PRECISE
PHASE SYNCHRONIZATION

Where Timing and Excellence Come as Standard

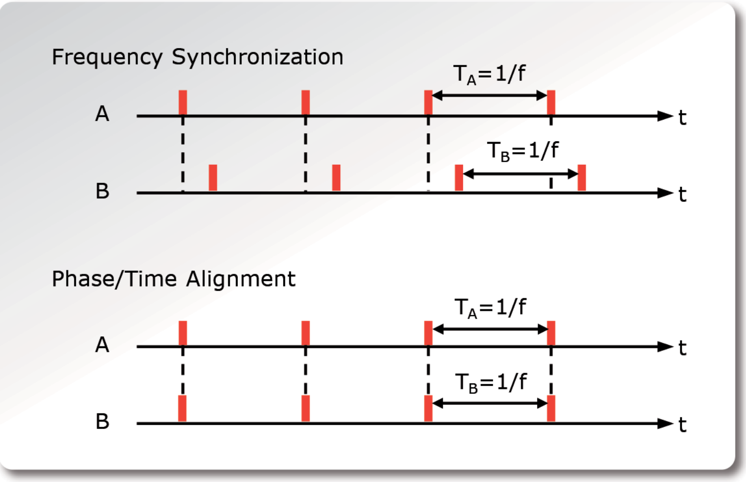
ADVA™ Optical Networking

RAN Evolution Drives Synchronization to New Limits

Mobile subscribers demand more and more bandwidth to support high-speed data and multimedia applications. Text messaging no longer satisfies subscribers' needs. Unlike voice services, mobile broadband is always-on and considered to be always available. To satisfy this demand, reduce costs and improve operating efficiencies, mobile operators around the world are evolving their Radio Access Networks (RAN). Various capacity-enhancing techniques enable them to squeeze more out of their macro cell networks. These techniques, however, do not sufficiently scale in dense urban areas where data traffic is rapidly increasing. Public access small cells have emerged as a cost-effective way to improve coverage and capacity of mobile services in such locations. Small cells are low-power wireless access points that operate in licensed spectrum, are operator-managed and feature edge-based intelligence.

Interference Coordination and Radio Spectrum Control

The resulting Heterogeneous Network (HetNet) deployment is a cost-effective way to counter unrelenting traffic demand. HetNets are a combination of macro cells, remote radio heads and low-power small cells. However, the deployment of a large number of small cells overlaying the macro cell layer introduces new technical challenges including interference coordination and radio spectrum control. When deploying a large number of small cells, cell overlap significantly increases and the number of users suffering from low throughput due to severe interference grows. Enhanced Inter-Cell Interference Coordination (eICIC) and Coordinated Multipoint Transmission (CoMP) provide important means for LTE-Advanced macro and small cells to time-share the radio resources for downlink transmission and therefore improve user experience. Both require stringent phase alignment to enable base stations to coordinate transmission time instants and avoid interference.



Capitalizing on Unpaired Spectrum

Unpaired spectrum offers a cost-effective solution for mobile operators to meet the growing demand for data. However, drawbacks of Time Division Duplex (TDD) technology need to be overcome to unlock the capacity potential of this spectrum. Using TDD technology in unpaired spectrum allows both uplink and downlink to be carried by the same frequency band. In addition, the TDD mode of LTE and LTE-Advanced allows for an asymmetric ratio of up- and downlink bandwidth, ideally suited for more efficient spectrum utilization with the increasingly asymmetric data consumption expected in the future. One challenge with TDD is that operators using adjacent blocks of spectrum need to synchronize their RANs so that base stations are sending uplink and downlink transmissions at the same time. If there is a misalignment, the base station trying to receive uplink traffic will receive interference from the base station transmitting downlink traffic.

Mobile Backhaul Needs to Deliver Phase Synchronization

New LTE-Advanced functionalities require base station clocks to be in phase with sub-microsecond accuracy to efficiently exploit the benefits of interference coordination and spectrum control techniques. The TDD operation mode of LTE and LTE-Advanced also requires base station clocks to operate in phase to coordinate up- and downlink transmission times. The distribution of timing information for phase synchronization of the RAN constitutes a particular challenge. Mobile backhaul networks need to actively contribute to timing distribution and provide on-path support in order to achieve highly accurate phase alignment. This is a new requirement and currently not supported by most backhaul network architectures.

