RAN Synchronization in Cellular Networks Using PTP

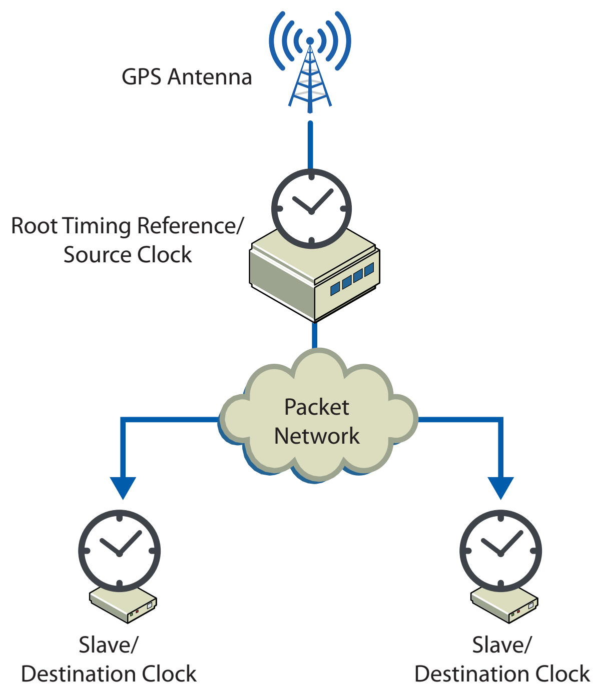
In order to meet the basic Wireless Network access requirements, frequency synchronization precision is an essential prerequisite, failing which users may suffer network outages when switched from one node to another. Radio base stations rely on having access to reliable and accurate reference timing signals in order to generate radio signals and maintain frame alignment. Routers and switches in the transport network may therefore be required to provide synchronization to the radio base stations in order for them to handle and transport data properly. Different radio technologies and features have different synchronization requirements; some wireless standards require time synchronization in addition to frequency synchronization as well.

While global wireless networks rapidly evolve from 2G to 3G and now towards Long-Term Evolution (LTE), GPS-based synchronization solutions may encounter several challenges associated with costs and security. Most 3G and LTE base stations are deployed in dense areas serving a high number of users; therefore deploying and maintaining traditional GPS receivers at all the base stations results in significantly high operational costs and potential interference caused due to intentional or unintentional signal transmissions. Therefore, to accommodate the precision requirements of these wireless systems, while mitigating potential hitches associated with a GPS solution, network operators prefer a robust, affordable solution.

As a result, Precision Timing Protocol (PTP) was introduced. PTP was originally defined in IEEE 1588 and is a protocol used to achieve clock synchronization through Computer Networks.

IEEE 1588 is designed to fill a niche not well served by either of the two dominant protocols, NTP and GPS. IEEE 1588 is designed for local systems requiring accuracies beyond those attainable using NTP. It is also designed for applications that cannot bear the cost of a GPS receiver at each node, or for which GPS signals are inaccessible.[1]

On Local Area Networks, the clock accuracy is in the sub-microsecond range, allowing for Mobile Network Operators and BTS vendors to implement PTP in order to ultimately deliver a high quality user experience.



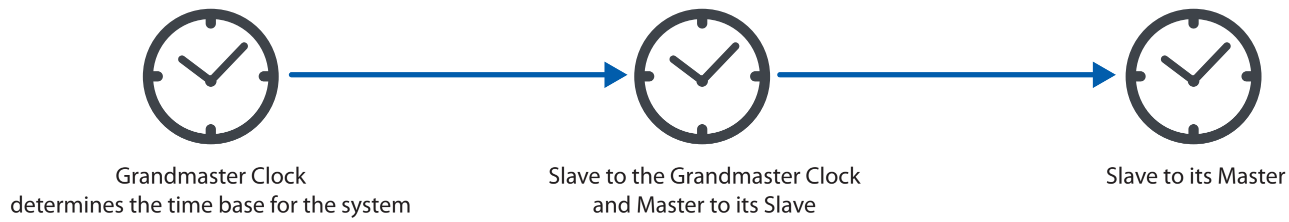
Precision Timing Protocol

What is PTP?

