

Understanding PTP

The Precision Time Protocol (PTP), as defined in the IEEE 1588 standard, synchronizes withnanosecond accuracy the real-time clocks of the devices in a network. The clocks in are organized into a server-client hierarchy. PTP identifies the port that is connected to a device with the most precise clock. This clock is referred to as the server clock. All the other devices on the network synchronize their clocks with the server clock and are referred to as members. Constantly-exchanged timing messages ensure continued synchronization.

Precision Time Protocol (PTP) is defined in IEEE 1588 as Precision Clock Synchronization for Networked Measurements and Control Systems, and was developed to synchronize the clocks in packet-based networks that include distributed device clocks of varying precision and stability. PTP is designed specifically for industrial, networked measurement and control systems, and is optimal for use in distributed systems because it requires minimal bandwidth and little processing overhead.

Table 1: Nodes within a PTP Network

Network Element	Description
Grandmaster (GM)	A network device physically attached to the primary time source. All clocks are synchronized to the grandmaster clock.
Ordinary Clock (OC)	An ordinary clock is a 1588 clock with a single PTP port that can operate in one of the following modes: • Server mode—Distributes timing information over the network to one or more client clocks, thus allowing the client to synchronize its clock to the server clock. • Client mode—Synchronizes its clock to a server clock. You can enable the client mode on up to two interfaces simultaneously in order to connect to two different server clocks.

Network Element	Description
Boundary Clock (BC)	The device participates in selecting the best server clock and can act as the server clock if no better clocks are detected. Boundary clock starts its own PTP session with a number of downstream clients. The boundary clock mitigates the number of network hops and results in packet delay variations in the packet network between the Grandmaster and client.
Transparent Clock (TC)	A transparent clock is a device or a switch that calculates the time it requires to forward traffic and updates the PTP time correction field to account for the delay, making the device transparent in terms of time calculations.

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Why PTP?

Smart grid power automation applications, such as peak-hour billing, virtual power generators, and outage monitoring and management, require extremely precise time accuracy and stability. Timing precision improves network monitoring accuracy and troubleshooting ability.

In addition to providing time accuracy and synchronization, the PTP message-based protocol can be implemented on packet-based networks, such as Ethernet networks. The benefits of using PTP in an Ethernet network include:

- Low cost and easy setup in existing Ethernet networks
- Limited bandwidth requirement for PTP data packets

Routers and Delays

In an IP network, routers provide a full-duplex communication path between network devices. Routers send data packets to packet destinations using IP address information contained in the packets. When the router attempts to send multiple packets simultaneously, the router buffers some packets so that they are not lost before they are sent. When the buffer is full, the router delays sending packets. This delay can cause device clocks on the network to lose synchronization with one another.

Additional delays can occur when packets entering a router are stored in its local memory while the router searches the address table to verify packet fields. This process causes variations in packet forwarding time latency, and these variations can result in asymmetrical packet delay times.

Adding PTP to a network can compensate for these latency and delay problems by correctly adjusting device clocks so that they stay synchronized with one another. PTP enables network routers to function as PTP devices, including boundary clocks (BCs) and transparent clocks (TCs).

For more information about PTP clock devices and their role in a PTP network, see the *PTP Clocks* section.

Message-Based Synchronization

To ensure clock synchronization, PTP requires an accurate measurement of the communication path delay between the time source (server) and the receiver (client). PTP sends messages between the server and client device to determine the delay measurement. Then, PTP measures the exact message transmit and receive times and uses these times to calculate the communication path delay.

PTP then adjusts current time information contained in network data for the calculated delay, resulting in more accurate time information.

This delay measurement principle determines path delay between devices on the network. The local clocks are adjusted for this delay using a series of messages sent between servers and clients. The one-way delay time is calculated by averaging the path delay of the transmit and receive messages. This calculation assumes a symmetrical communication path; however, routed networks do not necessarily have symmetrical communication paths, due to the various asymmetries in the network.

Using transparent clocks, PTP provides a method to measure and account for the delay in a time-interval field in network timing packets. This makes the routers temporarily transparent to the server and client nodes on the network. An end-to-end transparent clock forwards all messages on the network in the same way that a router does.

To read a detailed description of synchronization messages, see the *PTP Event Message Sequences* section. To learn more about how transparent clocks calculate network delays, refer to Transparent Clock, on page 7.

PTP Event Message Sequences

This section describes the PTP event message sequences that occur during synchronization.

Synchronizing with Boundary Clocks

The ordinary and boundary clocks configured for the delay request-response mechanism use the following event messages to generate and communicate timing information:

- Sync
- Delay_Req
- Follow_Up
- Delay_Resp

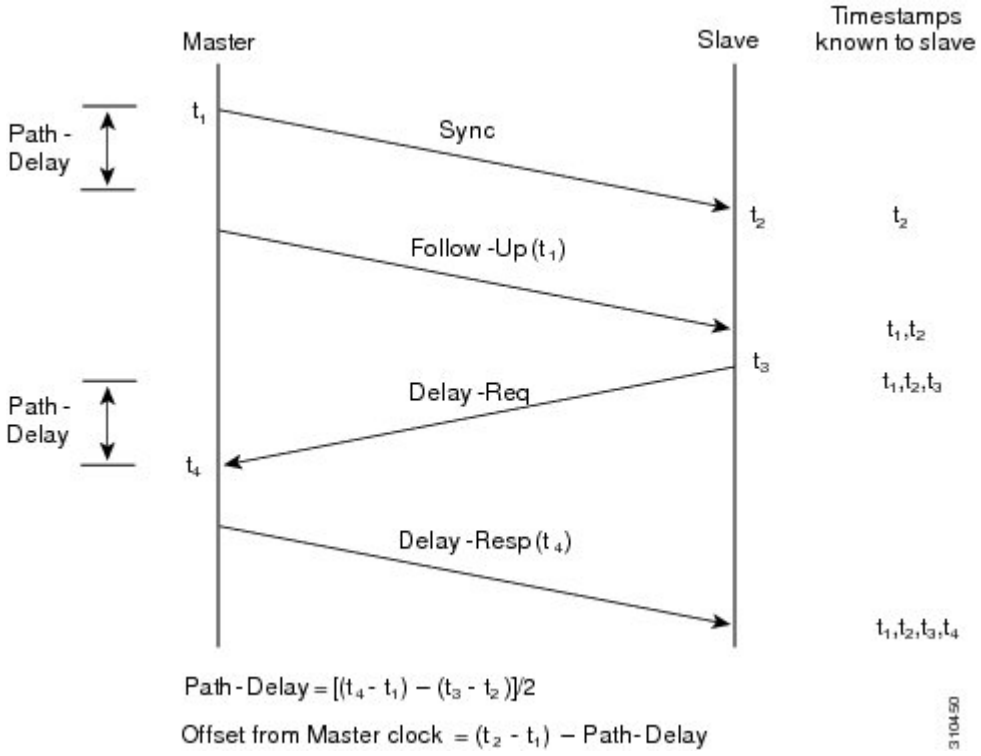
These messages are sent in the following sequence:

- The server sends a Sync message to the client and notes the time (t1) at which it was sent.
- The client receives the Sync message and notes the time of reception (t2).
- The server conveys to the client the timestamp t1 by embedding the timestamp t1 in a Follow_Up message.
- The client sends a Delay_Req message to the server and notes the time (t3) at which it was sent.
- The server receives the Delay_Req message and notes the time of reception (t4).
- The server conveys to the client the timestamp t4 by embedding it in a Delay_Resp message.

After this sequence, the client possesses all four timestamps. These timestamps can be used to compute the offset of the client clock relative to the server, and the mean propagation time of messages between the two clocks.

The offset calculation is based on the assumption that the time for the message to propagate from server to client is the same as the time required from client to server. This assumption is not always valid on an Ethernet/IP network due to asymmetrical packet delay times.

Figure 1: Detailed Steps—Boundary Clock Synchronization



Delay-Response Mechanism

The Delay Request-response mechanism (defined in section 11.3 of IEEE Std 1588-2008) lets a slave port estimate the difference between its own clock-time and the clock-time of its master. The following options are supported:

- One-step mechanism - The timestamp for a Sync message is received in the Sync message itself.
- Two-step mechanism - The timestamp for a Sync message is received later in a Follow-up message.

