Configuring Precision Time Protocol (PTP)

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Restrictions and Limitations for Precision Time Protocol

- The output of the **show clock** command on the device and PTP servo clock that is displayed in the output of the **show platform software fed active ptp domain** command are not synchronized. These are two different clocks that are used on the switch.
- Synchronization of PTP clock from system clock and vice versa is not supported.
- Inter-VLAN is not supported in PTP Transparent Clock Mode.
- The Cisco PTP implementation supports only the two-step clock and not the one-step clock. If the switch receives a one-step message from the Grand Master Clock, the message will be dropped.
- We do not recommend having non-PTP enabled devices in the PTP network since it decreases clock synchronization accuracy.
- Management messages with broadcast target id will be forwarded with a reduced hop count when the boundary clock mode is enabled. Management messages will be forwarded without decreasing the boundary hop count when transparent clock mode is enabled.
- Moving directly from one PTP mode to the other is not recommended. Clear the existing mode using **no PTP mode** and then configure a new mode.
- IPv6 and VRF do not support PTP.
- Transparent clock mode is not supported on native Layer 3 ports and EtherChannel interfaces. (boundary clock mode is supported on native Layer 3 ports)
- PTP cannot be configured on supervisor modules.
- PTP is not supported on supervisor uplink ports.
- PTPv2 on Cisco StackWise Virtual is supported only on single supervisor chassis.

Information About Precision Time Protocol

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.

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 required for PTP data packets

Ethernet Switches and Delays

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

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

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

Message-Based Synchronisation

To ensure clock synchronization, PTP requires an accurate measurement of the communication path delay between the time source (master) and the receiver (slave). PTP sends messages between the master and slave device to determine the delay measurement. Messages are described in detail in #unique_188. 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 network data for the calculated delay, resulting in more accurate time information.

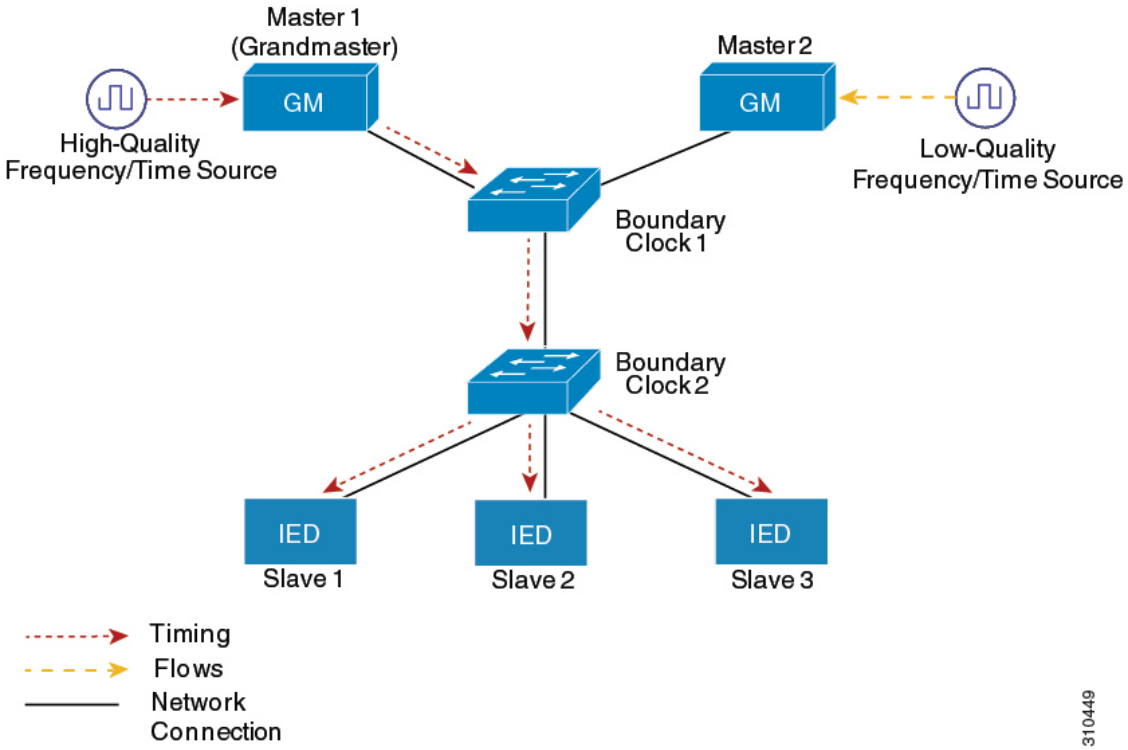
This delay measurement principle determines path delay between devices on the network, and the local clocks are adjusted for this delay using a series of messages that are sent between masters and slaves. The one-way delay time is calculated by averaging the path delay of the transmit and receive messages. This calculation assumes a symmetrical communication path; switched networks do not necessarily have symmetrical communication paths, due to the buffering process.

PTP provides a method, using transparent clocks, to measure and account for the delay in a time-interval field in network timing packets, making the switches temporarily transparent to the master and slave nodes on the network. An end-to-end transparent clock forwards all messages on the network the same way that a switch does.

Note Cisco PTP supports multicast PTP messages only.

The following figure shows a typical 1588 PTP network that includes grandmaster clocks, switches in boundary clock mode, and Intelligent Electronic Device (IEDs) such as a digital relays or protection devices. In this diagram, Master 1 is the grandmaster clock. If Master 1 becomes unavailable, the boundary clock slaves switch to Master 2 for synchronization.

Figure 1: A PTP Network with Switches in Boundary Clock Mode



Note PTP with etherchannel interface and MACsec is supported.

Precision Time Protocol Version 2 Message Types

PTP messages are categorized into the following types:

Event Messages are tagged with timestamps when data packets reach or leave a port and are used to calculate the link delay based on the timestamps. Messages:

- Sync

- Delay_Req
- Pdelay_Req
- Pdelay_Resp

General Messages are not tagged with timestamps and are used to establish a master-slave hierarchy. General messages are listed below:

- Announce
- Follow_Up
- Delay_Resp
- Pdelay_Resp_Follow_Up

Announce messages are used to establish the synchronization hierarchy.

Sync, Delay_Req, Follow_Up, and Delay_Resp messages are used to synchronize ordinary and boundary clocks.

Pdelay_Req, Pdelay_Resp, and Pdelay_Resp_Follow_Up messages are used to measure the link delay in transparent clocks.

The (Best Master Clock Algorithm (BMCA) elects the grandmaster clock and assign the ports as master or slave. Following this, all the master ports start sourcing the clock to the downstream slaves using the Sync and Follow_Up messages. The downstream slaves receive the clock and update their clock after computing the delay of the link, time offset, frequency offset and drift error parameters.

The downstream slaves compute the link delay using one of the mechanisms.

