Technical introduction

Precision Time Protocol Advanced

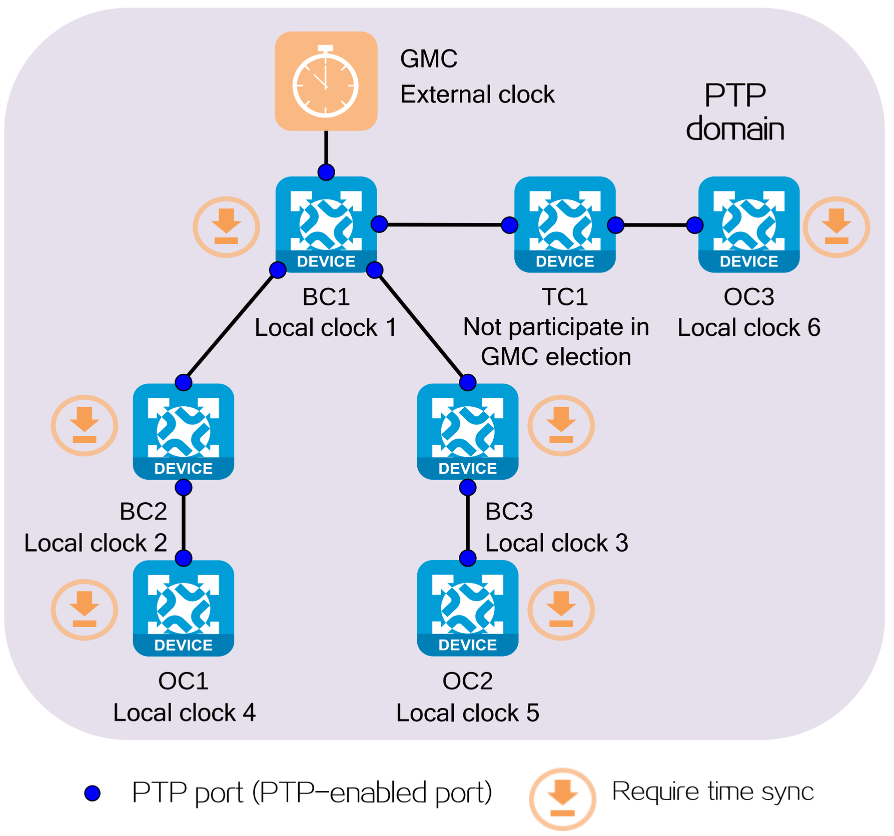
About PTP

Precision Time Protocol (PTP) is a time synchronization protocol used for high-precision frequency and phase synchronization between devices. It provides time synchronization among devices with submicrosecond and even nanosecond accuracy and can meet requirements of various network environments for high-precision time synchronization.

The basic PTP protocol IEEE 1588 defines the mechanism and message interaction and processing flow for high-precision time synchronization on the network. 1588 has two versions: v1 and v2. Based on 1588, PTP protocols including IEEE 802.1AS, ITU-T G.8275.1, and SMPTE ST 2059-2 were developed to adapt to different application scenarios. Among them, 1588v2 is most widely used. This document focuses on the implementation mechanism of 1588v2.

1588v2 architecture

- PTP domain: A network or part of a network on which PTP is configured.
- Clock source: Source of time in a PTP domain. The device supports two types of clock sources:
  - ✓ Local clock—38.88 MHz clock signals generated by a crystal oscillator inside the device.
  - ✓ External clock—Clock signals generated by an external clock. The signals are received by 1PPS/TOD ports on the MPU.
- Grandmaster clock (GMC): Clock with the highest stability and precision in a PTP domain. All clocks in the PTP domain synchronize to this clock.
- Clock node: Device that participates in time synchronization in a PTP domain. The following table describes the basic clock nodes defined in 1588v2.



Clock node type	PTP ports	Whether to be synchronized	Description
OC	1	Yes	• A clock that can operate as a master clock to synchronize its downstream clock nodes through the only PTP port, or as a member clock to synchronize to its upstream clock node through the port. • It runs the Best Master Clock (BMC) algorithm.
BC	≥ 1	Yes	• A clock that can operate as a member clock to synchronize to its upstream clock node with one of the PTP ports and as a master clock to synchronize its downstream clock nodes with other PTP ports. • It runs the BMC algorithm to automatically avoid loops in PTP message forwarding on a ring network and implement failover.
TC	≥ 1	No	• A clock that forwards PTP messages and performs delay corrections for the messages, instead of performing time synchronization. • It does not run the BMC algorithm. You must avoid physical loops when deploying TCs and manual failover is required when a failure occurs.

