# ASSISTED
# PARTIAL TIMING SUPPORT

Assured Delivery of Precise Time and Phase Synchronization

OSCILLOQUARTZ
An ADVA Optical Networking Company

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## Need for Phase Synchronization

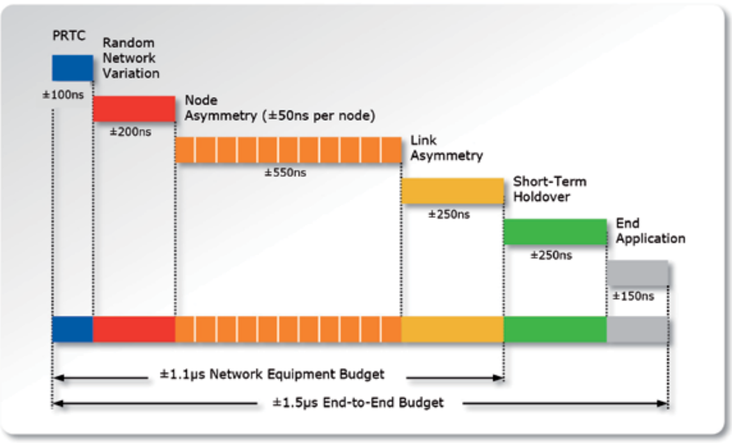
*Rising demand for mobile broadband services and the evolution of cellular networks toward higher capacities and new air interfaces create a need to evolve existing synchronization network architectures. Driven by the rollout of public access small cells and LTE-Advanced functionalities such as Enhanced Inter-Cell Interference Coordination (eICIC) and Coordinated Multipoint (CoMP) transmission, radio base station clocks are now required to operate in phase with sub-microsecond accuracy in addition to legacy frequency synchronization.*

*Inaccurate phase alignment not only reduces the efficiency of interference coordination and spectrum control techniques, it also causes additional interference and may degrade user experience or cause network outages. The Time Division Duplex (TDD) operation mode of LTE and LTE-Advanced, which allows assigning up- and downlink capacity asymmetrically and flexibly, also comes at the expense of tightly coordinating transmission times of adjacent base stations. Precise phase alignment is an important new requirement currently not supported by most mobile backhaul network architectures.*

### Synchronization Aspects in LTE and LTE-Advanced

In order to permit correct handover between adjacent radio base stations in the presence of Doppler shift generated by a moving mobile user, the 3rd Generation Partnership Project (3GPP) requires the radio frequency at an LTE or LTE-Advanced base station to be accurate to within 50 parts per billion (ppb) of the nominal frequency at all times. In order to accommodate for timing holdover behavior and random network variation, ITU-T G.8261.1 specifies the reference input to the base station to be more stable than 16ppb.

While requirements for frequency synchronization are generally identical for all radio access technologies including LTE and LTE-Advanced, the mandatory accuracy of phase alignment depends on the type of radio interface and the spectrum coordination and interference control techniques applied. TDD operation requires precise phase alignment of ±1.5µs, whereas eICIC and CoMP have implementation dependent requirements between ±1.5 and ±5µs.




Considering margins for short term holdover behavior and the slave clock end application leads to an end-to-end network equipment budget of ±1.1µs according to ITU-T G.8271.1. This budget includes implications generated by reference clock accuracy, random network variation plus node and link asymmetry compensation.

### Network Performance Challenge

Deriving timing information for the synchronization of radio base stations inherently from the backhaul network is considered the preferred solution. This approach is relatively simple and straightforward for frequency synchronization. The distribution of phase alignment information across packet-switched networks, however, constitutes a significant challenge when targeting an accuracy of ±1µs or better. The non-deterministic store-and-forward principle applied by packet switching technology imposes Packet Delay Variation (PDV) and asymmetry in delay on all packets traversing the network. While PDV can be filtered effectively by clock recovery algorithms, both static and dynamic delay asymmetries have a significantly negative impact on the accuracy of the recovered clock. Dynamic delay asymmetries require additional effort to compensate for in particular.

### Operational Boundary Conditions

Frequency and phase of radio base station clocks must be synchronized to a reference at all times to provide superior user experience and avoid network outage. Clock holdover strategies are therefore critical in case of losing traceability of the reference. Local oscillators deployed at cell site locations are generally a practical solution for maintaining frequency synchronization for a holdover target of 72 hours, which is a common requirement for efficient network operations. Maintaining accurate phase synchronization during holdover periods, however, constitutes a far bigger challenge. Even the deployment of Cesium clocks will hold ±1µs for only one day. Note that ±1µs corresponds to approximately 0.004ppb, which is stricter than the standard requirement for a Primary Reference Time Clock (PRTC). Alternative solutions are therefore mandatory.