When running a port in Slave state, a router shall send Delay-request messages and handle incoming Sync, Follow-up, and Delay-response messages. The timeout periods for both Sync and Delay-response messages are individually configurable.

When running a port in Master state, only one-step is supported, and in slave state, both one-step and two-step are supported without configuration.

Synchronizing the Local Clock

In an ideal PTP network, the server and client clock operate at the same frequency. However, drift can occur on the network. Drift is the frequency difference between the server and client clock. You can compensate for drift by using the time stamp information in the device hardware and follow-up messages (intercepted by the router) to adjust the frequency of the local clock to match the frequency of the server clock.

PTP Clocks

A PTP network is made up of PTP-enabled devices and devices that are not using PTP. The PTP-enabled devices typically consist of the following clock types.

Grandmaster Clock

Within a PTP domain, the grandmaster clock is the primary source of time for clock synchronization using PTP. The grandmaster clock usually has a very precise time source, such as a GPS or atomic clock. When the network does not require any external time reference and only needs to be synchronized internally, the grandmaster clock can free run.

Ordinary Clock

An ordinary clock is a PTP clock with a single PTP port. It functions as a node in a PTP network and can be selected by the BMCA as a server or client within a subdomain. Ordinary clocks are the most common clock type on a PTP network because they are used as end nodes on a network that is connected to devices requiring synchronization. Ordinary clocks have various interfaces to external devices.

Boundary Clock

A boundary clock in a PTP network operates in place of a standard network router. Boundary clocks have more than one PTP port, and each port provides access to a separate PTP communication path. Boundary clocks provide an interface between PTP domains. They intercept and process all PTP messages, and pass all other network traffic. The boundary clock uses the BMCA to select the best clock seen by any port. The selected port is then set as a client. The server port synchronizes the clocks connected downstream, while the client port synchronizes with the upstream server clock.

Transparent Clock

The role of transparent clocks in a PTP network is to update the time-interval field that is part of the PTP event message. This update compensates for switch delay and has an accuracy of within one picosecond.

Restrictions for PTP

- PTP over MPLS is not supported.
- On Cisco N540X-16Z4G8Q2C-D routers, use the dedicated copper ports 0 through 3 when copper connectivity is required. Do not install a copper SFP in an optical port. This configuration can cause SyncE problems.
- Configure one endpoint as a PTP server and the peer as a PTP client simultaneously. A PTP session does not establish when both endpoints are forced to the same role.

PTP Phase Difference Threshold Between Passive and Secondary Ports

Table 2: Feature History Table

Feature Name	Release Information	Feature Description
PTP Phase Difference Threshold Between Passive and Secondary Ports	Release 24.2.1	Passive ports can now be included in the Delay Request-Response Mechanism (DRRM), which allows for the monitoring of PTP phase differences between a passive port and a secondary port. If these PTP phase differences surpass a predefined limit, system logs are triggered. This feature enables you to detect potential errors such as fiber asymmetry or a clock failure in the PTP network. This feature introduces these changes: **CLI:** • **phase-difference-threshold-breach** • The **show ptp foreign-masters** command output is enhanced to include phase difference values and servo status. **YANG Data Models:** The following data models are enhanced: • `Cisco-IOS-XR-ptp-cfg.yang` • `Cisco-IOS-XR-um-ptp-cfg.yang`

The Precision Time Protocol (PTP), as defined in the IEEE 1588 standard, is designed for precise time synchronization across networked devices. It operates by having Foreign Masters (FMs) broadcast timing

information to interfaces within the network. The selection of the Grandmaster (GM), the primary reference clock, is determined by the Best Master Clock Algorithm (BMCA). Devices synchronize their clocks to the GM through a process known as the Delay Request-Response Mechanism (DRRM), wherein ports that are directly synchronizing with the GM enter a secondary state.

Historically, ports in a passive state—those that receive timing messages from FMs but aren't used for synchronization to the GM were not monitored by the router. Starting with Cisco IOS XR Software Release 24.2.1, these passive ports are enabled for the calculation of PTP phase differences between the FMs on passive ports and the GM.

This calculated PTP phase difference provides a valuable insight into the timing characteristics of other foreign masters in the network by using the grandmaster as a reference point. It can be utilized on any boundary clock or slave clock that has connections to at least one other foreign master.

You can access these measurements and the calculated PTP phase differences using show commands through the router's CLI. Also, the information can be retrieved programmatically through operational data models in YANG, providing flexibility in how you can access and utilize this synchronization data.

Phase Difference Alarm

PTP phase difference can also be used to monitor the timing properties of the network. You can configure a value at which a bistate alarm is triggered when the PTP phase difference of a FM exceeds the threshold. The PTP phase difference can have a negative or positive value, but the threshold can only be the absolute value. You can configure the PTP phase difference threshold using the **phase-difference-threshold-breach** command.

System Log for PTP Phase Difference

When the configured threshold is reached, system logs (syslogs) are displayed. The following syslog is triggered if the configured PTP phase difference threshold is passed through by any master.

```
Phase difference for clock ACDE48FFFE234567, steps removed 1, receiving-port 1, received
on interface GigabitEthernet0/2/0/3 is 40ns, configured threshold is 30ns. Raising phase
difference alarm.
```

Isolate Foreign Masters Causing Packet Timing Signal Fail

Table 3: Feature History Table

Feature Name	Release Information	Feature Description
Isolate Foreign Masters Causing Packet Timing Signal Fail	Release 24.2.1	This feature permits the flexible selection of timing sources by filtering out Foreign Master (FM) clocks that exhibit unstable timing. This filtering causes the secondary clocks to produce a signal deemed Packet Timing Signal Fail (PTSF)-unusable, from consideration within the Best Master Clock Algorithm (BMCA). The system continuously monitors these clocks for timing stabilization, and upon detecting enhanced stability, it may reevaluate and possibly reintegrate them as suitable time sources. This feature introduces these changes: **CLI:** • **detect-ptsf-unusable** • The **show ptp foreign-masters** command output is enhanced to include phase difference values and servo status. **YANG Data Models:** The following data models are enhanced: • `Cisco-IOS-XR-ptp-cfg.yang` • `Cisco-IOS-XR-um-ptp-cfg.yang`

Starting Cisco IOS XR Software Release 24.2.1, the servo mechanism now has the ability to detect unusable clocks due to packet timing signal fail by analyzing timestamps from foreign masters. This enhancement allows the system to identify foreign masters with unstable timing as unsuitable for use. A platform supports multiple masters, such a master can be excluded from the BMCA selection process while remaining under observation for potential recovery. Even after a master is deemed unusable, the DRRM continues to operate and timestamps from it are still provided to the servo. This ongoing monitoring enables PTP to detect and respond to any improvements in the primary's timing, allowing it to be reconsidered as usable.

System Log for PTSF-unusable

When the master becomes PTSF-unusable, and if its the current Grandmaster, the following system log (syslogs) is displayed:

```
Foreign master with clock ID ACDE48FFFE234567, steps removed 1, receiving-port 1, received
 on interface GigabitEthernet0/2/0/4 is now PTSF-unusable and disqualified from selection.
```

PTP Profiles

ITU-T Telecom Profiles for PTP

Cisco IOS XR software supports ITU-T Telecom Profiles for PTP as defined in the ITU-T recommendation. A profile consists of PTP configuration options applicable only to a specific application.

Separate profiles can be defined to incorporate PTP in different scenarios based on the IEEE 1588-2008 standard. A telecom profile differs in several ways from the default behavior defined in the IEEE 1588-2008 standard and the key differences are mentioned in the subsequent sections.

The following sections describe the ITU-T Telecom Profiles that are supported for PTP.