1588v2 implementations

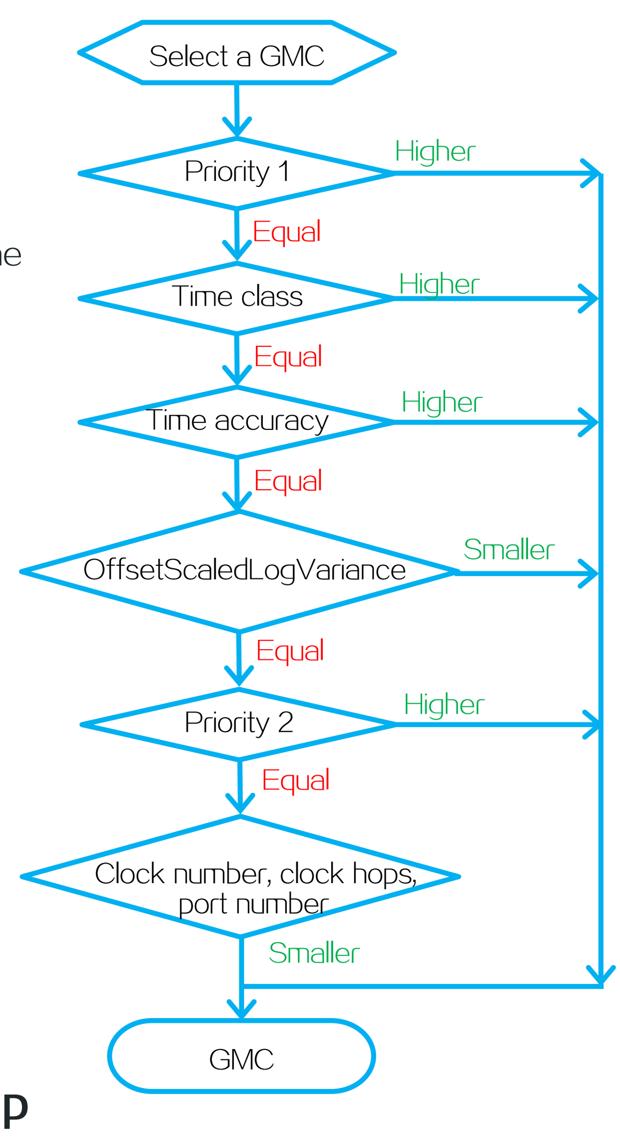
PTP is implemented as follows for time synchronization:

1. Selects a GMC and establishes master-member/subordinate relationships.
2. Calculates the frequency offset and time offset (phase offset) between the local clock and the GMC.
3. Adjusts the frequency and time of the local clock based on the frequency and time offsets to achieve time synchronization with the GMC.