FSP 150 Mobile Backhaul for LTE-Advanced

- Universal end-to-end solution for service aggregation and demarcation
- Syncjack™ for provisioning of SLA-based synchronization services
- Etherjack™ OAM tools for performance assured service delivery
- MEF 2.0 service flexibility for efficient resource utilization
- Integrated service-based management of data and synchronization network

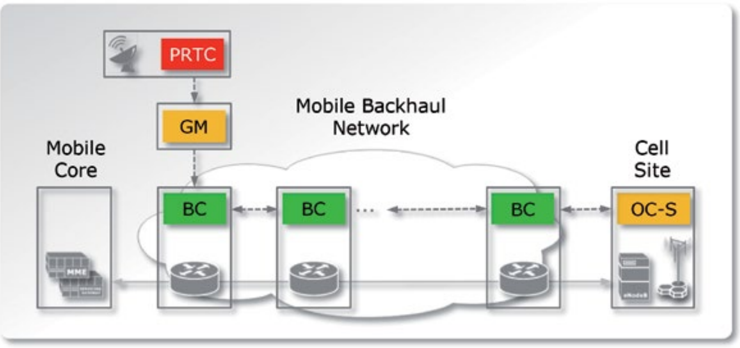
Etherjack™

Time Synchronization Principles

Mobile network operators face many challenges when starting to rollout small cells, upgrading to LTE-Advanced and utilizing unpaired spectrum. One challenge is synchronizing base station clocks to operate in phase. In the past, a centralized primary reference clock or distributed primary reference clocks using Global Navigation Satellite Systems (GNSS) such as Global Positioning System (GPS) were the technologies of choice for synchronization. With the emerging requirement for precise phase synchronization and concerns about relying only on GNSS, methods based on packet protocols like IEEE 1588v2 Precision Time Protocol (PTP) have been developed to deliver an accurate synchronization signal over mobile backhaul networks. Clock synchronization is trivial, in principle. The problem is that packet-based backhaul networks introduce delay that can be unpredictable, asymmetrical and highly variable. The key challenge is to be able to cope with these variations and to robustly and precisely negate the errors caused by delay variability.

Packet-Based Time Synchronization

IEEE 1588v2 PTP specifies different types of clocks and acts as a master to slave protocol exchanging packets in both directions that carry time stamps for recovering frequency, phase and time-of-day information. A slave clock in an end device is known as an Ordinary Slave Clock (OC-S), a clock in a transmission component like a Carrier Ethernet aggregation or network demarcation device is a Boundary Clock (BC) or Transparent Clock (TC). A Grandmaster (GM) linked to a Primary Reference Time Clock (PRTC), which is controlled ideally by a radio clock or a GNSS receiver, synchronizes the respective slaves connected to it. Operators can use PTP to provide synchronization directly across any packet network. However, they must ensure that the synchronization flow is not distorted by packet loss, asymmetrical delay or delay variation beyond the filtering capabilities of the slave clock.



On-Path Timing Support

The new LTE-Advanced functions require base station clocks to be in phase with accuracy in the range of 500 nanoseconds to efficiently operate eICIC and CoMP and ensure 911-service in North America. This clock accuracy is difficult to achieve without on-path support, i.e. backhaul networks need to participate actively in timing distribution. With Recommendation G.8275.1, the ITU-T has defined a Telecom Profile facilitating end-to-end frequency and phase synchronization across packet-based backhaul networks with on-path support. G.8275.1 indicates the deployment of BCs wherever there is a network component that inserts significant delay fluctuation. A BC has multiple network connections and can accurately bridge synchronization from one network segment to another. BCs improve the accuracy of clock synchronization by filtering network jitter and deliver better scale on the master.

Hybrid Technology Option

Synchronization techniques may be deployed in conjunction with others, providing a more robust and reliable solution. PTP and Synchronous Ethernet (SyncE) may be used co-operatively to deliver a frequency and time-of-day signal, taking advantage of the physical layer to transport traceable frequency information. ITU-T Recommendation G.8271.1 describes a reference model where SyncE is used to syntonize a chain of BCs from the master to the slave. The stability of the frequency reference reduces the dynamic time error accumulated in the chain of BCs, allowing PTP to deliver a time reference accurate to a few hundred nanoseconds. In addition, the stable frequency reference can be used to maintain accurate time synchronization for a certain period of time if the connection to the GM was broken.