Precision Time Protocol (PTP), based on IEEE 1588v2 is a field-proven method to support synchronization through an IP transport network using the master/slave synchronization paradigm. The protocol primarily organizes the clocks into a master–slave hierarchy based on the Best Master Clock (BMC) algorithm running on each port. The BMC uses a hierarchical selection algorithm based on certain attributes, such as priority, variance, traceability, accuracy, etc., to choose a candidate clock. These attributes are contained within the PTP Announce messages.

When an Ordinary clock works as the system clock source, it is also called the grandmaster clock (GMC). The GMC functions as the reference clock, which is the highest-stratum clock of the entire system. Time of the GMC will be synchronized to the system through 1588v2 message interactions between clock nodes. The GMC can be statically configured or dynamically elected through the best master clock (BMC) algorithm. The master–slave hierarchy sets the framework for the time-base to be locked to a primary reference clock. The master clock sends a message to its slaves to initiate the synchronization via multicast transmission; then each slave accomplishes the synchronization by responding to the master. Thus, each slave clock eventually synchronizes with the grandmaster clock based on the exchanged event messages.

1 Eidson, John C. (April 2006). Measurement, Control and Communication Using IEEE 1588. Springer. ISBN 1-84628-250-0



Master–Slave Hierarchy in PTP

The 1588v2 standard defines five network node models:

- Ordinary clock (OC)
- Boundary clock (BC)
- End-to-end transparent clock (E2E TC)
- Peer-to-peer transparent clock (P2P TC)
- Management node

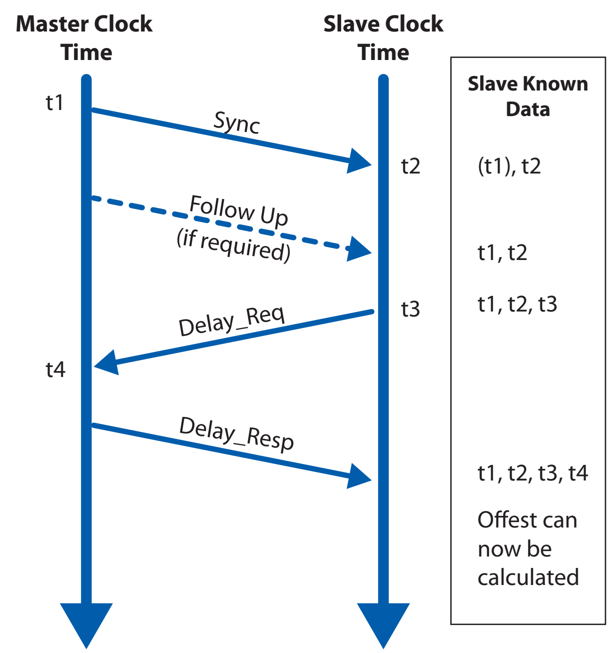
The actual synchronization process starts after the master–slave hierarchy is established by calculating the link delay (offset) and time difference between the master and slave devices based on timestamps generated when the devices exchange event messages.

PTP calculates the link delay and time difference between the master and slave devices based on the timestamps generated when the devices exchange event messages. PTP then synchronizes the time and frequency between the master and slave devices. Timestamps can be carried in PTP messages in either one-step or two-step mode.

The synchronization process is categorized in two distinct phases: In phase 1, the offset time between the master and slave clock is corrected, and in phase 2, the propagation delay between master and slave clock is computed.

The first phase comprises of the grandmaster clock sending a SYNC message to the slave clocks; and the slave clocks recording the packet arrival time (t2). The GMC then sends a follow-up message with the actual timestamp when the first sync message was sent (t1), therefore allowing the slave clocks to exactly calculate the master–slave delay.

The second phase comprises of the slave clock sending a delay request message to the master (t3). The master clock responds to this message with a delay response message (t4), allowing for the slave clock to determine the slave-master delay. At this state, both the clocks are aware of the offset; therefore the ability to calculate the exact propagation delay.