- End-to-End Delay Mechanism, on page 4
- Peer-to-Peer Delay Mechanism, on page 6

Precision Time Protocol and Software Defined Architecture Overlay

- Software Defined Architecture (SDA) fabric switches do not support PTP messages with hardware timestamp.
- PTP clock accuracy and latency gets affected when overlay PTP messages are forwarded without hardware timestamp. PTP clock accuracy and latency gets affected as the number of hops increases.
- Configure multicast protocols — IGMP and PIM to forward Layer 2, Layer 3 format of PTP messages in overlay.

Precision Time Protocol Event Message Sequences

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

End-to-End Delay Mechanism

The ordinary and boundary clocks that are 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

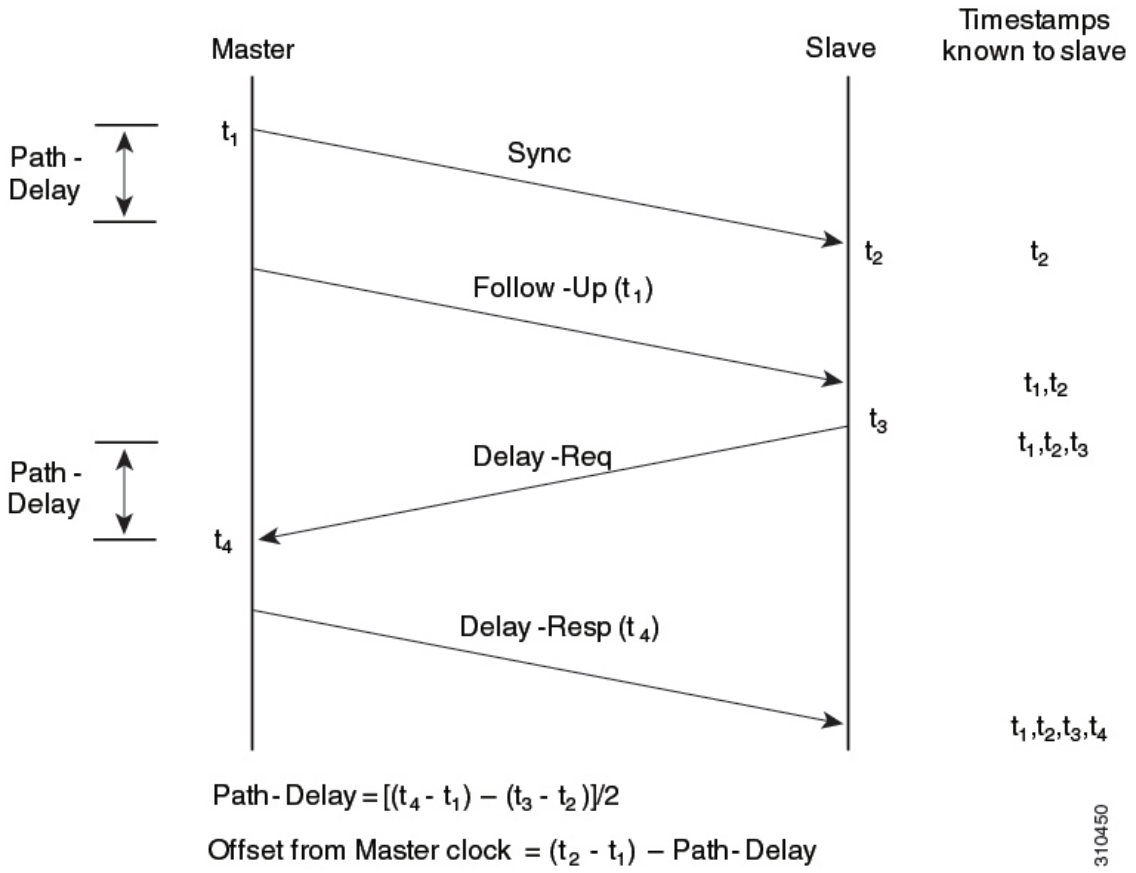
These messages are sent in the following sequence:

1. The master sends a Sync message to the slave and notes the time (t1) at which it was sent.
2. The slave receives the Sync message and notes the time of reception (t2).
3. The master conveys to the slave the timestamp t1 by embedding the timestamp t1 in a Follow_Up message.
4. The slave sends a Delay_Req message to the master and notes the time (t3) at which it was sent.
5. The master receives the Delay_Req message and notes the time of reception (t4).
6. The master conveys to the slave the timestamp t4 by embedding it in a Delay_Resp message.

After this sequence, the slave possesses all four timestamps. These timestamps can be used to compute the offset of the slave clock relative to the master, 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 master to slave is the same as the time required from slave to master. Assumption is not always valid on an Ethernet network due to asymmetrical packet delay times.

Figure 2: End-to-End Delay Mechanism



Peer-to-Peer Delay Mechanism

When the network includes multiple levels of boundary clocks in the hierarchy, with non-PTP enabled devices between them, synchronization accuracy decreases.

The round-trip time is assumed to be equal to mean_path_delay/2, this is not always valid for Ethernet networks. To improve accuracy, the resident time of each intermediary clock is added to the offset in the end-to-end transparent clock. Resident time, however, does not take into consideration the link delay between peers, which is handled by peer-to-peer transparent clocks.

Peer-to-peer transparent clocks measure the link delay between two clock ports implementing the peer delay mechanism. The link delay is used to correct timing information in Sync and Follow_Up messages.

Peer-to-peer transparent clocks use the following event messages:

- Pdelay_Req
- Pdelay_Resp
- Pdelay_Resp_Follow_Up

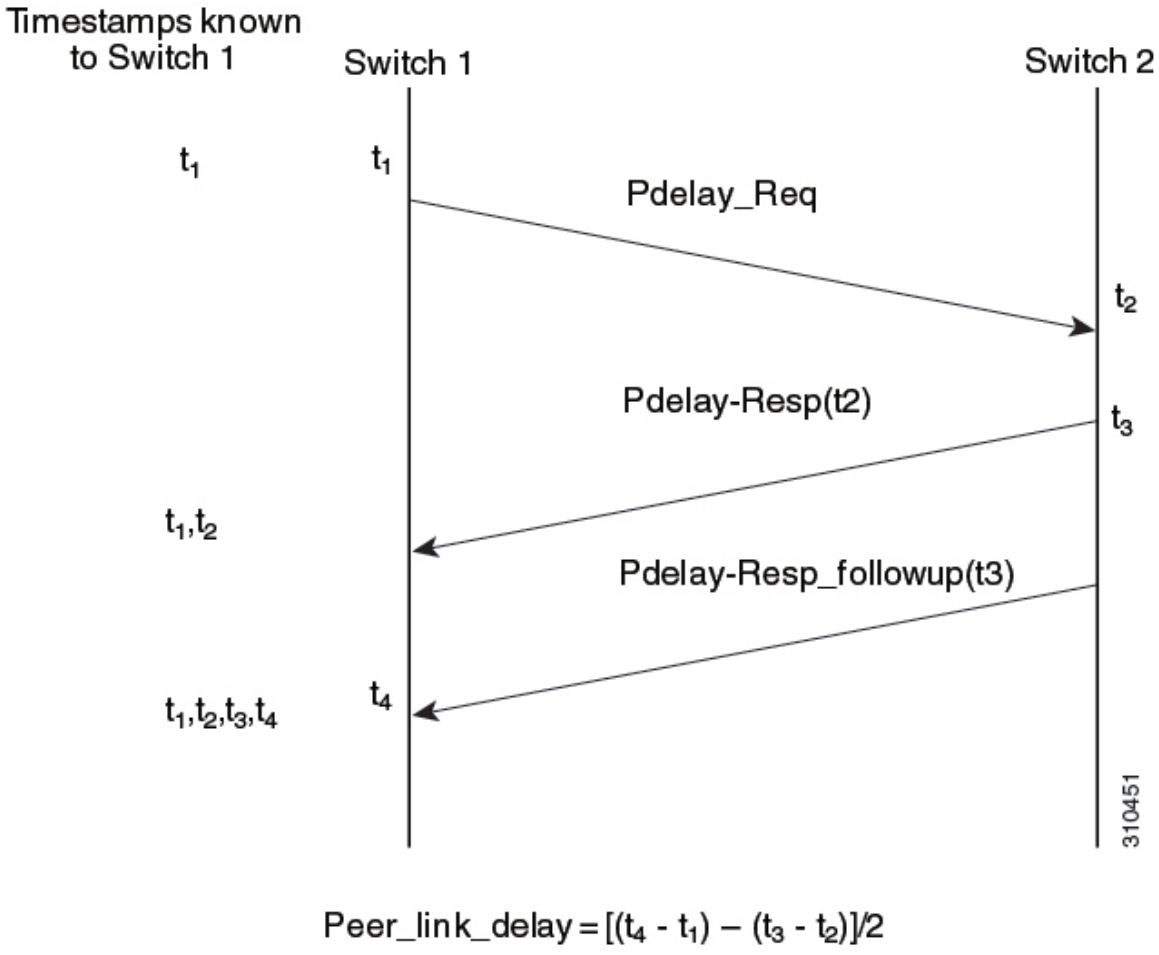
These messages are sent in the following sequence:

1. Port 1 generates timestamp t1 for a Pdelay_Req message.

2. Port 2 receives and generates timestamp t2 for this message.
3. Port 2 returns and generates timestamp t3 for a Pdelay_Resp message.

   To minimize errors due to any frequency offset between the two ports, Port 2 returns the Pdelay_Resp message as quickly as possible after the receipt of the Pdelay_Req message.
4. Port 2 returns timestamps t2 and t3 in the Pdelay_Resp and Pdelay_Resp_Follow_Up messages respectively.
5. Port 1 generates timestamp t4 after receiving the Pdelay_Resp message. Port 1 then uses the four timestamps (t1, t2, t3, and t4) to calculate the mean link delay.

Figure 3: Peer-to-Peer Delay Mechanism



Synchronizing the Local Clock

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

Best Master Clock Algorithm

The Best Master Clock Algorithm (BMCA) is the basis of PTP functionality. The BMCA specifies how each clock on the network determines the best master clock in the subdomain of all the clocks that it can see, including itself. The BMCA runs locally on each port in network continuously for every Announce interval and quickly adjusts for changes in network configuration. BMCA based on IEEE 1588-2008 uses Announce messages for advertising clock properties.

The BMCA uses the following criteria to determine the best master clock in the subdomain:

- Clock quality. Example, GPS is considered the highest quality.
- Accuracy of the clock's time base
- Stability of the local oscillator
- Closest clock to the grandmaster

BMCA based on IEEE 1588-2008 uses own data set with the received data set to determine the best clock based on the attributes with the following properties, in the indicated order:

1. Priority1: User-assigned priority to each clock. The range is from 0 to 255. The default value is 128.
2. Class: Class to which a clock belongs, each class has its own priority.
3. Accuracy: Precision between clock and UTC, in nanoseconds
4. Variance: Variability of clock
5. Priority2: Final priority. The range is from 0 to 255. The default value is 128.
6. Unique Identifier: 64-bit Extended Unique Identifier (EUI)

In addition to identifying the best master clock, the BMCA also ensures that clock conflicts do not occur on the PTP network by ensuring that:

- There is no misconfiguration, such as two master clocks or no master clocks, as a result of the master clock identification process.
- Clocks do not have to negotiate with one another

Note Starting Cisco IOS XE Bengaluru 17.6.4 release, the default PTP profile determines its own synchronization tree, and this synchronization tree is different from spanning tree.

PTP Ports

This topic decribes about the different PTP port states and their respective functions:

PTP Port State	Description
INITIALIZING	When a port is in the INITIALIZING state, it initiates data sets, hardware and communication facilities. There are no PTP messages placed by the ports of the clock in its communication path. If one of the ports of boundary clock is in INITIALIZING state, then all the ports will be in the INITIALIZING state.

PTP Port State	Description
FAULTY	When a port is in the FAULTY state, there are no PTP messages allowed in the communication path. Ports in a boundary clock is not affected by a FAULTY port with no activity. When the port link status is down, PTP port state moves to FAULTY.
DISABLED	A DISABLED port places no messages on it's communication path. This port state affects no activity at any other port of the boundary clock. A DISABLED port state discards all PTP messages received except for peer delay messages.
LISTENING	The LISTENING port state waits for the announceReceiptTimeout to expire or to receive an Announce message from the master clock. This port state essentially allows orderly addition of clocks to a domain. When a port is in LISTENING state, does not accept any PTP messages except for Pdelay_Req, Pdelay_Resp, Pdelay_Resp_Follow_Up messages.
PRE_MASTER	The PRE_MASTER port behaves similar to a MASTER port state. The PRE_MASTER port state does not place any messages on its communication path except for Pdelay_Req, Pdelay_Resp, Pdelay_Resp_Follow_Up, signaling, or management messages.
MASTER	This port state behaves as the MASTER of the time source.
PASSIVE	The PASSIVE port state does not place any messages on its communication path except for Pdelay_Req, Pdelay_Resp, Pdelay_Resp_Follow_Up.
UNCALIBRATED	A port state is UNCALIBATED when there is more than one master port in the domain. This happens when the appropriate master port is selected and the local port is preparing to synchronize with the selected master port. This is a transient state that allows initialization of synchronization servos, updating of data sets when a new master port has been selected, and other implementation-specific activity.
SLAVE	This port state synchonises with the selected MASTER port.

Precision Time Protocol Clocks

A PTP network is made up of PTP-enabled devices. These 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 have a free run.

Note Use the device as grandmaster clock in the network considering its reduced clock accuracy.

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 master or slave within a subdomain. These 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 switch or 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 BMCA is used to select the best clock seen by any port. The selected port is then set as a slave and the other ports are set as master. The master port synchronizes the clocks that are connected downstream, while the slave port synchronizes with the upstream master clock.