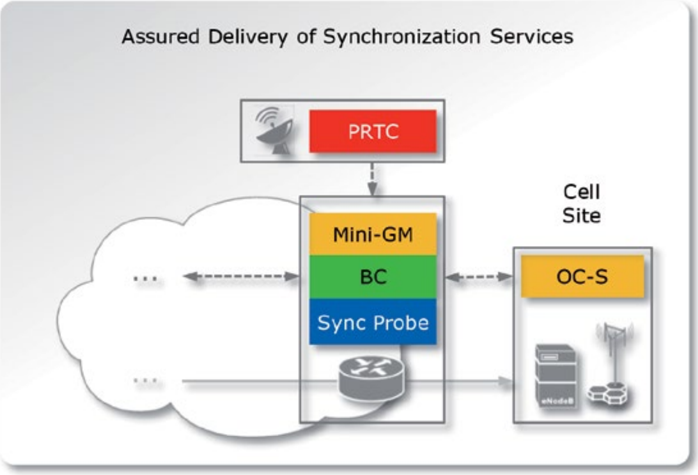
The ADVA FSP 150 Mobile Backhaul Solution

Telecom Profiles for Synchronization Services

The IEEE 1588v2 PTP is a complex protocol designed to be used in a number of different applications and environments. Some parts of the protocol are specifically aimed at certain applications and are not applicable to others, making it difficult to understand which sections of the protocol should be used in a particular environment. The concept of PTP profiles was therefore introduced by the ITU to enable other standards bodies to tailor PTP to particular applications. The idea of a profile is to specify particular combinations of options and attribute values to support a given application, with the goal of inter-operability between equipment designed for that application.

Evolving Standards to Cope with the Challenges

Focusing on telecom networks, the ITU-T is developing a broad set of recommendations addressing time and phase synchronization of RANs. Network limits for time synchronization across packet networks are an important performance characteristic and are defined in ITU-T Recommendation G.8271.1. The recommendation addresses the case of time and phase distribution across a packet network with full timing support to the protocol level and outlines the minimum requirements for the synchronization function of network elements. Maximum network limits of phase and time error are specified and the minimum equipment tolerance is defined in dependence of the phase and time error that shall not be exceeded. A second standard, ITU-T Recommendation G.8273, outlines a framework for phase and time clocks used in synchronizing network equipment that operates in a network according to G.8271.1. The recommendation defines testing and measurement architectures for time and phase clock accuracy including BCs, TCs and OCs.



1588v2 Telecom Service Profiles

ITU-T Recommendation G.8265.1 defines a telecom profile aimed at the distribution of accurate frequency over packet networks. This is primarily intended for use with synchronization of radio base stations, where the main requirement is to operate the radio interface at a frequency accuracy of within 50 parts per billion, which requires the recovered clock to operate within 16 parts per billion. 1588v2 PTP phase and time distribution across packet networks is addressed by the telecom profile defined in ITU-T Recommendation G.8275.1. The upcoming standard mandates the deployment of a BC at each intermediate node in conjunction with the use of SyncE to syntonize the chain of BCs from the master to the slave. It is targeted to fulfill the stringent requirements for phase synchronization imposed by interference coordination and radio spectrum control in LTE-Advanced. Delivering phase accuracy in the range of 500 nanoseconds is envisaged. The approach anticipated in the ITU-T Recommendation G.8275.2 aims at time and phase distribution with partial support from the backhaul network in contrast to full on-path support. Both architecture and performance aspects of this telecom profile still need to be specified. Partial network support would allow for simpler design of mobile backhaul networks.

Distributed Grandmaster Clocks

Reliable delivery of precise phase synchronization to the RAN can be supported by deploying distributed mini-GM functionality at the network edge. Mini-GM clocks are specifically designed to support HetNet deployments. They are compact and often integrated into Carrier Ethernet aggregation and network termination devices and are less costly compared to traditional GM clock implementations due to their adapted scalability. The deployment of mini-GM functionality at the network edge provides an alternative solution in case of losing traceability to the PRTC due to networking problems. It also enables continuous timing accuracy testing and measurement, which is a basic requirement for the assurance of precise time and phase synchronization.