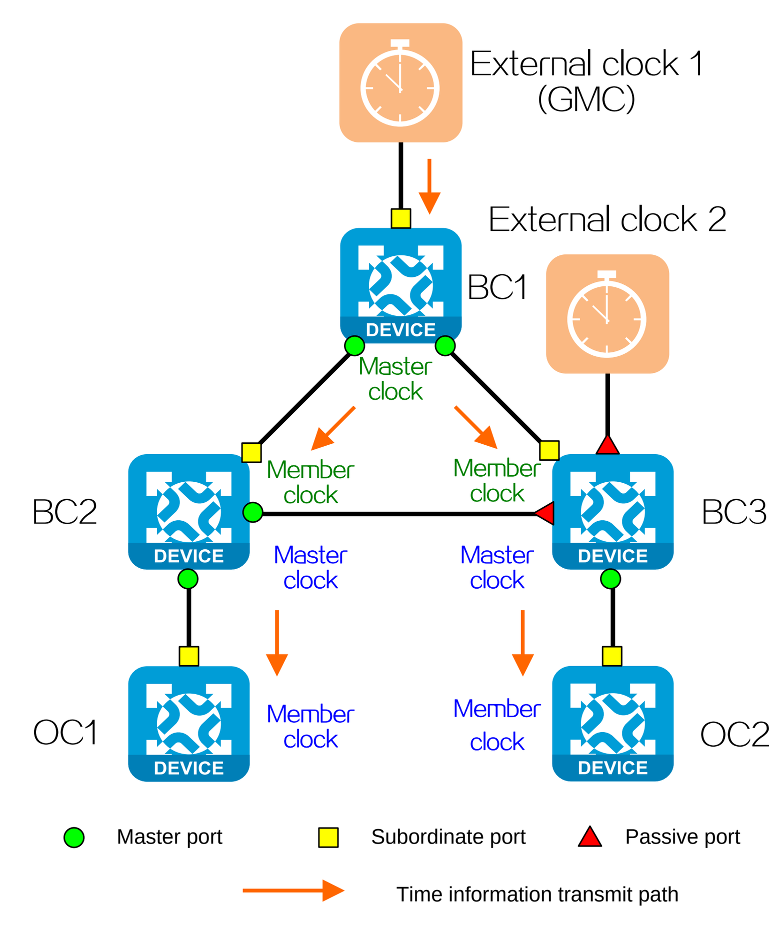
Selecting a GMC

In a PTP domain that has multiple clock sources, a GMC is automatically selected through the BMC algorithm. You can also specify a GMC manually. All BC and OC nodes in the domain are synchronized to the GMC.

During automatic selection of GMC, the clock nodes in the PTP domain exchange announce messages and obtain parameters such as priority 1, time level, and time accuracy of other clocks. They compare the parameters with those of the local clock and elect a GMC finally. The figure to the right shows the parameter comparison rules.



Establishing master-member/subordinate relationship



While the GMC is being selected, the master-member/subordinate relationships are established simultaneously between the nodes and between the ports through the BMC algorithm.

The master-member/subordinate relationships are defined as follows:

- Master/Member node—A master node sends synchronization messages, and a member node receives the synchronization messages.
- Master/Member clock—The clock on a master node is a master clock. The clock on a member node is a member clock.
- Master/Subordinate/Passive port—A master port sends synchronization messages, and a subordinate port receives the synchronization messages. A passive port neither receives nor sends synchronization messages.

After the master-member/subordinate relationship is established, a loop-free, all connected shortest path tree with the GMC as the root is established for the PTP domain.

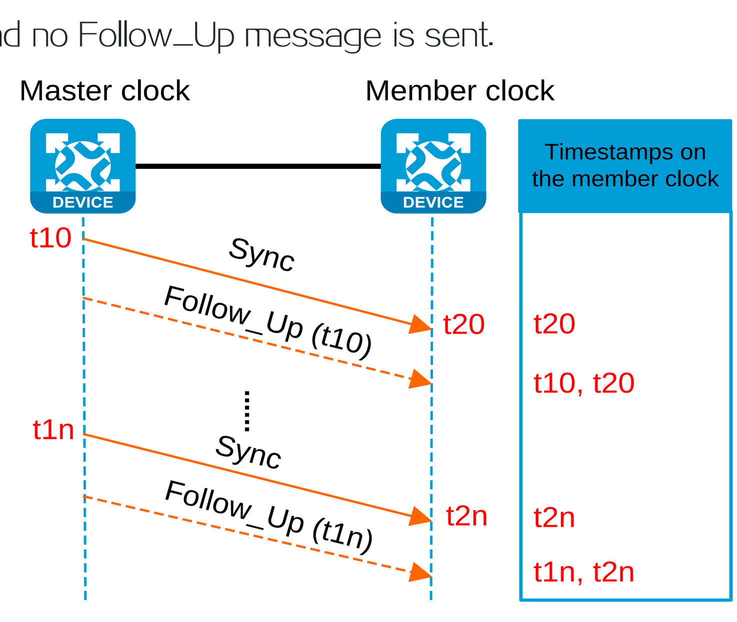
Synchronizing the time

Frequency synchronization

The master clock periodically sends Sync messages to the member clocks. The member clocks calculate the frequency offset based on the time difference between two consecutively received Sync messages and adjust the frequency accordingly to achieve frequency synchronization with the master node.

- If t2n – t20 > t1n – t10, the member clock is fast and will be slowed down.
- If t2n – t20 < t1n – t10, the member clock is slow and will be adjusted faster.

PTP frequency synchronization can be implemented in single-step mode or two-step mode. The figure below shows the most commonly used two-step frequency synchronization mode. In single-step mode, t10 and t1n timestamps are carried in a Sync message, and no Follow_Up message is sent.