G.8265.1

G.8265.1 profile fulfills specific frequency-distribution requirements in telecom networks. Features of G.8265.1 profile are:

- Clock advertisement: G.8265.1 profile specifies changes to values used in Announce messages for advertising PTP clocks. The clock class value is used to advertise the quality level of the clock, while the other values are not used.
- Clock Selection: G.8265.1 profile also defines an alternate BMCA to select port states and clocks is defined for the profile. This profile also requires to receive Sync messages (and optionally, Delay-Response messages) to qualify a clock for selection.
- Port State Decision: The ports are statically configured to be Server or Client instead of using FSM to dynamically set port states.
- Packet Rates: The packet rates higher than rates specified in the IEEE 1588-2008 standard are used. They are:
  - Sync/Follow-Up Packets: Rates from 128 packets-per-second to 16 seconds-per-packet.
  - Delay-Request/Delay-Response Packets: Rates from 128 packets-per-second to 16 seconds-per-packet.
  - Announce Packets: Rates from 8 packets-per-second to 64 packets-per-second.
- Transport Mechanism: G.8265.1 profile only supports IPv4 PTP transport mechanism.
- Mode: G.8265.1 profile supports transport of data packets only in unicast mode.
- Clock Type: G.8265.1 profile only supports Ordinary Clock-type (a clock with only one PTP port).
- Domain Numbers: The domain numbers that can be used in a G.8265.1 profile network ranges from 4 to 23. The default domain number is 4.

- Port Numbers: Multiple ports can be configured; however, all ports must be of the same type, either Server or Client.

Note The G.8265.1 profile is not supported in this release.

G.8275.1

G.8275.1 profile fulfills the time-of-day and phase synchronization requirements in telecom networks with all network devices participating in the PTP protocol. G.8275.1 profile with SyncE provides better frequency stability for the time-of-day and phase synchronization.

Features of G.8275.1 profile are:

- Synchronization Model: G.8275.1 profile adopts hop-by-hop synchronization model. Each network device in the path from Server to Client clock synchronizes its local clock to upstream devices and provides synchronization to downstream devices.
- Clock Selection: G.8275.1 profile also defines an alternate BMCA that selects a clock for synchronization and port state for the local ports of all devices in the network is defined for the profile. The parameters defined as a part of the BMCA are:
  - Clock Class
  - Clock Accuracy
  - Offset Scaled Log Variance
  - Priority 2
  - Clock Identity
  - Steps Removed
  - Port Identity
  - notSlave flag
  - Local Priority
- Port State Decision: The port states are selected based on the alternate BMCA algorithm. A port is configured to a server-only port state to enforce the port to be a server for multicast transport mode.
- Packet Rates: The nominal packet rate for Announce packets is 8 packets-per-second and 16 packets-per-second for Sync/Follow-Up and Delay-Request/Delay-Response packets.
- Transport Mechanism: G.8275.1 profile only supports Ethernet PTP transport mechanism.
- Mode: G.8275.1 profile supports transport of data packets only in multicast mode. The forwarding is done based on forwardable or non-forwardable multicast MAC address.
- Clock Type: G.8275.1 profile supports the following clock types:
  - Telecom Grandmaster (T-GM)
  - Telecom Time subordinate/client Clock (T-TSC)

- Telecom Boundary Clock (T-BC)

- Domain Numbers: The domain numbers that can be used in a G.8275.1 profile network ranges from 24 to 43. The default domain number is 24.

The G.8275.1 supports the following:

- T-GM: The telecom grandmaster (T-GM) provides timing to all other devices on the network. It does not synchronize its local clock with any other network element other than the Primary Reference Time Clock (PRTC).
- T-BC: The telecom boundary clock (T-BC) synchronizes its local clock to a T-GM or an upstream T-BC, and provides timing information to downstream T-BCs or T-TSCs. If at a given point in time there are no higher-quality clocks available, T-BC continues to provide its own timing information to its peers, although derived clock is not as accurate as the T-GM.
- T-TSC: The telecom time subordinate/client clock (T-TSC) synchronizes its local clock to another PTP clock (in most cases, the T-BC), and does not provide synchronization through PTP to any other device.

Performance Requirements

The router is compliant with Class B performance requirements for T-TSC and T-BC as documented in G.8273.2.

G.8275.2

The G.8275.2 is a PTP profile for use in telecom networks where phase or time-of-day synchronization is required. It differs from G.8275.1 in that it is not required that each device in the network participates in the PTP protocol. Also, G.8275.2 uses PTP over IPv4 in unicast mode.

The G.8275.2 profile is based on the partial timing support from the network. Hence nodes using G.8275.2 are not required to be directly connected.

The G.8275.2 profile is used in mobile cellular systems that require accurate synchronization of time and phase. For example, the fourth generation (4G) of mobile telecommunications technology.

Features of G.8275.2 profile are:

- Clock Selection: G.8275.2 profile also defines an alternate BMCA that selects a clock for synchronization and port state for the local ports of all devices in the network is defined for the profile. The parameters defined as a part of the BMCA are:
  - Clock Class
  - Clock Accuracy
  - Offset Scaled Log Variance
  - Priority 2
  - Clock Identity
  - Steps Removed
  - Port Identity
  - notSlave flag
  - Local Priority

Note See ITU-T G.8275.2 document to determine the valid values for Clock Class parameter.

- Port State Decision: The port states are selected based on the alternate BMCA algorithm. A port can be configured as "server-only", "client-only", or "any" mode.
- Packet Rates:
  - Synchronization/Follow-Up—minimum is one packet-per-second and maximum of 128 packets-per-second.
  - Packet rate for Announce packets—minimum of one packet-per-second and maximum of eight packets-per-second.
  - Delay-Request/Delay-Response packets—minimum is one packet-per-second and maximum of 128 packets-per-second.
- Transport Mechanism: G.8275.2 profile supports only IPv4 PTP transport mechanism.
- Mode: G.8275.2 profile supports transport of data packets only in unicast mode.
- Clock Type: G.8275.2 profile supports the following clock types:
  - Telecom Grandmaster (T-GM): Provides timing for other network devices and does not synchronize its local clock to other network devices. However, T-GM can be connected to a GPS or GNSS for deriving better clock information.
  - Telecom Time Subordinate/Client Clock (T-TSC) and Partial-Support Telecom Time Subordinate/Client Clocks (T-TSC-P): A client clock synchronizes its local clock to another PTP clock, but does not provide PTP synchronization to any other network devices.
  - Telecom Boundary Clock (T-BC) and Partial-Support Telecom Boundary Clocks (T-BC-P): Synchronizes its local clock to a T-GM or an upstream T-BC clock and provides timing information to downstream T-BC or T-TSC clocks.
- Domain Numbers: The domain numbers that can be used in a G.8275.2 profile network ranges from 44 to 63. The default domain number is 44.

PTP Virtual Port

Feature Name	Release Information	Feature Description
PTP Virtual Port Support for Cisco NCS 560 routers	Release 7.9.1	You can now select the best available timing source for your routers by using the PTP Virtual Port feature. This feature allows you to compare, select, and advertise the best clock source between a PTP server and other local timing sources connected to the routers. Vitual Port is an external frequency, phase, and time input interface on a Telecom Boundary Clock (T-BC), and thus participates in the timing source selection.

G.8275.1 introduces the concept of a virtual port on the T-BC. A virtual port is an external frequency, phase, and time input interface on a T-BC, which can participate in the source selection.

Limitations

- Assisted Partial Timing Support (APTS) is supported only for the G8275.2 non hybrid mode.
- Virtual port is supported for G8275.1 and G8275.2 in hybrid and non-hybrid modes.
- Virtual port configuration is not allowed under Ordinary Clocks.
- Virtual port cannot be configured if the time of day (ToD) priority is not set under the global PTP configuration mode. Use the **time-of-day priority** command to set the ToD.

Assisted Partial Timing Support

Table 4: Feature History Table

Feature Name	Release Information	Description
Assisted Partial Timing Support on this routers	Release 7.9.1	Assisted Partial Timing Support (APTS) enables you to select timing and synchronization for mobile backhaul networks. APTS allows for proper distribution of phase and time synchronization in the network.

In a network having GNSS or GPS reference, all nodes (or secondary clocks) at the edge of the network follow the GNSS primary clock that runs at the core. When GNSS or GPS reference fails at the core, the secondary clocks running at the edge no longer receive accurate time stamps from the primary clock.

With the use of APTS, the nodes at the edge of the network identify GNSS or GPS as primary clock source, and PTP as the secondary source. So even if the GNSS reference is lost, the nodes fall back to the backup PTP session running between the primary clock at core and the nodes at the edge, and are thereby able to maintain an accurate time stamp.