Syncjack™ Timing Distribution

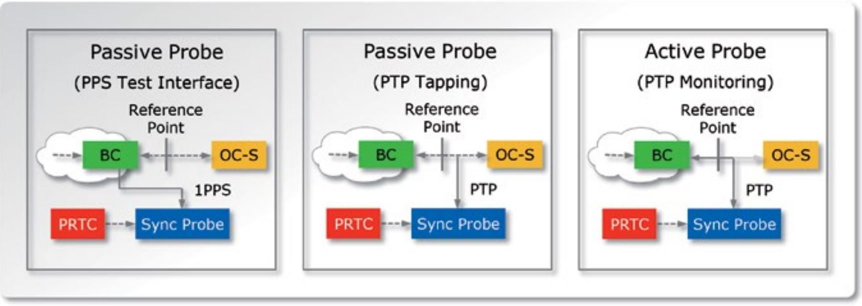
- Complete ordinary slave, boundary and transparent clock implementation
- Synchronous Ethernet for boundary clock syntonization
- Advanced mini-grandmaster functionality for efficient small cell rollout
- GNSS (GPS and GLONASS) primary reference time clock
- Compliant to ITU-T telecom profiles for time and phase synchronization

Assuring Precise Synchronization

The ability to consistently monitor and accurately test and troubleshoot synchronization infrastructure when delivering precise timing information utilizing IEEE 1588v2 PTP is mandatory for assuring clock accuracy. This directly affects the quality of experience observed by the mobile user. Assured delivery with guaranteed quality of service metrics is a necessity not only for data services but also for timing services. Timing service assurance tools similar to those developed for Operations, Administration and Maintenance (OAM) of Carrier Ethernet services and networks are required as PTP packet flows potentially traverse different technologies and operator networks.

Effective Monitoring Provides the Basis

What is the timing distribution topology? How accurate is the slave clock performing? Are all slave clocks tracking their masters? How to localize a fault? From a service assurance perspective, this is relevant and important information for all network operators delivering synchronization services. 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. Assurance becomes increasingly critical when network elements such as 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 the synchronization domain during all phases of the network lifecycle – installation, turn-up, in-service and troubleshooting. This is exactly what ADVA Optical Networking's Syncjack™ technology provides.



Testing and Probing the Network

Measuring the time and phase behavior of clocks is substantively different from measuring the frequency behavior. Metrics such as Maximum Time Interval Error (MTIE) and Time Deviation (TDEV) can be applied to time and phase accuracy measurement when assessing the dynamic error and wander of clocks. However, they are not sufficient to characterize the time error, i.e. monitoring static phase errors. Absolute phase and time accuracy of clocks can be measured by comparing clock signals against a time reference such as GNSS or alternatively and accurate PTP clock. Both active and passive modes are possible and specified in ITU-T Recommendation G.8273. With the active technique, a sync probe device participates in the packet exchange and performs measurements at the same time as it transmits and receives the timing packets. With the passive technique, a sync probe device monitors packet exchanges over a communication link and acts as an observer. ADVA Optical Networking's Syncjack™-enabled probe and network demarcation devices support both alternatives and can be deployed flexibly in fixed and mobile network operator infrastructures.

Simplified Synchronization Network Operations

To reduce the complexity of monitoring and testing synchronization networks and to identify potential problems before they cause outages, an integrated and automated test and measurement system can reduce the number of different tools required. It ensures that operators have the capabilities they need to effectively operate and test their synchronization network, address all problems and most importantly assign strict SLAs to synchronization delivery. Displaying information with different levels of detail simplifies step-by-step troubleshooting. Ideally, a first level provides an overall synchronization health indication. A second level gives high level health indication of each reporting tool, while a third level delivers detailed information for fault localization and troubleshooting. ADVA Optical Networking's Syncjack™ technology comes with a sophisticated management tool offering operators different layers of synchronization performance reporting in a structured and compact implementation. It unites precise frequency, phase and time-of-day synchronization delivery and assurance under one umbrella.

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™

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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.

Optical+Ethernet Innovation • Speed for Customers • Trusted Partner

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