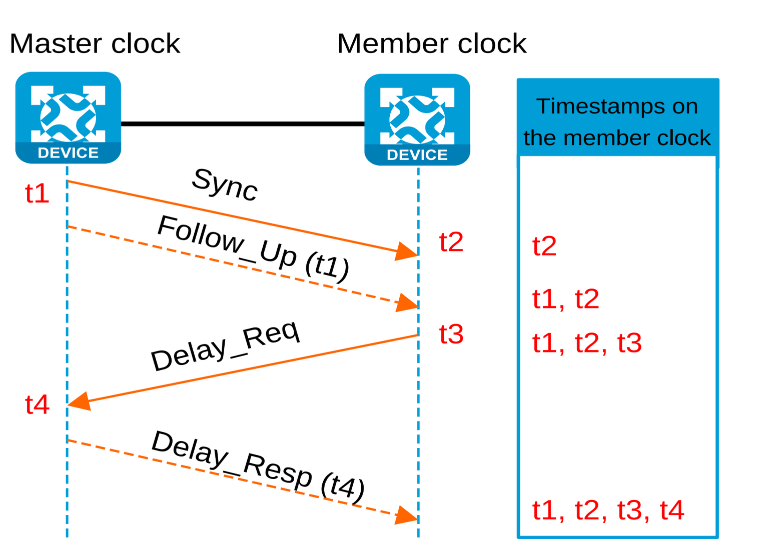


Phase synchronization

The master and member clocks exchange PTP messages periodically, and the member clocks calculate the current time offset from the master clock based on the timestamps.

Accurate local time = Current local time – time offset

1588v2 defines two link delay measurement mechanisms: request-response (Delay-Req) and peer delay (Pdelay) to calculate the time offset. These two mechanisms support single-step mode and two-step mode. The figure below shows the most commonly used two-step Delay-Req delay measurement mode. In single-step mode, the t1 timestamp is carried in a Sync message, and no Follow_Up message is sent.