To set a port permanently as primary (master), use the **ptp role primary** command in interface configuration mode. Setting a port permanently as primary (master) ensures that the port remains as a primary (master) even if a clock connected to the port can be elected as a grandmaster clock.

Note The command **ptp role primary** must be used only on ports that are used as end nodes on a network that are connected to devices requiring synchronization.

Use the **show ptp port** *interface_id* command to verify if the port is set as primary (master).

Transparent Clock

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

There are two types of transparent clocks:

End-to-end (E2E) transparent clocks measure the PTP event message transit time (also known as resident time) for SYNC and DELAY_REQUEST messages. This measured transit time is added to a data field (correction field) in the corresponding messages:

- The measured transit time of a SYNC message is added to the correction field of the corresponding SYNC or the FOLLOW_UP message.
- The measured transit time of a DELAY_REQUEST message is added to the correction field of the corresponding DELAY_RESPONSE message.

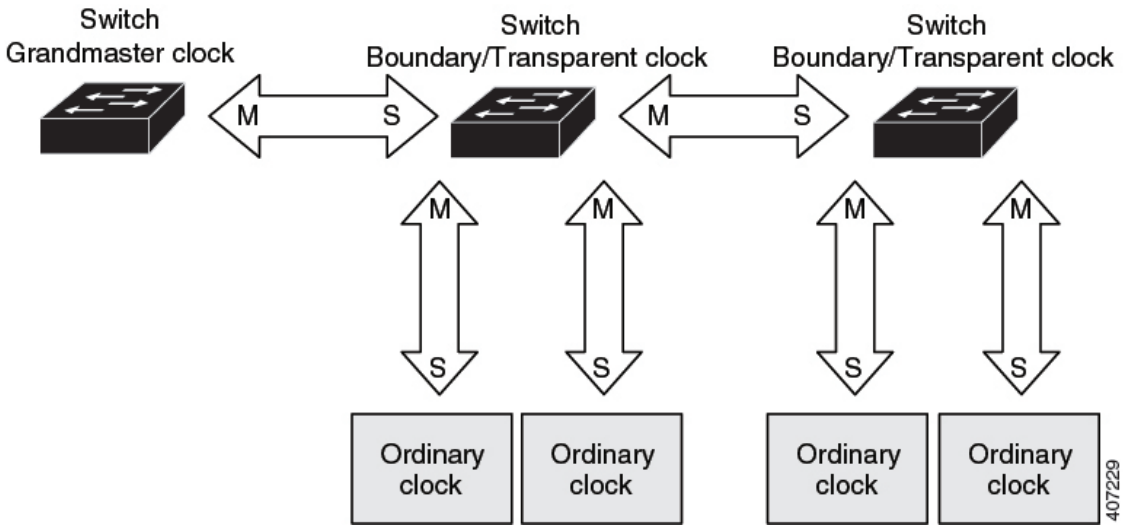
The slave uses this information when determining the offset between the slave's and the master's time. E2E transparent clocks do not provide correction for the propagation delay of the link itself.

Peer-to-peer (P2P) transparent clocks measure PTP event message transit time the same way E2E transparent clocks do. In addition, P2P transparent clocks measure the upstream link delay. The upstream link delay is the estimated packet propagation delay between the upstream neighbor P2P transparent clock and the P2P transparent clock under consideration.

These two times (message transit time and upstream link delay time) are both added to the correction field of the PTP event message, correction field of the message that is received by the slave contains the sum of all link delays. In theory, this is the total end-to-end delay (from master to slave) of the SYNC packet.

The following figure illustrates PTP clocks in a master-slave hierarchy within a PTP network.

Figure 4: PTP Clock Hierarchy



Precision Time Protocol Profiles

The IEEE 1588 definition of a PTP profile is the set of allowed PTP features applicable to a device . A PTP profile is usually specific to a particular type of application or environment and defines the following values:

- Best master clock algorithm options
- Configuration management options
- Path delay mechanisms (peer delay)
- Range and default values of all PTP configurable attributes and data set members
- Closest clock to the grandmaster
- Transport mechanisms that are required, permitted, or prohibited
- Node types that are required, permitted, or prohibited
- Options that are required, permitted, or prohibited

Default Profile

The default PTP profile mode on switch is default profile mode. The PTP mode of transport is Layer 2 and Layer 3.

By default, PTP default profile is disabled globally on these platforms.

Precision Time Protocol on an EtherChannel Interface

An EtherChannel interface allows multiple physical Ethernet links to combine into one logical channel. Configuring EtherChannel interface allows load sharing of traffic among the links in the channel as well as redundancy if one or more links in the EtherChannel fail. This behaviour of an EtherChannel interface does

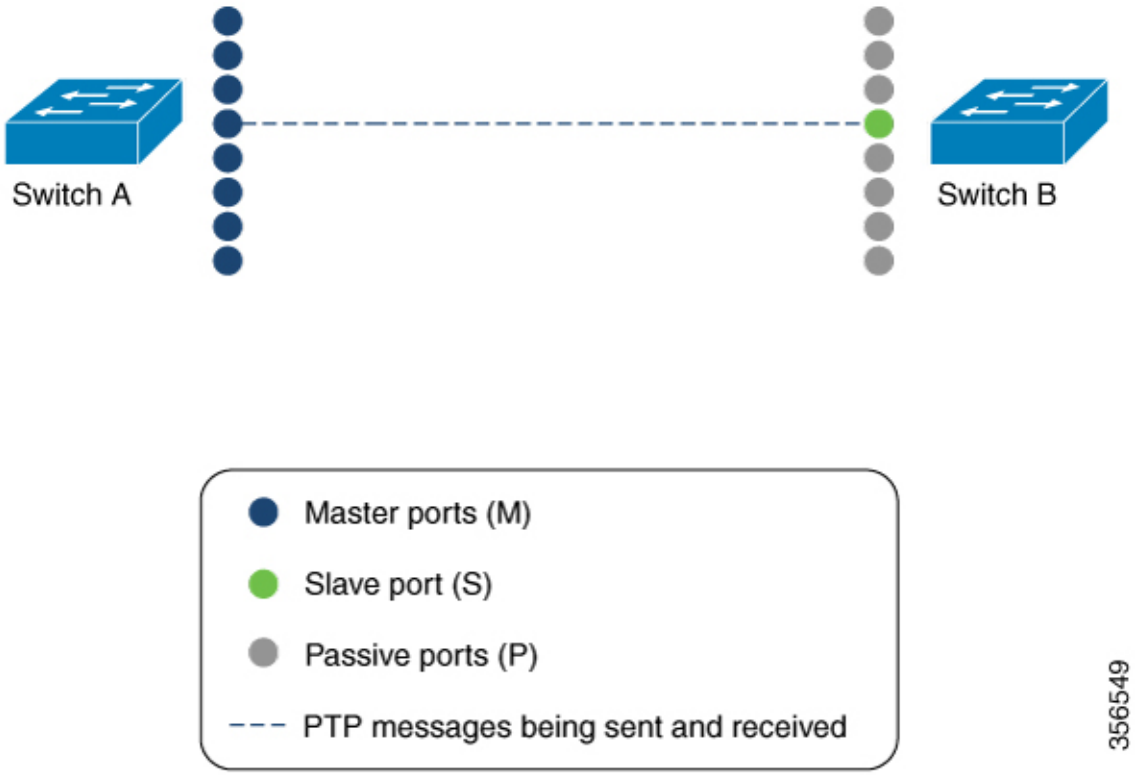
not change when PTP is configured. The example below illustrates how PTP works when it is configured on an EtherChannel interface.