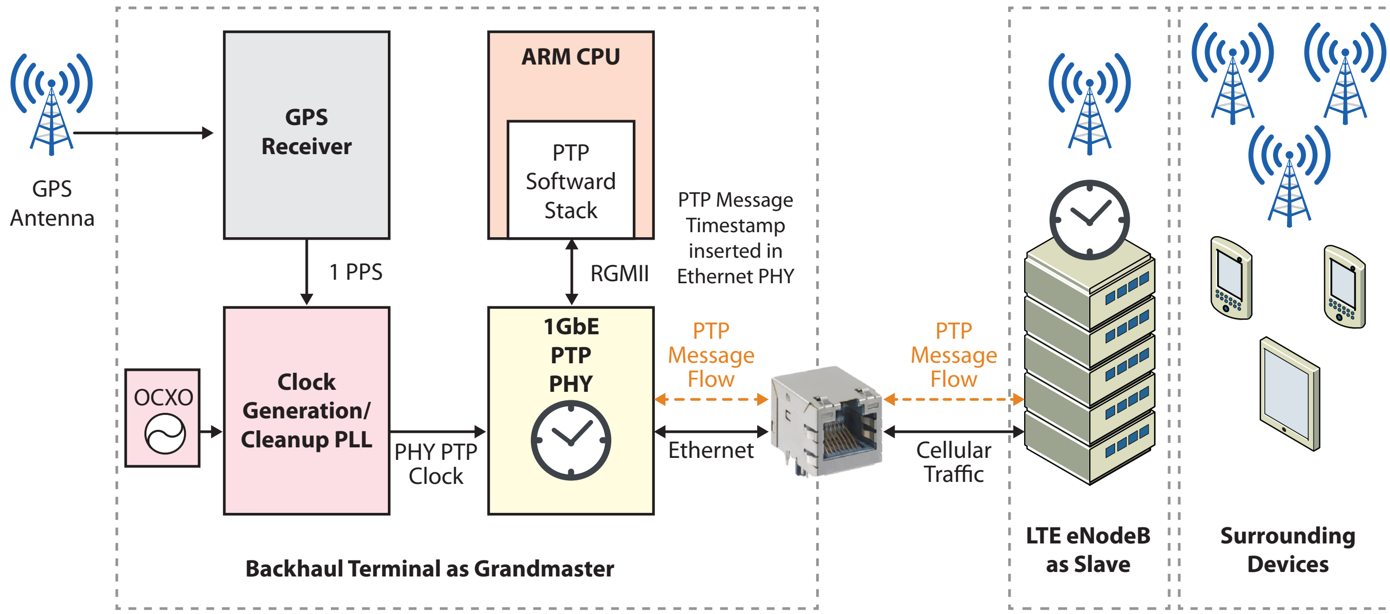


Application of PTP in Hughes Cellular Backhaul Solution

The Hughes Cellular Backhaul terminals include an onboard GPS Receiver, a clock generator, and a dedicated processor to support the PTP functionality.

The backhaul terminal acts as the grandmaster clock while the cellular base station (LTE eNodeB in the following figure) acts as the slave clock. Within the backhaul terminal is the GPS receiver which receives one timestamp and the local oscillator generates a second timestamp. The PLL system calculates the time difference between master and slave devices based on the timestamp information and sends the time difference information to the local processor. The PTP message timestamp is further sent to the subsequent network element acting as a slave for synchronization.

The accuracy requirements of a PTP system are much more refined than any other method of synchronization, as a result of which there is better synchronization between all the network elements. 1588v2 PTP can provide nanosecond-level precision time synchronization, which improves the network efficiency by fewer call drops and better X2 handover performance.



Conclusion

Network asymmetry (delay difference between the send path and receive path) and Packet Delay Variation (PDV) are critical elements for the accuracy of the recovered clock. The PTP algorithm uses as its main assumption that the delay between the master and the slave is equivalent to half of the round-trip delay, but if network asymmetry is introduced in the physical layer when the PTP messages do not travel via the same send and receive paths, the accuracy of time recovery will be impacted.

The network should be engineered to minimize such differences, or if the asymmetry value is known the PTP algorithm can correct for it. A chain of network elements between the master and the slave with variable network load and varying queuing and processing delays can cause delay variations in the PTP messages.

Because the PTP algorithm assumes a constant network delay, changes in packet arrival time are problematic for the slave. It cannot identify the difference between variation in packet delay and a timing drift in the master. Most often specific algorithms are implemented in the slave to filter out as much as possible of the PDV. To a lesser extent packet loss, packet error, or duplicated packets are also common traffic impairments that can affect PTP.

The Hughes Cellular Backhaul Solution has a built-in PTP chip that supports time synchronization within nanosecond-level precision. It offers several advantages in addition to those of a GPS solution, including lower OpEx cost and an improved user experience.

Proprietary Statement

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