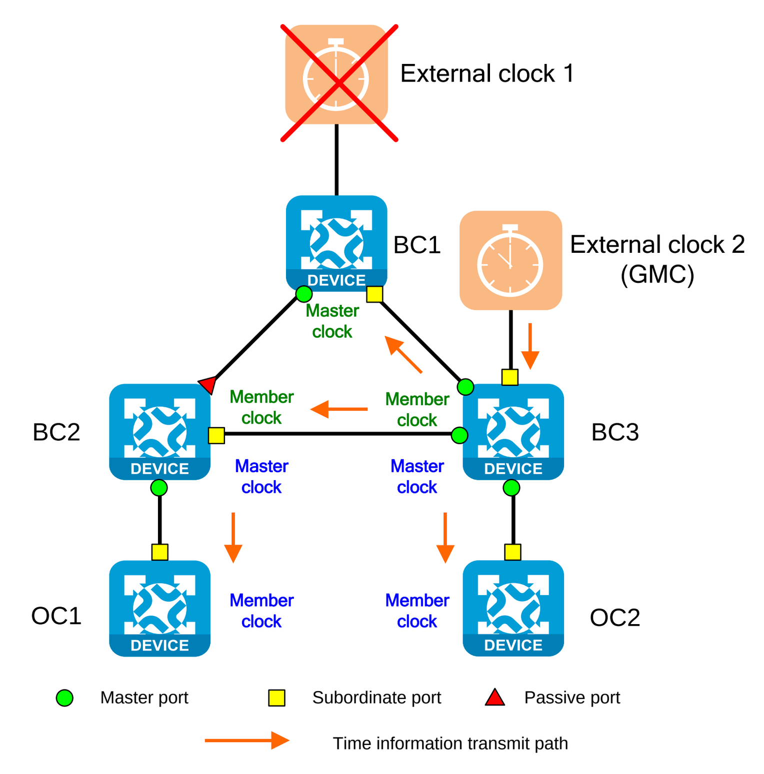


Time offset=(t2−t1)−[(t2−t1)+(t4−t3)]/2=[(t2−t1)−(t4−t3)]/2

Failover

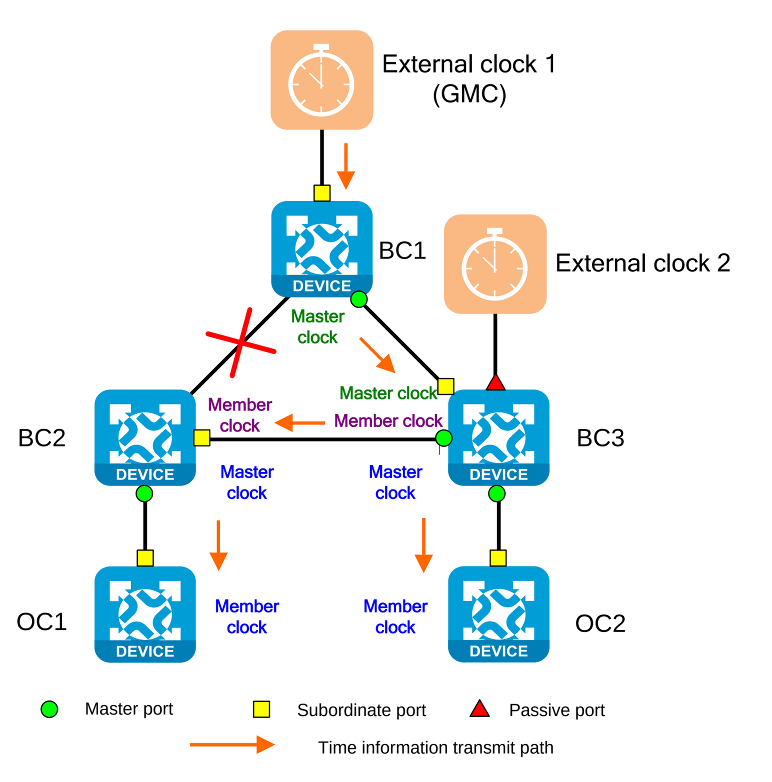
Clock source failure

A PTP domain typically has multiple clock sources deployed for availability. The clock source with the highest priority provides the clock signals. If the clock source fails, the clock nodes will re-elect the GMC and establish the shortest path tree with the new GMC as a root through the BMC algorithm.



Clock link failure

A ring network topology is typically set up between important clock nodes for clock availability. To avoid loops, the BMC algorithm automatically blocks passive ports. When a clock link fails, the BMC automatically unblocks the passive ports and establishes a new shortest path tree.



PTP protocols

Based on the 1588v2 protocol, multiple PTP protocols were developed to adapt to different scenarios. In a PTP domain, all clock nodes must run the same PTP protocol. In a multi-domain environment, each PTP domain can run its own PTP protocol. The Comware system supports PTP multi-domain and the following PTP protocols. Support for PTP multi-domain and PTP protocols depends on the device model.

PTP protocol	Application scenarios	Main features
IEEE 1588v2	Applicable to various networking environments and can be customized, enhanced, or tailored as needed.	• Algorithm: BMC • Delay measurement mechanisms: Request_Response and Peer Delay • Encapsulation of protocol packets: IEEE 802.3/Ethernet and UDP
IEEE 802.1AS	Profile developed based on IEEE 1588-2008 for time synchronization over a virtual bridged LAN. It supports point-to-point full-duplex Ethernet, IEEE 802.11, and IEEE 802.3 EPON links.	• Algorithm: MSTP • Delay measurement mechanisms: Peer Delay • Encapsulation of protocol packets: IEEE 802.3/Ethernet
ITU-T G.8275.1	Telecom industry	• Algorithm: Alternate BMCA • Delay measurement mechanisms: Request_Response • Encapsulation of protocol packets: IEEE 802.3/Ethernet
ITU-T G.8275.2	Telecom industry	• Algorithm: Alternate BMCA • Client-server architecture: The clients (member clock nodes) synchronize to the server (master clock node) by exchanging PTP messages. Layer 2 devices do not need to support PTP, because clients and the server communicate at Layer 3. • Delay measurement mechanisms: Request_Response • Encapsulation of protocol packets: UDP
SMPTE ST 2059-2	Time synchronization between audio and video devices in professional broadcast environment	• Algorithm: BMC • Delay measurement mechanisms: Request_Response and Peer Delay • Encapsulation of protocol packets: UDP • Default protocol packet rate: Higher than 1588v2
AES67-2015	Time synchronization between broadcast, music production and postproduction devices	• Algorithm: BMC • Delay measurement mechanisms: Request_Response and Peer Delay • Encapsulation of protocol packets: UDP • Default protocol packet rate: Higher than 1588v2

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