Configuring the G.8275.1 Profile



Note The Sync 2 port and GNSS receiver configuration listed below are not supported simultaneously for network synchronization. Choose only one synchronization method at a time.

Configuring the Global Settings: Example

```
ptp
clock
 domain 24
 profile g.8275.1 clock-type [T-BC | TGM | TTSC]
!
profile profile1
 transport ethernet
 sync frequency 16
 announce frequency 8
 delay-request frequency 16
!
 profile profile2
 transport ethernet
 sync frequency 16
 announce frequency 8
 delay-request frequency 16
 !
 !
     physical-layer-frequency
 !
```

Configuring Client Port: Example

```
interface GigabitEthernet0/0/0/3
 ptp
  profile profile1
  multicast target-address ethernet 01-1B-19-00-00-00
  transport ethernet
  port state slave-only
  local-priority 10
!
  frequency synchronization
  selection input
  priority 1
  wait-to-restore 0
 !
!
```

Configuring Server Port: Example

```
interface GigabitEthernet0/0/0/1
 ptp
  profile profile2
  multicast target-address ethernet 01-1B-19-00-00-00
  port state master-only
  transport ethernet
  sync frequency 16
```

```
  announce frequency 8
  delay-request frequency 16
 !
 frequency synchronization
 !
!
```

Multiple PTP profile interoperability

Multiple PTP profile interoperability is a clock synchronization method that allows a Cisco router to run a profile while you configure an interface to synchronize with a peer clock running a different profile.

Table 5: Feature History Table

Feature Name	Release Information	Feature Description
PTP profile interoperation	Release 25.2.1	PTP profile interoperability is now extended to the **A900-IMA8CS1Z-M** NCS 560 router variant.
PTP profile interoperation	Release 7.5.1	PTP profile interoperation enables users to deploy newer profiles in a network containing older devices that do not support these profiles. This support allows for a gradual upgrade path. This feature is supported on these NCS 560 router variants: • N560-IMA1W • N560-IMA-8Q/4L For this release, interoperation is supported only between the G.8275.1 and G.8275.2 profiles.

Restrictions and guidelines for multiple PTP profile interoperability

To effectively configure and manage PTP profile interoperability, it is essential to understand the specific restrictions and guidelines that govern the process. These elements ensure accurate clock synchronization and seamless operation across different profiles.

Restrictions

To ensure proper configuration and operation, these restrictions must be observed:

- Peer clock profile specification: Specify the profile of the peer clock; if not specified, the local clock's profile is used.
- Domain number specification: Use the domain number of the peer clock; if not specified, the local clock's domain number is used. Drop incoming PTP messages with a different domain number.

- Priority values mapping: Apply the default mapping for Priority1 and Priority2 values if not specified.
- Clock accuracy mapping: Apply the default mapping for **ClockAccuracy** value if not specified.
- Offset scaled log variance mapping: Apply the default mapping for **OffsetScaledLogVariance** value if not specified.

Guidelines

To ensure that accurate attributes of a clock are applied to define its behavior, these guidelines must be followed:

- Ingress-conversion behavior: Convert clock properties received in incoming **Announce** messages using Ingress-Conversion behavior.
- Clock-class mappings: Override default mappings with any number of **Clock-Class-Mappings** whenever present.
- Clock-class default value usage: Use **Clock-Class-Default** value for all clock class values without a more specific mapping.
- Egress-conversion behavior: Convert clock properties sent in outgoing **Announce** messages using Egress-Conversion behavior, with options such as Ingress-Conversion.

How multiple PTP profile interoperation works

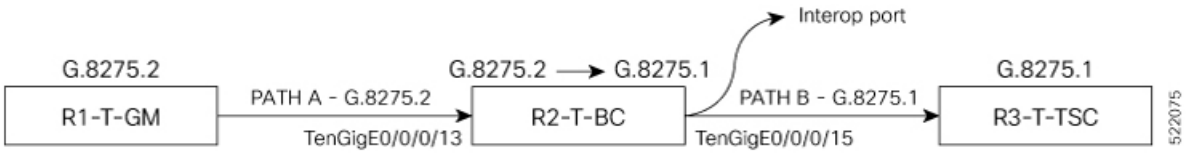
Summary

The key components that are involved in the process are:

- R1: Acts as the grandmaster clock.
- R2: Acts as a boundary clock.
- R3: Acts as the timeReceiver or ordinary clock.

Workflow

Figure 2: PTP profile interoperation



These stages describe how multiple PTP profile interoperation works.

1. R1 runs the G.8275.2 profile and sends synchronization information to R2.
2. R2 initially runs the G.8275.2 profile. The egress interface of R2 is configured with the **interop** command. The egress interface converts the profile from G.8275.2 to G.8275.1 before sending it to R3.
3. R3 receives the synchronization information from R2 and synchronizes its clock.

Result

This setup ensures that R2 can interoperate between different PTP profiles, converting the synchronization data from one profile to another as needed.

Configure multiple PTP profile interoperability

The purpose of this task is to configure multiple PTP profile interoperability. Use Figure: PTP profile interoperation to configure these steps. We have used interface TenGigE0/0/0/15 to configure the interoperability.

Follow these steps to configure multiple PTP profile interoperability.

Procedure

Step 1 Enter the **interop** command to configure the egress interface for multiple PTP profile interoperability.

```
R2(config)#interface TenGigE0/0/0/15
R2(config-if)#ptp
R2(config-if-ptp)#interop
```

Step 2 Enter the **profile** <*profile number*> command to configure the PTP profile to be used on this interface.

```
R2(config-if-ptp-interop)#profile g.8275.1
```

Step 3 Enter the **domain** <*domain number*> command to configure the domain of the peer clock.

```
R2(config-if-ptp-interop)#domain 24
```

Figure 3:

Step 4 Enter the **ptp multicast target-address ethernet** <*forwarding MAC address*> command to specify the Ethernet multicast group address to send multicast messages.

```
R2(config-if)#ptp multicast target-address ethernet 01-1B-19-00-00-00
```

Step 5 Enter the **transport ethernet** command to configure the transport type as Ethernet in the PTP profile.

```
R2(config-ptp-profile)#transport ethernet
```

Step 6 Enter the **port state master-only** command to configure the PTP port to operate exclusively as a timeTransmitter.

```
R2(config-if-ptp)#port state master-only
```

The port will only send PTP timing information to downstream devices.

Step 7 Enter these commands to configure frequency synchronization.

```
R2(config-if-ptp)#sync frequency 64
R2(config-if-ptp)#announce interval 1
R2(config-if-ptp)#delay-request frequency 32
R2(config-if-ptp)#frequency synchronization
```

Step 8 Run the **show ptp interop** command to view the egress profile conversion.

```
R2#show ptp interop
Sat Jul  3 17:28:53.477 UTC
Interface TenGigE0/0/0/15
```

```
Egress Conversions:
  Profile:                 G.8275.2 -> G.8275.1
  Domain:                        44 -> 24
  Priority1:                    128 -> 128
  Priority2:                    128 -> 128
  ClockClass:                     6 -> 6
  ClockAccuracy:               0x21 -> 0x21
  OffsetScaledLogVariance:   0x4e5d -> 0x4e5d

Ingress Conversions:
  This port is not receiving Announce messages
```

Configuring Virtual Port

Effective Cisco IOS XR Release 7.4.1, you can configure virtual port on the G8275.1 and G8275.2 profiles in hybrid and non-hybrid modes.

For virtual port configuration to work, GNSS or Sync2 must be configured.

```
ptp
clock
domain 44
profile g.8275.2 clock-type T-BC
!
profile profile1
transport ipv4
sync frequency 64
announce frequency 8
delay-request frequency 64
!
virtual-port
offset-scaled-log-variance 20061
priority2 128
clock-class 6
clock-accuracy 33
local-priority 127
!
frequency priority 254
time-of-day priority 90     <<--time-of-day priority is a required parameter if you want
to configure virtual port-->>
log
```

PTP over Bridged Virtual Interface

Table 6: Feature History

Feature Name	Release Information	Description
PTP over BVI	Release 25.4.1	This feature allows PTP traffic to flow over a bridged virtual interface.