### AnyCell™ Connectivity for LTE-Advanced

- Universal end-to-end solution for service aggregation and demarcation
- Economic solutions for both macro cell and small cell backhaul
- Managed CPRI fronthaul for single and pooled remote radio heads
- Syncjack™ for provisioning of SLA-based synchronization services
- Integrated service-based management of data and synchronization network

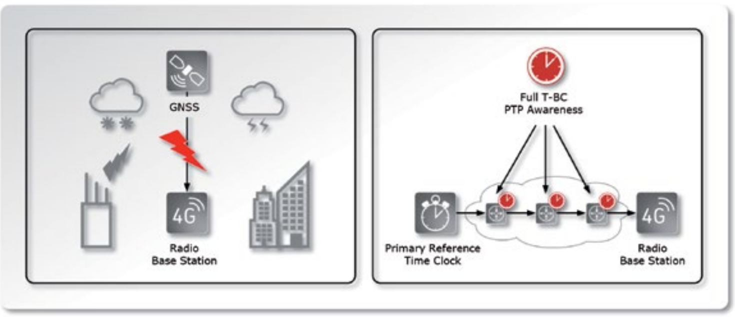
# Delivering Time and Phase Synchronization

*Precise time and phase synchronization of radio base stations can be achieved by two fundamentally different technologies. Building a network-based timing architecture utilizes the IEEE 1588v2 Precision Time Protocol (PTP) for distributing timing information from a centrally located PTP Grandmaster device to the slave clocks situated at cell site locations. This communication is typically facilitated in-band across the mobile backhaul network. Alternatively, a precise timing signal can be retrieved from a dedicated Global Navigation Satellite System (GNSS) receiver deployed at cell site locations and providing an accurate clock signal locally. Both technology options come with benefits and challenges when it comes to precision, availability and operational simplicity. The feasibility and economic viability of upgrading existing network infrastructure plays a role, too.*

## Global Navigation Satellite System

GNSS satellites are equipped with atomic clocks which utilize internal oscillators to deliver timing measurements accurate to ±20ns. This provides timing-critical applications with the world's most precise and stable source of timing information. The 31 satellites comprising the Global Positioning System (GPS) provide global coverage and facilitate time synchronization accurate to within ±100ns of Coordinated Universal Time (UTC). Alternative GNSS platforms are the Russian Global Navigation Satellite System (GLONASS) and Galileo launched by the European Union.

While deployment of GNSS receivers is relatively simple and fast, providing timing exclusively based on local GNSS receivers introduces significant challenges. The most critical shortcomings are that antennas need to have line-of-sight to multiple satellites, the fact that the signal is easy to jam both maliciously and inadvertently, interference caused by weather conditions and reflections at tall buildings. In addition, deployment and maintenance cost in urban areas and at small cell sites is comparatively high. There is also no adequate solution to achieve 72 hour holdover at ±1.1µs accuracy in case of GNSS outage.




## Precision Time Protocol

Network-based timing distribution utilizing IEEE 1588v2 PTP is not impacted by the aforementioned challenges. It operates in a controlled environment, is suitable for both frequency and phase synchronization and is able to deliver the clock precision required. Following a building block approach, the overall architecture and clock specifications are defined by the ITU-T, with examples of time error budgets outlined in ITU-T G.8271.1. The drawback of this approach is that the network needs to actively contribute to timing distribution. All network elements on the distribution path need to be PTP-aware, i.e. providing Telecom Boundary Clock (T-BC) functionality and syntonization based on Synchronous Ethernet (SyncE). This strict requirement implies upgrading existing network infrastructure, which in many cases is not feasible or economically viable. Furthermore, static and dynamic delay asymmetries, the most critical network performance criteria affecting phase synchronization, cannot be actively monitored and controlled.

## Assisted Partial Timing Support

In order to overcome these challenges, Assisted Partial Timing Support (APTS) was developed as a new concept integrating the benefits of both technologies. The main idea behind this approach is using GNSS as the primary time reference at cell site locations or at an aggregation point close to the cell sites, complemented by network-based timing distribution to assist and maintain the time base during holdover periods when GNSS tracking is not available. Precise and accurate clock behavior during holdover periods longer than 72 hours is consequently assured, 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 mobile network performance. Distributed deployment of reference time sources also enables auto-calibration of the IEEE 1588v2 PTP recovery algorithm to actively compensate for dynamic network asymmetries and to monitor whether the recovered clock signal is suitable for service. Auto-calibration in APTS also relaxes the requirement to exclusively deploy PTP-aware network elements along the communication path.

