Technical Introduction

Precision Time Protocol Basics

Background

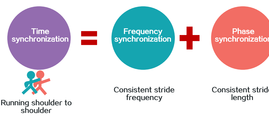
What is time synchronization?

In telecommunications, the sender and receiver interact as follows:

1. The sender converts texts, voices, videos, and other information into signals (pulses , light waves, or electromagnetic waves), and sends the signals to the receiver over a wired or wireless network. Each signal has its frequency and phase.

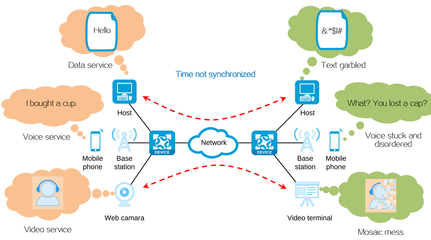
2. The receiver converts the received signals back to the original texts, voices, and videos by using the same frequency and phase.

The sender and receiver achieve time synchronization if they are completely consistent in signal frequency and phase.



Why is time synchronization required?

If the sender and receiver are not time synchronized in the communication process, the receiver might fail to restore the original signals, resulting in a series of issues as shown in the following figure. On wireless access networks, if base stations are not synchronized in time, serious issues, such as wireless client disconnection and network access failure, might occur.



Comparison with other time synchronization solutions

PTP is a time synchronization protocol used for high-precision frequency and phase synchronization between network nodes. It provides time synchronization among devices with submicrosecond accuracy and is the optimal solution for scenarios such as broadcast and television networks, urban rail transit, and wireless access networks that require high-precision time synchronization.

The following table compares PTP and other time synchronization solutions, including Global Positioning System (GPS), Beidou Navigation Satellite System (BDS), Synchronous Ethernet (SyncE), and Network Time Protocol (NTP).

Time sync solution	Frequency sync	Phase sync	Sync accuracy	Description
GPS	Yes	Yes	< 100 ns	Carries frequency and phase information in electromagnetic waves to achieve time synchronization. In recent years, the accuracy of GPS has been continuously improved.
BDS	Yes	Yes	ns level	Carries frequency and phase information in electromagnetic waves to achieve time synchronization. BDS is currently under development and is expected to provide global coverage by 2035.
SyncE	Yes	No	N/A	Carries and restores frequency information at the physical layer to achieve frequency synchronization.
NTP	No	Yes	ms level	Transmits phase signals in NTP messages to achieve phase synchronization, inadequate for scenarios such as wireless access networks that require microsecond-level time synchronization.
PTP	Yes	Yes	Sub-ns level to tens of nanoseconds	Transmits frequency and phase information in PTP messages and combines hardware-based timestamping to deliver high-precision time synchronization. With the development of software and hardware technologies, the accuracy of PTP can reach tens of nanoseconds or even better.

Benefits

Low cost

Compared with GPS and BDS, PTP does not require deployment and maintenance of satellite receiving equipment at each base station, with lower construction and maintenance costs.

High precision

PTP provides time synchronization with sub-microsecond accuracy to fully meet the requirements of various networks for high-precision time synchronization.

Security

PTP supports multiple types of clock sources (such as local clock source and line clock sources), which is of great significance to security.

Excellent scalability

Based on IEEE 1588, multiple other PTP protocols (including IEEE 802.1AS, SMPTE ST 2059-2, AES67-2015, and ITU-T G.8275.1) were developed to adapt to different application environments.

In line with the IP-based network trends

PTP transmits clock information through network devices, uses Layer 2 encapsulation and UDP encapsulation, and supports unicast and multicast transmission, in line with the IP-based network trends.

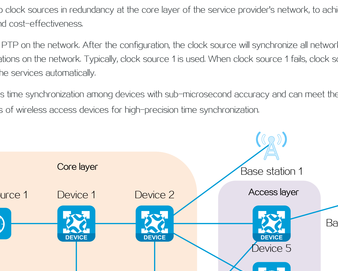
Implementations

PTP is implemented as follows for time synchronization:

1. The network nodes in the PTP domain elect a PTP clock source and establish master-member/subordinate relationships. The PTP clock source can also be specified manually. A PTP domain can have only one clock source, and all devices in the domain synchronize to this source.

2. The network nodes in the PTP domain exchange PTP messages and calculate the frequency offset and time offset between the local clock and the clock source.

3. The network nodes adjust the frequency and time of the local clock based on the frequency and time offsets to achieve time synchronization with the clock source.



Application scenario

As shown in the following figure, the base stations access the service provider's network through network devices. For wireless clients to move smoothly between base stations, all neighboring base stations must be synchronized in time with microsecond accuracy.

1. Deploy two clock sources in redundancy at the core layer of the service provider's network, to achieve service availability and cost-effectiveness.

2. Configure PTP on the network. After the configuration, the clock source will synchronize all network devices and base stations on the network. Typically, clock source 1 is used. When clock source 1 fails, clock source 2 takes over the services automatically.

PTP provides time synchronization among devices with sub-microsecond accuracy and can meet the requirements of wireless access devices for high-precision time synchronization.