Limitations

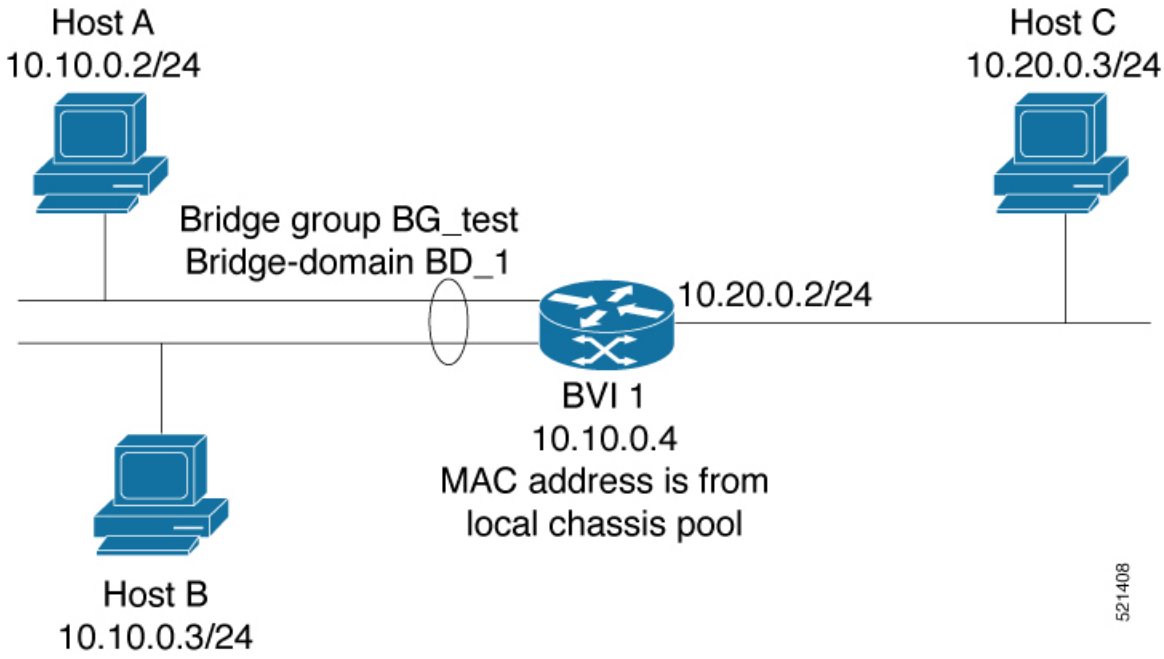
- PTP over BVI is supported only for PTP IPv4 sessions on BVI.
- PTP over BVI is supported only on the PTP transmitter interfaces of a T-BC.
- Starting with Cisco IOS XR Release 25.4.1, BVI bridge members can be bundle interfaces. However, if the PTP transmit and receive path is across different bundle member interfaces, it may impact PTP accuracy.

Configuring PTP over BVI

Consider the following topology:

Router BVI1 acts as PTP server or a BC node. Hosts A and B act as clients. Bridge group ***BG_test*** and bridge-domain ***BD_1*** are part of a Layer 2 cloud.

Figure 4: Sample Topology for Configuring PTP Over BVI



On the PTP Server, BVI1, configure the following:

```
ptp
!
interface GigabitEthernet0/0/0/1
l2transport
!
Interface Bundle-Ether 100
L2transport
!
interface BVI1
ptp
  profile master
!
```

```
ipv4 address 10.10.0.4 255.255.255.0
!
l2vpn
bridge group foo
  bridge-domain bar
   interface GigabitEthernet0/0/0/0
   !
   interface GigabitEthernet0/0/0/1
   !
   Interface Bundle-Ether 100
   !
   routed interface BVI1
   !
  !
!
!
```

Note Host routers A and B have the standard PTP client configuration.

Verifying PTP over BVI

To check for the packet counters at BVI interface on the server, use the **show ptp packet-counters bvi** *bvi-name* command.

To check the state of PTP on the BVI interface on the server, use the **show ptp interfaces brief** command.

Slow Tracking

Under normal configured conditions, any change in offset triggers an immediate reaction in the servo. With the Slow Tracking feature enabled, the servo corrects the phase offset based on the configured value. If the phase offset exceeds the acceptable range, servo goes into Holdover state. In such a condition, the Slow Tracking feature becomes inactive and the servo corrects itself to the latest offset and goes into Phase locked state. Slow Tracking becomes active again.

Note

- The supported slow tracking rate range is from 8-894 nanoseconds per second and must be in multiples of 8.
- This feature is active only when servo is in Phase locked mode.

```
Router:# config
ptp
clock
domain 24
profile g.8275.1 clock-type T-BC
!
profile profile1
multicast target-address ethernet 01-1B-19-00-00-00
transport ethernet
sync frequency 16
announce frequency 8
```

```
delay-request frequency 16
!
physical-layer-frequency
servo-slow-tracking 16
!
```

PTP Holdover Traceability Suppression

Table 7: Feature History Table

Feature Name	Release Information	Feature Description
PTP frequency-assisted holdover	Release 26.3.1	The frequency-assisted holdover feature enhances network stability by allowing for an extended holdover duration when a Primary Reference Clock (PRC) frequency source remains available. This ensures that even if the GNSS or PTP time source is lost, the system can maintain timing stability for a longer, user-defined period without significant degradation. CLI: • holdover-spec-frequency-assisted-duration
PTP Holdover Traceability Suppression	Release 7.4.1	When a device which is configured as a Boundary clock (T-BC) loses synchronization with a quality Primary clock, to ensure that the downstream nodes continue to receive the configured clock class for a specified duration, and it's traceable you can configure this feature.

When the device loses synchronization with a quality Primary clock, to ensure that the downstream nodes continue to receive the configured clock class, and it's traceable you can configure this feature.

This feature enables the device which is configured as a boundary clock (T-BC) with PTP Profiles G.8275.1 or G.8275.2 to send out the configured clock-class as holdover clock-class and the time traceability flag to be set as TRUE for the specified duration. This is to ensure the down-stream nodes do not have an impact as this is a deviation from prescribed G.8275.1 ITU-T standards.

Note

- There are PTP flaps during switchovers or ISSU as the PTP holdover timer is running on the active RSP.
- Once the configured holdover override duration has lapsed and the device is unable to receive a quality Primary clock within this duration, the device sends the prescribed default clock class of 165, and the traceability flag will be set as FALSE to advertise loss of clock to downstream nodes.

Configuring PTP Holdover traceability suppression

This section describes how to configure the PTP holdover traceability suppression feature:

```
Router# config
Router(config)# ptp
Router(config-ptp)# holdover-spec-duration 1000
Router(config-ptp)# holdover-spec-clock-class 135
Router(config-ptp)# uncalibrated-traceable-override
Router(config-ptp)# holdover-spec-traceable-override
Router(config-ptp)# holdover-spec-frequency assisted-duration 410000
```

IEEE Default Profile

The IEEE default profile is a PTP configuration profile that

- defines the parameters for time-of-day distribution using the Precision Time Protocol (PTP) in accordance with IEEE 1588-2008 and IEEE 1588-2019 standards,
- supports Delay Request-Response mechanisms on Cisco IOS XR Release 24.1.1 or later, and
- enables both ordinary clock and boundary clock operation, allowing flexible roles for routers in hybrid synchronization networks.

The IEEE default PTP profile prescribes a domain number value of 0, or within a range of 4–127. You may configure PTP on multiple router ports, with best clock selection governed by the Best Master Clock Algorithm (BMCA). If no superior clocks are detected, the router assumes the role of grandmaster clock and synchronizes all connected devices. Alternatively, if a clock connected to the router is determined to be superior, the router acts as a client for synchronization, then serves as a clock source for other devices. After synchronizing initial time, routers and devices exchange timing messages to correct clock offsets and network delays.

This PTP profile is typically deployed in hybrid mode—PTP carries time-of-day information, while frequency synchronization is provided by physical-layer sources such as SyncE. The default profile supports IPv4 unicast negotiation and, on compatible platforms, IPv6. Ethernet and multicast transports are not supported.