Note PTP configurations can be done only on EtherChannel member interfaces and not on the main EtherChannel or PortChannel interface.

For example, in the figure below there are two switches (Switch A and Switch B) connected through an eight member EtherChannel. If you consider Switch A as the master clock, all the ports part of the EtherChannel are master ports. Similarly, Switch B is the slave clock and one of the ports from the EtherChannel bundle becomes the slave port while all other ports become passive ports. It is always the port with the lowest port number in the Etherchannel bundle that is designated as the slave port. If that slave port is disabled or shut down for any reason, the next port with the lowest port number is designated as the slave port.

The master and slave relationship is established when the feature is configured on an EtherChannel interface as well. The master ports from Switch A send and receives PTP messages. In Switch B only the slave port exchanges PTP messages. There is no exchange of PTP messages in the passive ports.

Figure 5: Precision Time Protocol on an EtherChannel Interface



AES67 Media Profile

The AES67 PTP media profile is based on the AES67 standard that is used for high-performance streaming and audio-over-IP interoperability in audio devices. AES67 uses IEEE 1588-2008 PTP for clock synchronization

of devices and prioritization of control and data traffic. IEEE 1588-2008 also defines various parameters for audio traffic and device discovery protocol that are not required to be implemented in switches or bridges.

The following table defines the various parameters for PTP to be compliant with AES67.

Table 1: PTP Parameters for AES67 Compliance

Attribute	1588 Profile Range (Default Value)	AES67 Profile Range (Default Value)
PTP Domain	0 to 255 (0)	0 to 255 (0)
Priority1/Priority2	0 to 255 (128)	0 to 255 (128)
Announce Interval	0 to 4 (1)	0 to 4 (1)
Announce Timeout	2 to 10 (3)	2 to 10 (3)
Sync Interval	-3 to +1 (0)	-4 to 1 (-3)
Delay Request Minimum Interval	0 to 5 (0)	-3 to 5 (0)

AES67 uses three traffic classes with different traffic types. PTP packets sent by a device must be marked with DSCP EF (46) for expedited forwarding through IP networks. For media and best-effort classes, traffic streams are marked by end devices with DSCP values, as mentioned in the following table. You can also configure QoS policies on the interface for data packets, and re-mark using QoS ingress policies.

Table 2: Traffic Classification

Class Name	Traffic Type	Default DiffServ Class (DSCP Decimal Value)
Clock	IEEE 1588-2008 Announce, Sync, Follow_Up, Delay_Req, Delay_Resp, Pdelay_Req, Pdelay_Resp and Pdelay_Resp_Follow_Up packets	EF (46)
Media	Real-time Transport Protocol (RTP) and Real-Time Transport Control Protocol (RTCP) media stream data	AF41 (34)
Best Effort	IEEE 1588-2008 signalling and management messages. Discovery and connection management messages.	DF (0)

IP IGMPv2 and IGMPv3 snooping enables transmission of multicast audio traffic on specified interfaces. For AES67 deployments using Dante PTPv1 messages, the device enables IGMP snooping by default on the VLAN, and interested endpoints can express the need for PTPv1 groups. This enables multicast snooping entries to be created, which in turn allows forwarding of PTPv1 messages.

Note

- SMPTE PTP media profile is not supported. However, because SMPTE uses IEEE 1588 PTP profile, if SMPTE can operate PTP with AES67 PTP definitions, SMPTE can be added to the network.
- The audio-over-IP interoperability in audio devices is supported only if both devices use AES67 media profile.

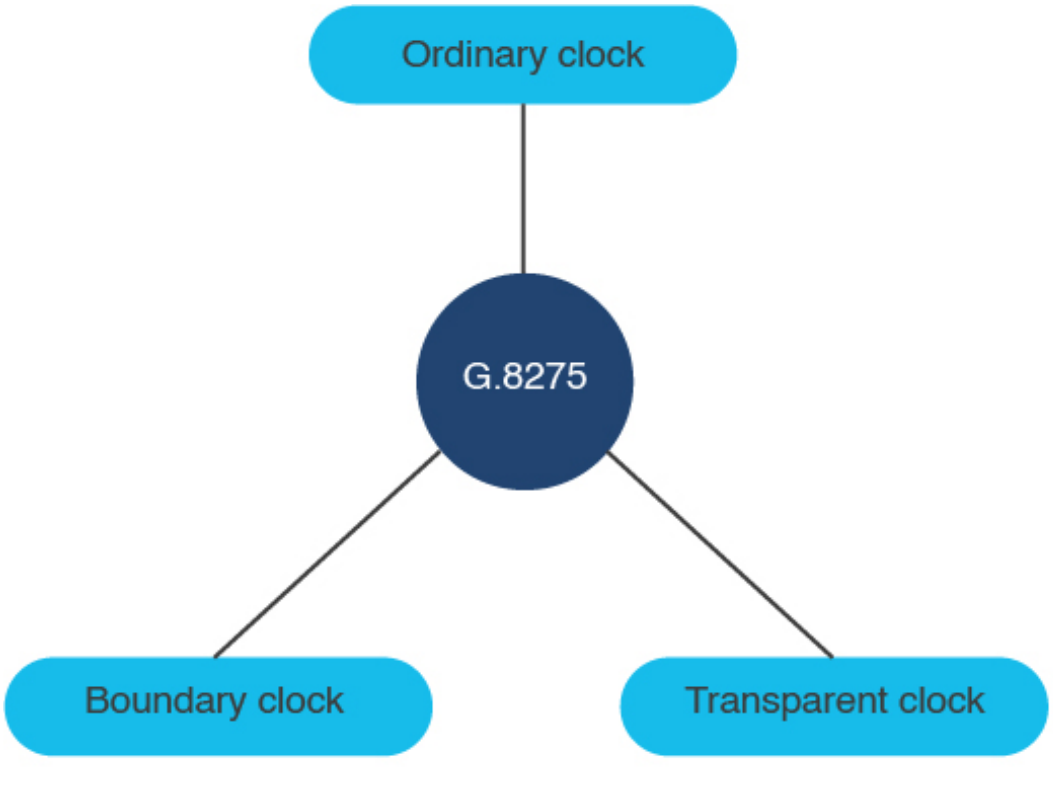
G8275.1 Telecom Profile

The G8275.1 telecom profile is based on the ITU-T standard that is used to ensure network interoperability for accurate delivery of phase and time synchronization. The G8275.1 specifies a profile for telecommunication applications based on IEEE 1588 PTP.