## Oscilloquartz Synchronization Delivery and Assurance Solution

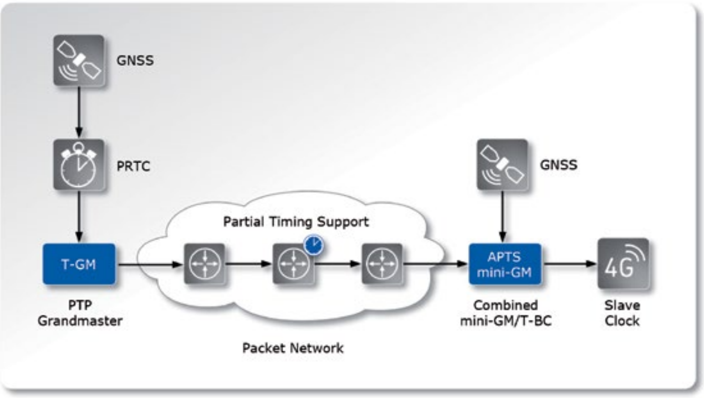
# Synergetic Operation of GNSS and PTP

*APTS is currently discussed by the ITU-T, defining the architecture and corresponding clock specifications. Amending the existing set of specifications by a profile addressing partial timing support is predominantly driven by the need to enable precise phase alignment also over existing networks, including third party access networks that may not have built-in PTP support.*

*The main component of APTS is to synchronize to a GNSS signal as primary source and provide backup by tracking a PRTC situated further back in the network via IEEE 1588v2 PTP and SyncE. A mini-Grandmaster deployed at cell tower hub sites can act as a timing reference for the local base station and slave clocks operating in subtended cell sites including public access small cells. Simultaneously tracking two independent reference clocks allows superior holdover performance in case a connection is lost. This is also valid over longer periods of time.*

## Distributed Mini-Grandmaster Approach

In IEEE 1588v2 PTP timing distribution architectures for frequency synchronization, Grandmaster clocks are deployed at central network locations and synchronize to an external PRTC. Each Grandmaster communicates timing information to synchronize subtended telecom slave clocks. Scalability to support a large number of slave clocks is a key attribute of synchronization network designs and minimizes capital expenditure and operational cost. This architecture is implemented in many networks and has proven to be efficient for frequency synchronization.




Deriving accurate phase synchronization to within ±1.1µs or better, however, requires the entire mobile backhaul network to be PTP-aware and perform T-BCs operation at each node. An alternative approach is to deploy mini-Grandmaster functionality at significantly lower cost to the edge of the network. Locating such devices at the first aggregation stage or at cell tower hub sites where GNSS antennas for timing reference can be installed easily, enables IEEE 1588v2 PTP distribution to begin closer to the cell site. Involving a minimal number of hops between the mini-Grandmaster and the slave clocks simplifies maintenance of the integrity of the PTP timing reference. The distributed mini-Grandmaster approach also provides a significantly better scalability of the timing architecture and reduced cost compared to installing GNSS at every cell site, which are important factors in the context of large-scale rollouts of public access small cells.

## Assisted Holdover

One key characteristic of a PTP Grandmaster clock is the provision of holdover capability. The intention is to maintain an accurate timing output even when the input reference is not available for any reason. A general requirement of mobile network operators is that the system must remain operational for 72 hours to allow time for troubleshooting.

Since even Cesium clocks will hold ±1µs only for one day, holdover assistance is a must to meet synchronization requirements. In APTS, support from network-based timing through PTP and SyncE maintains phase accuracy in case of a lost connection to the primary timing source GNSS. The Grandmaster controlling the mini-Grandmaster can be located further back in the core of the network or at an aggregation point closer to the cell sites.

## Operation over Legacy Networks

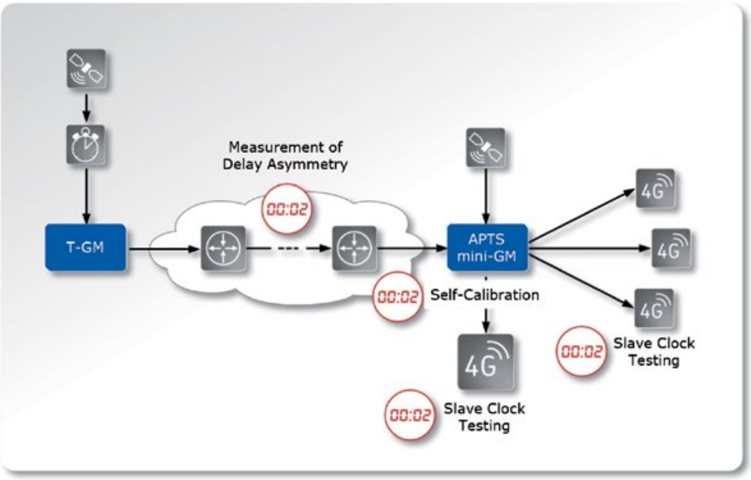
Tracking the reference time of two independent PRTCs during normal operation allows relaxing the requirement for full PTP on-path support across the mobile backhaul network. Static delay asymmetries experienced by timing packets travelling between the PTP Grandmaster deployed centrally and the local slave clock can be quantified accurately, enabling precise calibration of the slave clock. The network budget for dynamic time error is therefore significantly enlarged, consequently simplifying the operation of IEEE 1588v2 PTP across legacy or leased networks without full on-path support. Strict priority forwarding of packets carrying timing information, however, is still mandatory and the number of hops should be kept at a minimum.