Example: Global PTP Configuration

Global PTP Configuration:

```
ptp
 clock
  domain 0
 !
 profile ptp_node
  transport ipv4
```

```
  sync frequency 32
  announce frequency 1
  delay-request frequency 32
 !
 physical-layer-frequency
!
```

Example: PTP Master Configuration

PTP Master Configuration:

```
interface TenGigE0/0/0/19
 ptp
  profile ptp_node
  !
 !
frequency synchronization
  wait-to-restore 0
 !
 ipv4 address 192.0.2.0/24
!
```

Example:PTP Slave Configuration

PTP Slave Configuration:

```
interface TenGigE0/0/0/18
 ptp
  profile ptp_node
 master ipv4 192.0.2.0/24
  !
frequency synchronization
  selection input
  wait-to-restore 0
 !
 !
 ipv4 address 192.0.2.0/24
!
```

PTP Hybrid Mode

Your router allows the ability to select separate sources for frequency and time-of-day (ToD). Frequency selection can be between any source of frequency available to the router, such as: GPS, SyncE or IEEE 1588 PTP. The ToD selection is between the source selected for frequency and PTP, if available (ToD selection is from GPS or PTP). This is known as hybrid mode, where a physical frequency source (SyncE) is used to provide frequency synchronization, while PTP is used to provide ToD synchronization.

Frequency selection uses the algorithm described in ITU-T recommendation G.781, and is described in the Configuring Frequency Synchronization module in this document. The ToD selection is controlled using the time-of-day priority configuration. This configuration is found under the source interface frequency synchronization configuration mode and under the global PTP configuration mode. It controls the order for which sources are selected for ToD. Values in the range of 1 to 254 are allowed, with lower numbers.

Configuring PTP Hybrid Mode

Note You must configure the PTP hybrid mode when using the G.8275.1 PTP profile.

Configure hybrid mode by selecting PTP for the time-of-day (ToD) and another source for the frequency. This task summaries the hybrid configuration. See the other PTP configuration modules for more detailed information regarding the PTP configurations. For more information on SyncE configurations, see the *Configuring Ethernet Interfaces* section in the *Interface and Hardware Component Configuration Guide for Cisco NCS 560 Series Routers*.

Note Configure appropriate clock priorities when using synchronous Ethernet for frequency synchronization. This ensures the system selects the frequency source from the same interface as the PTP source. Aligning both frequency and time synchronization to the same interface helps maintain consistency and reduces configuration complexity.

To configure PTP Hybrid mode:

1. Configure Global Frequency Synchronization

```
RP/0/RP0/CPU0:router(config)# frequency synchronization
    RP/0/RP0/CPU0:router(config)# commit
    RP/0/RP0/CPU0:router(config)# quality itu-t option [1 | 2]
```

2. Configure Frequency Synchronization in Interface.

```
RP/0/RP0/CPU0:router(config)# interface GigabitEthernet 0/0/0/0
RP/0/RP0/CPU0:router(config-if)# frequency synchronization
RP/0/RP0/CPU0:router(config-if-freqsync)# selection input
RP/0/RP0/CPU0:router(config-if-freqsync)# time-of-day-priority 100
RP/0/RP0/CPU0:router(config-if-freqsync)# commit
```

3. Configure Global PTP

```
RP/0/RP0/CPU0:router(config)# ptp
RP/0/RP0/CPU0:router(config-ptp)# time-of-day priority 1
RP/0/RP0/CPU0:router(config)# commit
```

4. Configure Client Port

```
RP/0/RP0/CPU0:router(config)# interface GigabitEthernet0/0/0/2
RP/0/RP0/CPU0:router(config-if)# ptp
RP/0/RP0/CPU0:router(config-if)# profile slave
RP/0/RP0/CPU0:router(config-if)# multicast target-address ethernet 01-1B-19-00-00-00
RP/0/RP0/CPU0:router(config-if)# transport ethernet sync frequency 16
RP/0/RP0/CPU0:router(config-if)# announce frequency 8
RP/0/RP0/CPU0:router(config-if)# delay-request frequency 16
RP/0/RP0/CPU0:router(config-if)# frequency synchronization
RP/0/RP0/CPU0:router(config-if-freqsync)# selection input
RP/0/RP0/CPU0:router(config-if-freqsync)# priority 1
RP/0/RP0/CPU0:router(config-if-freqsync)# wait-to-restore 0
```

5. Configure Server Port

```
RP/0/RP0/CPU0:router(config)# interface GigabitEthernet0/0/0/3
RP/0/RP0/CPU0:router(config)# ptp
RP/0/RP0/CPU0:router(config)# profile master
```

```
RP/0/RP0/CPU0:router(config)# multicast target-address ethernet 01-1B-19-00-00-00
RP/0/RP0/CPU0:router(config)# port state master-only
RP/0/RP0/CPU0:router(config)# transport ethernet
RP/0/RP0/CPU0:router(config)# sync frequency 16
RP/0/RP0/CPU0:router(config)# announce frequency 8
RP/0/RP0/CPU0:router(config)# delay-request frequency 16
RP/0/RP0/CPU0:router(config)# frequency synchronization
RP/0/RP0/CPU0:router(config-if-freqsync)# exit
```

Configure PTP for SyncE and PTP Traceability

In the hybrid mode of operation, if the SyncE and PTP clocks are coming from separate nodes and are not traceable to each other, and if the offset between the clocks is high, then the PTP-receiver may fail to synchronize with the PTP-transmitter node.

Starting with Cisco IOS XR Release 24.4.1, a new command, **synchronous-ethernet prefer-interface ptp-receiver**is introduced in the global frequency-synchronisation mode to ensure traceability between the PTP and SyncE clocks.

If you configure this CLI, note these points:

- A SyncE source among *equal sources* [1] is selected on the same interface on which PTP is selected by the router.
- If the SyncE source on the PTP receiver interface is inferior (in terms of QL and user configured priority) than any other available SyncE source, then the SyncE source is selected using the default criteria (based on the ITU-T G.781 requirements).
- In the event that the selected PTP source goes down or if the PTP source's quality degrades, the system may switch to another PTP source. In such case, use the **synchronous-ethernet prefer-interface ptp-receiver** command so that the SyncE source selection would also switch to the new PTP receiver interface. Here, the preferred switching of SyncE source to the new PTP receiver interface shall happen only if the new interface uses the same SyncE QL and the user configured priority as the previously selected interface.



Note The router can monitor only limited number of interfaces for SyncE selection. The **synchronous-ethernet prefer-interface ptp-receiver** command selects a SyncE source from the PTP receiver interface only if the interface is part of the list displayed using the **show frequency synchronization selection** command.

This example shows how to configure the **synchronous-ethernet prefer-interface ptp-receiver** command.

```
RP/0/RP0/CPU0:router(config)# frequency synchronization synchronous-ethernet prefer-interface
 ptp-receiver
RP/0/RP0/CPU0:router(config)# commit
```

This example verifies the **synchronous-ethernet prefer-interface ptp-receiver** configuration.

```
RP/0/RP0/CPU0:router(config)# show running-config frequency synchronization
Thu Aug 8 04:50:13.638 UTC
frequency-synchronization
 synchronous-ethernet prefer-interface ptp-receiver
!
```

[1] sources equal in their advertised QL and user configured priority

Verifying the PTP Hybrid Mode Configurations

Use the following show commands to verify the configurations:

- **show ptp platform servo**

```
RP/0/RP0/CPU0:ios# show ptp platform servo
Tue Mar  5 07:08:00.134 UTC
Servo status: Running
Servo stat_index: 2
Device status: PHASE_LOCKED
Servo Mode: Hybrid
Servo log level: 0
Phase Alignment Accuracy: 0 ns
Sync timestamp updated: 8631
Sync timestamp discarded: 0
Delay timestamp updated: 8631
Delay timestamp discarded: 0
Previous Received Timestamp T1: 22521.011765183  T2: 22521.011766745  T3: 22521.018061685
  T4: 22521.018063247
Last Received Timestamp T1: 22521.073747183  T2: 22521.073748745  T3: 22521.080054957
 T4: 22521.080056515
Offset from master:  0 secs, 2 nsecs
Mean path delay   :  0 secs, 1560 nsecs
setTime():1  stepTime():1 adjustFreq():0
Last setTime: 21984.000000000 flag:0  Last stepTime:-276573300 Last adjustFreq:0
RP/0/RP1/CPU0:ios#
```