The G8275.1 profile can receive messages from one-step clock and two-step clocks without any specific configuration required. The clock is not required to support one-step or two-step mode to transmit messages. The ingress messages from one-step clock and egress messages from two-step clock is supported after processing

PTP Clocks Supported

The ordinary clock, boundary clock and transparent clock are used in this profile.



Note This profile supports only end-to-end transparent clock. You cannot use peer-to-peer transparent clock in this profile.

PTP Messages Supported

The G8275.1 profile uses Sync, Follow_Up, Announce, Delay_Req, and Delay_Resp messages only.

Figure 6: PTP Messages supported on G8275.1 profile

How to Configure Precision Time Protocol

The following sections provide information about the various tasks that comprise the configuration of PTP.

Configuring Precision Time Protocol Default Profile

To configure Layer 2 PTP globally, follow these steps:

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Device configure terminal`	Enters global configuration mode.

Step 3	**ptp mode** {**boundary** {**delay-req** | **pdelay-req** } | **e2etransparent** | **p2ptransparent**}
	Example:
	`Device(config)# ptp mode boundary delay-req`
	`Device(config)# ptp mode boundary pdelay-req`
	`Device(config)# ptp mode e2etransparent`
	`Device(config)# ptp mode p2ptransparent`
		Specifies the synchronization clock mode:
		• **boundary** to enable the switch to participate in selecting the best master clock. If no better clocks are detected, the switch becomes the grandmaster clock on the network and the parent clock to all connected devices. If the best master is determined to be a clock that is connected to the switch, the switch synchronizes to that clock as a child to the clock, then acts as a parent clock to devices connected to other ports. After initial synchronization, the switch and the connected devices exchange timing messages to correct time

	Command or Action	Purpose
		skew that is caused by clock offsets and network delays. Use this mode when overload or heavy load conditions produce significant delay jitter • **e2etransparent** for the switch to synchronize all switch ports with the grand master clock that is connected to the switch,. This is the default clock mode. The switch corrects for the delay that is incurred by every packet passing through it (referred to residence time). This mode causes less jitter and error accumulation than boundary mode. • **p2ptransparent** where the switch does not synchronize its clock with the master clock. A switch in this mode does not participate in master clock selection and uses the default PTP clock mode on all ports. **Note** Once PTP default profile is enabled globally, PTP is enabled on all the interfaces. To disable PTP selectively on individual interfaces, use **no ptp enable** command in interface configuration mode.
Step 4	[**no**]**ptp domain** *value* **Example:** `Device(config)# ptp domain 8`	Configures the domain value on PTP. • A single domain value can be set. The range is from 4 to 127. The default value is 0.**no ptp domain** command will set the value to default.

Configuring Precision Time Protocol on Layer 2 interface

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password if prompted.

	Command or Action	Purpose
Step 2	**configure terminal** **Example:** `Device configure terminal`	Enters global configuration mode.
Step 3	**interface** *interface-id* **Example:** `Device(config)# interface TenGigabitEthernet1/0/1`	Specifies the physical interface to be configured, and enters interface configuration mode. The interface that you specify can be part of an EtherChannel.
Step 4	[**no**]**ptp enable**	
Step 5	**ptp vlan** *vlan-id* **Example:** `Device(config-if)# ptp vlan 5`	Sets the PTP VLAN on a trunk port. The default is the native VLAN of the trunk port. In boundary mode, only PTP packets in PTP VLAN will be processed, PTP packets from other VLANs will be dropped. Before configuring the PTP VLAN on an interface, the PTP VLAN must be created and allowed on the trunk port.
Step 6	**end** **Example:** `Device(config-if)# end`	Returns to privileged EXEC mode.

Configuring Precision Time Protocol on EtherChannel Member Interface

To configure PTP on EtherChannel member interface, follow these steps:

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password, if prompted.
Step 2	**configure terminal** **Example:** `Device# configure terminal`	Enters global configuration mode.
Step 3	**interface port-channel** *number* **Example:** `Device(config-if)# interface port-channel 1`	Specifies the port channel interface to be configured, and enters interface configuration mode.

	Command or Action	Purpose
Step 4	**switchport mode trunk** **Example:** `Device(config-if)# switchport mode trunk`	Configures the port channel interface as a trunk port.
Step 5	**no shutdown** **Example:** `Device(config-if)# no shutdown`	Enables the port channel interface.
Step 6	**exit** **Example:** `Device(config-if)# exit`	Exits interface configuration mode and returns to global configuration mode.
Step 7	**interface** *interface-id* **Example:** `Device(config)# interface TenGigabitEthernet1/0/42`	Specifies the physical interface to be configured, and enters interface configuration mode.
Step 8	**switchport mode trunk** **Example:** `Device(config-if)# switchport mode trunk`	Configures the physical interface as a trunk port.
Step 9	**channel-group** *channel-number* **mode on** **Example:** `Device(config-if)# channel-group 1 mode on`	Configures the port in a channel group and sets the mode. The channel-number range is from 1 to 4096.
Step 10	**ptp enable** **Example:** `Device(config-if)# ptp enable`	Enables PTP on the member interface.
Step 11	**ptp sync interval** *value* **Example:** `Device(config-if)# ptp sync interval -3`	Configures the logarithmic mean interval to send synchronization messages. The range is –3 to 1. The default is 0 (1 second).
Step 12	**end** **Example:** `Device(config-if)# end`	Returns to privileged EXEC mode.

Configuring Precision Time Protocol on SVI or Layer 3 Interface

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Device# configure terminal`	Enters global configuration mode.
Step 3	**ptp transport ipv4 udp** **Example:** `Device(config)# ptp transport ipv4 udp`	Configures IPv4 as the PTP transport mode. **Note** Only IPv4 is supported as the PTP transport method for Layer 3 PTP.

Configuring the Source IP on Precision Time Protocol

To configure the source IP on PTP, perform this procedure:

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Device# configure terminal`	Enters global configuration mode.

Step 3	[**no**]**ptp source** {**source-address** | **loopback** |**vlan**}
	Example:
	`Device(config)# ptp source source address`
	`Device(config)# ptp source loopback`
	`Device(config)# ptp source vlan`
		Specifies the synchronization clock mode:
		• **source address** once configured, PTP messages in all the interfaces will carry this source ip.
		• **loopback** PTP messages in all the interfaces will carry the IP that is configured on the loopback interface.
		• **vlan** PTP messages will carry the IP configured on the SVI interface corresponding to the port.

	Command or Action	Purpose
		Note You can use **no ptp source** command as default.
Step 4	**end** **Example:** `Device(config-if)# end`	Returns to privileged EXEC mode.