# Assuring Precise Time and Phase Synchronization

*The ability to consistently monitor, accurately test and troubleshoot synchronization infrastructure when delivering precise timing is mandatory in order to assure clock accuracy. This directly affects the quality of experience observed by the mobile user. Network timing behavior is not a stationary process. It is subject to dynamic network and environmental conditions such as temperature fluctuations over the short and longer term. Timing assurance becomes increasingly critical when network elements like radio base stations have to operate in phase at highest precision. Appropriate tools are required for cost-effective and time-efficient end-to-end monitoring of all clocks deployed in the synchronization network during all phases of the network lifecycle.*

## Slave Clock Validation and Monitoring

Following the approach of APTS and implementing PTP mini-Grandmaster functionality at the edge of the mobile backhaul network provides the basis for efficient validation and monitoring of slave clocks locked to the mini-Grandmaster. PTP communication between a Grandmaster and its slaves is bidirectional, with all slaves continuously providing information about the recovered time back to the Grandmaster. Combining sync probe and mini-Grandmaster technology in a single network device enables timing distribution and assurance of slave clocks in local and subtended radio base stations.




The probe function essentially compares the feedback information sent by remote slaves against the reference time, giving real-time information on whether slave clocks are precisely locked. In addition, the slave clock running in a local base station can be monitored utilizing physical timing interfaces instead of analyzing the PTP packet flow. Deploying a supporting synchronization network management tool in the service provider Network Operations Center (NOC) enables the remote monitoring of all clocks and fault localization. Network operators have full visibility and can assure that all clocks in the network are locked to the PRTC.

## Auto-Calibration of Delay Asymmetry

The sensitivity of IEEE 1588v2 PTP to static and dynamic delay asymmetries requires calibration of slave clocks based on measured one-way delay information. Auto-calibration avoids manual calibration of the slave clock tracking a PRTC further back in the network and providing assistance during holdover periods. Automatic self-calibration algorithms compare the time recovered by the slave clock against the local reference and use the offset to control delay compensation.

Implementation of such functionality provides three major advantages with regard to simplified network operations and assured timing accuracy. First, the slave clock backing up GNSS can constantly be monitored to assure it is running at accurate frequency and phase. Second, manual calibration of the slave clock becomes obsolete. Fast, automatic adaptation to network protection and reconfiguration events on the corresponding backhaul link requires no manual intervention and increases stability. Last but not least, the requirement for full PTP on-path support across the mobile backhaul network is relaxed to partial or even no support.

## Integration with Forwarding Plane

Today, synchronization networks are predominantly deployed as an over-the-top solution to existing Carrier Ethernet or IP/MPLS networks. This approach suggests itself when there is little or no interaction between the forwarding plane and the synchronization plane. With the evolution of 4G air interfaces and the resulting requirement for phase synchronization accurate to within ±1.1µs, the need for PTP-awareness of switching and routing equipment becomes essential. Synchronization is no longer an over-the-top solution and mandates tighter integration with data forwarding devices. As a consequence, synchronization distribution and assurance functionality needs to be integrated into network devices. IEEE 1588v2 PTP slave clocks integrated into radio base stations are commonly available today. Integration of tools for synchronization distribution and assurance into packet-based network termination and aggregation devices is needed in addition to support precise phase synchronization.

## Syncjack™ Timing Assurance

- Complete end-to-end synchronization network management platform
- Clock accuracy measurement and enhanced statistics based on physical or packet-based timing
- Operates with external, internal or even self-recovered PTP clock reference
- Support of passive probe, active probe and testing mode
- New revenue from delivery of SLA-based synchronization services

Syncjack™

## 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

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## About ADVA Optical Networking

At ADVA Optical Networking we're creating new opportunities for tomorrow's networks, a new vision for a connected world. Our intelligent telecommunications hardware, software and services have been deployed by several hundred service providers and thousands of enterprises. Over the past twenty years, our innovative connectivity solutions have helped to drive our customers' networks forward, helped to drive their businesses to new levels of success. We forge close working relationships with all our customers. As your trusted partner we ensure that we're always ready to exceed your networking expectations. For more information on our products and our team, please visit us at: www.advaoptical.com.

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