- **show running-config ptp**

```
RP/0/RP0/CPU0:router# show running-config ptp
ptp
clock
domain 24
profile g.8275.1 clock-type T-BC
!
profile slave
transport ethernet
sync frequency 16
announce frequency 8
delay-request frequency 16
!
profile master
transport ethernet
sync frequency 16
announce frequency 8
delay-request frequency 16
!
!
physical-layer frequency
!
```

- **show running-config frequency synchronization**

```
RP/0/RP0/CPU0:router# show running-config frequency synchronization
Tue Feb 6 06:36:26.472 UTC
frequency synchronization
quality itu-t option 1
clock-interface timing-mode system
!
```

- **show frequency synchronization interface brief**

```
RP/0/RP0/CPU0:P3# show frequency synchronization interface brief

Tue Feb 6 06:37:49.234 UTC
Flags: > - Up D - Down S - Assigned for selection
d - SSM Disabled x - Peer timed out i - Init state
s - Output squelched
Fl Interface QLrcv QLuse Pri QLsnd Output driven by
==== ======================= ===== ===== === ===== =======================
>S GigabitEthernet0/0/0/2 PRC PRC 1 DNU GigabitEthernet0/0/0/2
>x GigabitEthernet0/0/0/3 Fail n/a 100 PRC GigabitEthernet0/0/0/2
>x GigabitEthernet0/0/0/4 Fail n/a 100 PRC GigabitEthernet0/0/0/2
RP/0/RP0/CPU0:P3#
```

Configure PTP Delay Asymmetry

Table 8: Feature History Table

Feature Name	Release Information	Description
PTP Delay Asymmetry	Release 7.3.1	Any delays on Precision Time Protocol (PTP) paths can impact PTP accuracy and in turn impact clock settings for all devices in a network. This feature allows you to configure the static asymmetry such that the delay is accounted for and the PTP synchronization remains accurate. The **delay-symmetry** command is introduced for this feature.
PTP Delay Asymmetry	Release 7.6.1	You can configure static asymmetry such that any delays on Precision Time Protocol (PTP) paths are accounted for, and the PTP synchronization remains accurate, thus avoiding any impact to clock settings for all devices in a network.

Configure PTP delay asymmetry to offset the static delays on a PTP path that occur due to different route selection for forward and reverse PTP traffic. Delays can also be due to any node having different delay for ingress or egress path. These delays can impact PTP accuracy due to the asymmetry in PTP. With this feature, you can enable a higher degree of accuracy in the PTP server performance leading to better synchronization between real-time clocks of the devices in a network.

Configuration of this delay asymmetry provides an option to configure static delays on a client clock for every server clock. You can configure this delay value in microseconds and nanoseconds. Configured PTP delay asymmetry is also synchronized with the Servo algorithm.

Note

- If you configure multiple PTP delay asymmetries for the same PTP profile, the latest PTP delay asymmetry that you configure is applied to the PTP profile.
- For G8275.1 and G8275.2 PTP profiles, PTP delay asymmetry is supported for both, client port and dynamic port that act as a client.
- Fixed delay can be measured by using any test and measurement tool. Fixed delay can be compensated by using the positive or negative values. For example, if the fixed delay is +10 nanoseconds, configure -10 nanoseconds to compensate the fixed delay.

A positive value indicates that the server-to-client propagation time is longer than the client-to-server propagation time, and conversely for negative values.

Supported PTP Profiles

The following PTP profiles support the configuration of PTP delay asymmetry:

- PTP over IP (G8275.2 or default profile)
- PTP over L2 (G8275.1)

Restrictions

- PTP delay asymmetry can be configured only on the PTP port of the grandmaster clock, which can either be a boundary clock or an ordinary clock.
- PTP delay asymmetry is supported for delay compensation of fixed cables and not for variable delay in the network.
- PTP delay asymmetry can be configured within the range of 3 microseconds and -3 microseconds or 3000 nanoseconds and -3000 nanoseconds.

Configuration

To configure PTP delay asymmetry:

1. Configure an interface with PTP.
2. Configure PTP delay asymmetry on the client side.

Configuration Example

```
/* Configure an interface with PTP. */
Router# configure
Router(config)# interface HundredGigE 0/1/0/0
Router(config-if)# ptp

/* Configure PTP delay asymmetry on the client side. */
Router(config-if-ptp)# delay-asymmetry 3 microseconds
Router(config-if-ptp)# commit
```

Running Configuration

```
interface preconfigure HundredGigE 0/1/0/0
 ptp
  delay-asymmetry 3 microseconds
```

Verification

To verify if PTP delay asymmetry is applied, use the **show ptp foreign-masters** command:

```
Router# show ptp foreign-masters
Sun Nov 1 10:19:21.874 UTC
Interface HundredGigE0/1/0/0 (PTP port number 1)
IPv4, Address 209.165.200.225, Unicast
Configured priority: 1
Configured clock class: None
Configured delay asymmetry: 3 microseconds <- configured variable delay asymmetry value
Announce granted: every 2 seconds, 300 seconds
Sync granted: 16 per-second, 300 seconds
Delay-resp granted: 16 per-second, 300 seconds
Qualified for 2 minutes, 45 seconds
Clock ID: 80e01dfffe8ab73f
Received clock properties:
Domain: 0, Priority1: 128, Priority2: 128, Class: 6
Accuracy: 0x22, Offset scaled log variance: 0xcd70
Steps-removed: 1, Time source: GPS, Timescale: PTP
Frequency-traceable, Time-traceable
Current UTC offset: 37 seconds (valid)
Parent properties:
Clock ID: 80e01dfffe8ab73f
Port number: 1
```

To validate the approximate compensated delay value, use the **show ptp platform servo** command:

```
Router# show ptp platform servo
Mon Jun 27 22:32:44.912 UTC
Servo status: Running
Servo stat_index: 2
Device status: PHASE_LOCKED
Servo Mode: Hybrid
Servo log level: 0
Phase Alignment Accuracy: -2 ns
Sync timestamp updated: 18838
Sync timestamp discarded: 0
Delay timestamp updated: 18837
Delay timestamp discarded: 0
Previous Received Timestamp T1: 1657002314.031435081  T2: 1657002314.031436686  T3:
1657002314.026815770  T4: 1657002314.026814372
Last Received Timestamp T1: 1657002314.031435081  T2: 1657002314.031436686  T3:
1657002314.088857790  T4: 1657002314.088856392
Offset from master:  0 secs, 1502 nsecs    <<--compensated value shows 1.5 microseconds
because the asymmetry configured under the interface is
3 microseconds.->>
Mean path delay   :  0 secs, 103 nsecs
setTime():0  stepTime():0 adjustFreq():2
Last setTime: 0.000000000 flag:0  Last stepTime:0 Last adjustFreq:-5093
```

Performance Monitoring for PTP Networks

Performance Monitoring in PTP involves tracking and analyzing the performance of PTP networks to ensure accurate time synchronization across devices. This includes monitoring various metrics such as clock accuracy,

synchronization status, and network delays. The goal is to identify and address any issues that may affect the precision and reliability of time synchronization in the network.

Performance Monitoring now has the ability to provide performance monitoring and time-stamp analysis information in a PTP network as per Annex J IEEE 1588-2019. This feature also includes additional monitoring granularity for time synchronization in telecommunication networks as per Annex F from the G8275 standard. For more information on PTP, Best TimeTransmitter Clock Algorithm (BTCA), see PTP Overview.

You can use the following parameters to define the Performance Monitoring in a PTP Network:

- Performance Monitoring Parameters
- Port Specific Parameters

Performance Monitoring Parameters

In addition to using the timestamps received from the grandmaster to sync to the grandmaster's clock, the timestamps can now be used to calculate parameters that are of your interest in performance monitoring:

- **TimeTransmitter - TimeReceiver Delay**: corrected propagation time from TimeTransmitter to TimeReceiver.
- **TimeReceiver - TimeTransmitter Delay**: corrected propagation time from TimeReceiver to TimeTransmitter.
- **Mean Path Delay**: mean propagation time over the PTP Communication Path.
- **Offset from TimeTransmitter**: time difference between a TimeTransmitter PTP instance and a TimeReceiver PTP instance as computed by the TimeReceiver PTP instance.