Configuring Precision Time Protocol Timers

To configure the PTP timer values from default to required values, follow these steps:

Before you begin

Timer inputs are measured in units of log mean message interval value. To determine the *value* in seconds for the **interval** keyword, use a logarithmic scale. The following table shows examples of the *value* keyword that is converted to seconds with a logarithmic scale:

Value Entered	Logarithmic Calculation	Value in Seconds
-1	2^{-1}	1/2
0	2^{0}	1

0 indicates 1 packet per second and -1 indicates 1 packet per 2 seconds.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Device# configure terminal`	Enters global configuration mode.
Step 3	**interface** *interface-id* **Example:** `Device(config)# interface gigabitethernet2/0/1`	Specifies the physical port to be configured, and enters interface configuration mode.
Step 4	**ptp announce** {**interval** *value* | **timeout** *count*} **Example:**	(Optional) Configures the interval between PTP announce messages on an interface or the

	Command or Action	Purpose
	`Device(config-if)# ptp announce interval 1`	number of PTP intervals before a timeout occurs on an interface. • **interval** *value* sets the logarithmic mean interval to send announce messages. The range is 0 to 4. The default is 0 (1 second). • **timeout** *count* sets the logarithmic mean interval in seconds to announce timeout messages. The range is 2 to 10. The default is 3 (8 seconds).
Step 5	**ptp sync** {**interval** *value* | **limit** *offset-value*} **Example:** `Device(config-if)# ptp sync interval 1`	(Optional) Configures the interval between PTP synchronization messages on an interface. • **interval** *value* sets the logarithmic mean interval to send synchronization messages. The range is –3 to 1. The default is 0 (1 second). • **limit** *offset-value* sets the maximum clock offset value before PTP attempts to resynchronize. The range is from 50 to 500000000 nanoseconds. The default is 500000000 nanoseconds.
Step 6	**ptp delay-req interval** *value* **Example:** `Device(config-if)# ptp delay-req interval 1`	(Optional) Configures the logarithmic mean interval allowed between PTP delay request messages when the port is in the master state. The range is 0 to 5. The default is 0 (1 second).
Step 7	**ptp pdelay-req interval** *value* **Example:** `Device(config-if)# ptp pdelay-req interval 1`	(Optional) Configures the logarithmic mean interval allowed between pdelay request messages when the port is in the master state. The range is 0 to 5. The default is 0 (1 second).
Step 8	**end** **Example:** `Device(config-if)# end`	Returns to privileged EXEC mode.

Configuring the Values of Precision Time Protocol Clocks

Follow these steps to configure the values of PTP clock priority1 and priority2:

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password, if prompted.
Step 2	**configure terminal** **Example:** `Device# configure terminal`	Enters global configuration mode.
Step 3	**ptp priority1** *value* **Example:** `Device(config)# ptp priority1 120`	Sets the value of PTP clock priority1. The range is from 0 to 255. The default value is 128. **Note** If the value of priority1 is configured as 255, the clock cannot be considered as Grandmaster.
Step 4	**ptp priority2** *value* **Example:** `Device(config)# ptp priority2 120`	Sets the value of PTP clock priority2. The range is from 0 to 255. The default value is 128.
Step 5	**exit** **Example:** `Device(config)# exit`	Returns to global configuration mode.

Configuring Precision Time Protocol Using AES67 Media Profile

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password, if prompted.
Step 2	**configure terminal** **Example:** `Device configure terminal`	Enters global configuration mode.
Step 3	**ptp transport-protocol ipv4 udp** **Example:** `Device(config)# ptp transport-protocol ipv4 udp`	Enables the PTP Layer 3 mode.

	Command or Action	Purpose
Step 4	**ptp mode boundary delay-req** **Example:** `Device(config)# ptp mode boundary delay-req`	Configures the device for boundary clock mode using the peer delay request mechanism.
Step 5	**interface range** *interface-range* **Example:** `Device(config)# interface range GigabitEthernet1/0/1-GigabitEthernet1/0/2`	Specifies the range of interfaces to be configured, and enters interface-range configuration mode.
Step 6	**ptp sync interval** *value* **Example:** `Device(config-if-range)# ptp sync interval -3`	Configures the interval between PTP synchronization messages on the interface range. The range is from -4 to 1.
Step 7	**ptp delay-req interval** *value* **Example:** `Device(config-if-range)# ptp delay-req interval -3`	Configures the logarithmic mean interval that is allowed between PTP delay request messages when the port is in the primary state. The range is from -3 to 5.
Step 8	**exit** **Example:** `Device(config-if-range)# exit`	Exits interface-range configuration mode and enters global configuration mode.
Step 9	**ptp ip dscp** *value* **message general** **Example:** `Device(config)# ptp ip dscp 46 message general`	Configures IP DSCP value for PTP general messages. The range is from 0 to 63.
Step 10	**ptp ip dscp** *value* **message event** **Example:** `Device(config)# ptp ip dscp 46 message event`	Configures IP DSCP value for PTP event messages. The range is from 0 to 63.
Step 11	**end** **Example:** `Device(config)# end`	Returns to privileged EXEC mode.

Configuring Precision Time Protocol Using G8275.1 Telecom Profile

To configure PTP using G8275.1 Telecom profile, perform this procedure:

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. Enter your password, if prompted.
Step 2	**configure terminal** **Example:** `Device configure terminal`	Enters global configuration mode.
Step 3	**ptp profile 8275.1** **clock-mode** {**boundary** | **transparent**} **Example:** `Device(config)# ptp profile 8275.1 clock-mode boundary`	Configures the clock mode for the device. • **boundary** mode sets the device to boundary clock mode. • **transparent** mode sets the device to transparent clock mode.
Step 4	**interface range** *interface-range* **Example:** `Device(config)# interface range GigabitEthernet1/0/1-GigabitEthernet1/0/2`	Specifies the range of interfaces to be configured, and enters interface-range configuration mode.
Step 5	**exit** **Example:** `Device(config-if-range)# exit`	Exits interface-range configuration mode and enters global configuration mode.
Step 6	**ptp ip dscp** *value* **message general** **Example:** `Device(config)# ptp ip dscp 46 message general`	Configures IP DSCP value for PTP general messages. The range is from 0 to 63.
Step 7	**ptp ip dscp** *value* **message event** **Example:** `Device(config)# ptp ip dscp 46 message event`	Configures IP DSCP value for PTP event messages. The range is from 0 to 63.
Step 8	**end** **Example:** `Device(config)# end`	Returns to privileged EXEC mode.

Configuration Examples for Precision Time Protocol

The following sections provide PTP configuration examples.

