. We're continually developing breakthrough hardware and software that leads the networking industry and creates new business opportunities. It's these open connectivity solutions that enable our customers to deliver the cloud and mobile services that are vital to today's society and for imagining new tomorrows. Together, we're building a truly connected and sustainable future. For more information on how we can help you, please visit us at: www.advaoptical.com.

About Oscilloquartz

Oscilloquartz is a pioneer in time and frequency synchronization. We design, manufacture and deploy end-to-end synchronization systems that ensure the delivery and assurance of highly precise timing information over next-generation packet and legacy networks. As an ADVA Optical Networking company, we're creating new opportunities for tomorrow's networks. For more information, please visit us at: www.oscilloquartz.com and www.advaoptical.com.

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