For each of these parameters, you can measure the average, minimum, maximum, and standard deviation for each measurement. These values are calculated and maintained for the following time intervals over the specified time periods:

- **3-minute**: maintained for the current 1-hour period.
- **15-minute**: maintained for the current 24-hour period.
- **1-hour**: maintained for the current 2-hour period.
- **24-hour**: maintained for the current 48-hour period.

The platform actively calculates the end-to-end latency between the TimeTransmitter and TimeReceiver through the Delay-Request-Response-Mechanism (DRRM), allowing Precision Time Protocol (PTP) to seamlessly operate across networks equipped with Transparent clocks, non-PTP aware switches, or a mix of both. Upon a request, PTP dynamically extracts these calculated values from the servo using a platform specific API, allowing you to make proactive changes to the network to ensure precise time synchronization essential for applications that depend on accurate timing.

Additional Port Specific Parameters

The parameters mentioned above apply to the entire Precision Time Protocol (PTP) instance, and there is an additional set of parameters specific to individual ports. These parameters include the counters for various packet types,

- received (rx) and

- transmitted (tx)

It is important to collect and maintain these counters for performance monitoring purposes, which follows the same time intervals and periods as those used for monitoring clock performance.

Port-specific parameters play a crucial role in ensuring accurate time synchronization. These packet types are essential for maintaining the accuracy and reliability of time synchronization in a PTP network:

- **Sync Packets**: These packets are sent by the master clock to the slave clocks to synchronize their time. They contain the precise time at which the packet was sent.
- **Delay Request Packets**: Sent by the slave clock to the master clock, these packets measure the delay between the master and slave clocks. The master clock responds with a Delay Response packet.
- **Follow-Up Packets**: These packets are sent by the master clock immediately after the Sync packet. They contain the exact time the Sync packet was sent, which helps in correcting any delays introduced by the network.
- **Announce Packets**: These packets are used by the master clock to announce its presence and capabilities to the slave clocks. They help in the selection of the best master clock in the network.
- **Management Packets**: These packets are used for configuration and management purposes within the PTP network. They allow for the adjustment of various parameters and settings.

Record format

Record format refers to the structure or layout of data within a record, which is used to store information about time synchronization events and measurements. This format can include various fields such as timestamps, event types, and other relevant data that PTP uses to maintain accurate time synchronization across a network. It is a single buffer for both annexes.

The format is the same for both clock and port performance monitoring parameters that is presented in the operational data. The data is stored over a 48-hour period, resulting in a list of records as per Annex J 1588-2019, composed of the following:

- 1 record for the current 15-minute set of statistics (stored at position 0 in the buffer).
- 96 records for the 15-minute sets of statistics over the last 24-hour period (stored between positions 1-96 in the buffer).
- 1 record for the current 24-hour set of statistics (stored at position 97 in the buffer).
- 1 record for the previous 24-hour set of statistics (stored at position 98 in the buffer).

The data buffer records data at 3-minute intervals over the most recent 1-hour period, creating a list of records that includes:

- 1 record for the current 3-minute set of statistics (stored at position 100 in the buffer).
- 20 records for the 3-minute set of statistics over the last 1-hour period (stored between positions 101-120).
- 1 record for the current 1-hour set of statistics (stored at position 121 in the buffer).
- 1 record for the previous 1-hour set of statistics (stored at position 122 in the buffer).

Configure PTP Performance Monitoring

The purpose of this task is to configure and verify PTP performance monitoring.

Procedure

Step 1 Configure the **performance-monitoring** command to enable collection of performance monitoring statistics and for the users to make performance monitoring requests.

Example:

```
Router(config)# ptp
Router(config-ptp)# performance-monitoring
Router(config-ptp)# commit
```

Step 2 Verify that PTP performance monitoring is enabled.

Example:

```
Router# show running-config ptp
```

Step 3 Run the **sh ptp platform performance-counters** command to display the details of all 123 records.

The existing command **show ptp platform** is extended to include the performance monitoring data for the local clock. The detail mode of the command displays all 123 records while the brief mode displays only the current windows for 15 minutes, 24 hours, 3minutes, and 1hour.

Example:

```
Router#sh ptp platform performance-counters detail

PTP Current record index 15 min: 96
PTP Current record index 3 min: 119

PTP performance monitoring statistics:
================================================================================================================
15 min stats
[0]     12 August 2024 07:08:59 UTC 15 min statistics
----------------------------------------------------------------------------------------------------------------

                Stat    Min(sec.nsec)        Max(sec.nsec)       Mean(sec.nsec)     Std
deviation           Samples
----------------------------------------------------------------------------------------------------------------

  Master-slave-delay -000000000.15937      000000000.333       -000000000.1780
000000000.71191      154
  Slave-master-delay  000000000.319        000000000.16593      000000000.2437
000000000.74103      154
     mean-path-delay  000000000.322        000000000.334        000000000.327
000000000.4057       154
  offset-from-master -000000000.16263      000000000.6         -000000000.2108
000000000.72546      154

----------------------------------------------------------------------------------------------------------------

            Complete      Valid      PmRef      ServoAtStart     ServoAtEnd
LastServoFlapTime
----------------------------------------------------------------------------------------------------------------
```

```
                FALSE      FALSE       TRUE        PHASE_LOCKED   HOLDOVER               12
 Apr 2024 07:09:09 UTC

==============

….
```

Step 4 Run the **show ptp dataset performance clock** command to display the performance monitoring data-set details in 15 minutes intervals.

Example:

```
Router#show ptp dataset performance clock

performanceMonitoringDS for the current 15-minute window:
Clock ID ccccfffecccc00, steps removed 1, receiving-port 2:
    Start of time window: Thursday, April 11, 2024 14:18:59
    Measurement is valid
    Period is complete
    Measurement has been taken with reference to system clock
    Master slave delay:
        Average: 50ns
        Min: 50ns
        Max: 70ns
        Std: 1ns
    Slave master delay:
        Average: 51ns
        Min: 51ns
        Max: 71ns
        Std: 2ns
    Mean path delay:
        Average: 52ns
        Min: 52ns
        Max: 72ns
        Std: 3ns
    Offset from master:
        Average: 53ns
        Min: 53ns
        Max: 73ns
        Std: 4ns

Clock ID aaaabbbecccc00, steps removed 1, receiving-port 2:
    Start of time window: Thursday, April 11, 2024 14:18:59
    Measurement is not valid
    Period is not complete
    Measurement has been taken with reference to system clock
    Master slave delay:
        Average: 50ns
        Min: 50ns
        Max: 70ns
        Std: 1ns
    Slave master delay:
        Average: 51ns
        Min: 51ns
        Max: 71ns
        Std: 2ns
    Mean path delay:
        Average: 52ns
        Min: 52ns
        Max: 72ns
        Std: 3ns
    Offset from master:
        Average: 53ns
```

```
        Min: 53ns
        Max: 73ns
        Std: 4ns
```

Step 5 Run the **show ptp dataset performance port** to display the Performance Monitoring Port Data-set in 15 minutes intervals.

Example:

```
Router#show ptp dataset performance port GigabitEthernet 0/0/0/1

performanceMonitoringPortDS for the current 15-minute window:
Interface GigabitEthernet 0/0/0/1
    Start of time window: Thursday, April 11, 2024 14:18:59
    Measurement is valid
    Period is not complete
    Measurement has been taken with reference to system clock
    Packets                      Sent        Received         Dropped
    ------------------------------------------------------------------
    Announce                        3              83              11
    Sync                            0              32               5
    Follow-Up                       0              31               0
    Delay-Req                      22               0               0
    Delay-Resp                      0              21               7
    Pdelay-Req                      0               7               0
    Pdelay-Resp                     0               0               0
    Pdelay-Resp-Follow-Up           0               0               0
    Signaling                       2               1               0
    Management                      0               0               0
    Other                           0               3              12
                                 -----           -----           -----
    TOTAL                          27             178              35
```

What to do next

To disable PTP performance monitoring, remove the global configuration and commit the change:

```
Router# configure
Router(config)# ptp
Router(config-ptp)# no performance-monitoring
Router(config-ptp)# commit
```

To verify the removal:

```
Router# show running-config ptp
```