Example: Configuring Precision Time Protocol Using AES67 Media Profile

The following is a sample PTP configuration to set up a device using AES67 media profile:

```
Device# configure terminal
Device(config)# ptp transport-protocol ipv4 udp
Device(config)# ptp mode boundary delay-req
Device(config)# interface range gigabitethernet1/0/1-gigabitethernet1/0/2
Device(config-if-range)# ptp sync interval -3
Device(config-if-range)# ptp delay-req interval -3
Device(config-if-range)# exit
Device(config)# ptp ip dscp 46 message general
Device(config)# ptp ip dscp 46 message event
Device(config)# end
```

The following is a sample QoS configuration to set up a device such that the expedited forwarding messages face minimal latency and media traffic faces no drops:

```
Device# configure terminal
Device(config)# class-map match-all PTP
Device(config-cmap)# match dscp 46
Device(config-cmap)# class-map match-any VOICE
Device(config-cmap)# match dscp 34
Device(config-cmap)# exit
Device(config)# policy-map GENERAL-QOS
Device(config-pmap)# class PTP
Device(config-pmap-c)# priority level 1 percent 10
Device(config-pmap-c)# class VOICE
Device(config-pmap-c)# bandwidth remaining percent 30
Device(config-pmap-c)# class class-default
Device(config-pmap-c)# bandwidth remaining percent 60
Device(config-pmap-c)# end
```

Verifying Precision Time Protocol Configurations

Verifying Layer 2 and Layer 3 PTP Configurations

show ptp port *interface-name*

To verify PTP port state, use **show ptp port** *interface-name* command.

To verify the PTP port states on all interfaces use **show ptp brief** command.

The following is a sample output for boundary mode configuration with delay request mechanism:

```
Device# show ptp port GigabitEthernet1/0/45
PTP PORT DATASET: GigabitEthernet1/0/45
  Port identity: clock identity: 0xCC:46:D6:FF:FE:C5:24:0
  Port identity: port number: 45
  PTP version: 2
  Port state: SLAVE
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 1
  Sync interval(log mean): 0
  Delay Mechanism: End to End
```

```
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000
```

The following is a sample output for boundary mode configuration with pdelay request mechanism:

```
Device# show ptp port GigabitEthernet1/0/45
 PTP PORT DATASET: GigabitEthernet1/0/45
  Port identity: clock identity: 0xCC:46:D6:FF:FE:C5:24:0
  Port identity: port number: 45
  PTP version: 2
  Port state: MASTER
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 1
  Sync interval(log mean): 0
  Delay Mechanism: Peer to Peer
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000
```

show ptp brief

To verify the PTP port states on all interfaces use **show ptp brief** command.

The following is a sample output for **show ptp brief** command:

```
Device# show ptp brief
Interface                      Domain    PTP State
TenGigabitEthernet1/0/1        0         MASTER
TenGigabitEthernet1/0/2        0         SLAVE
TenGigabitEthernet1/0/3        0         FAULTY
```

show ptp clock

To verify the PTP clock identity details and to verify the configured values of Priority1 and Priority2, use **show ptp clock** command.

The following is a sample output for **show ptp clock** command:

```
Device# show ptp clock
 PTP CLOCK INFO
  PTP Device Type: Boundary clock
  PTP Device Profile: Default Profile
  Clock Identity: 0xCC:46:D6:FF:FE:C5:24:0  <<clock identity of this
switch>>
  Clock Domain: 0
  Number of PTP ports: 52
  Priority1: 128
  Priority2: 128
  Clock Quality:
            Class: 248
            Accuracy: Unknown
            Offset (log variance): 16640
  Offset From Master(ns): 0
  Mean Path Delay(ns): 0
  Steps Removed: 1
```

show ptp parent

To identify which Grandmaster Clock identity the device is synced to in boundary mode, use **show ptp parent** command.

Note **show ptp parent** will not display any output if the device is configured in transparent clock mode.

The following is a sample output for **show ptp parent** command:

```
Device# show ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:11:1:FF:FE:0:0:1
  Parent Port Number: 1
  Observed Parent Offset (log variance): 16640
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:11:1:FF:FE:0:0:1     <<Grandmaster clock
 identity to which the device is synced to>>
  Grandmaster Clock Quality:
             Class: 6
             Accuracy: Within 25ns
             Offset (log variance): 0
             Priority1: 128
             Priority2: 128
```

show platform software fed active ptp domain 0

To verify the local servo PTP clock synchronization to Grandmaster clock on a device configured in boundary mode with delay-request mechanism, use **show platform software fed active ptp domain 0** command.

```
Device#
show platform software fed active ptp domain 0

Displaying data for domain number 0
============================

Profile Type : DEFAULT
Profile State: enabled
Clock Mode : BOUNDARY CLOCK
Delay mechanism: End-to-End
PTP clock : 2017-6-28 5:58:59
Transport Method: L2 Ethernet
```

By default, local servo PTP clock will be displaying EPOCH time(1970-1-1) when the device is not synced to any PTP Grandmaster Clock.

show ptp port *interface-name*

To verify PTP port state, use **show ptp port** *interface-name* command.

To verify the PTP port states on all interfaces use **show ptp brief** command.

The following is a sample output for boundary mode configuration with delay request mechanism:

```
Device# show ptp port FortyGigabitEthernet1/0/10
 PTP PORT DATASET: FortyGigabitEthernet1/0/10
  Port identity: clock identity: 0x0:A3:D1:FF:FE:5A:12:0
  Port identity: port number: 10
  PTP version: 2
  Port state: SLAVE
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 1
  Sync interval(log mean): 0
  Delay Mechanism: End to End
       << PTP mode delay >>
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000
```

show ptp parent

To identify which Grandmaster Clock identity the device is synced to in boundary mode, use **show ptp parent** command.

Note **show ptp parent** will not display any output if the device is configured in transparent clock mode.

The following is a sample output for **show ptp parent** command:

```
Device# show ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x38:E:4D:FF:FE:81:FE:29
<< Immediate next Master >>
  Parent Port Number: 196
  Observed Parent Offset (log variance): 17258
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:0:0:5:0:0:0:1
<< GM: External Clock Source acting Grand Master >>
  Grandmaster Clock Quality:
    Class: 6
    Accuracy: Within 1us
    Offset (log variance): 0
    Priority1: 128
    Priority2: 128
```

show platform software fed active ptp domain 0

To verify the local servo PTP clock synchronization to Grandmaster clock on a device configured in boundary mode with delay-request mechanism, use **show platform software fed active ptp domain 0** command.

```
Device#
show platform software fed active ptp domain 0
Displaying data for domain number 0
=====================================
```

```
Profile Type : DEFAULT
Profile State: enabled
Clock Mode : BOUNDARY CLOCK
Delay Mechanism: : END-TO-END
PTP clock : 2017-12-15 15:27:27
mean_path_delay 214 nanoseconds
Transport Method : udp-ipv4                          << PTP Transport Method
  >>
```

Table 3: Debug Commands

Command	Purpose
debug ptp messages	Enables debugging of PTP messages.
debug ptp error	Enables debugging of PTP errors.
debug ptp bmc	Enables debugging of the PTP Best Master Clock Algorithm.
debug ptp event	Enables debugging of PTP state event.

Verifying PTP Configurations on an EtherChannel Interface

Master Clock

The following command verifies the PTP state on an interface:

```
Device# show ptp port tengigabitethernet 1/0/39
PTP PORT DATASET: TenGigE1/0/39
  Port identity: clock identity: 0x0:A7:42:FF:FE:8A:84:C0
  Port identity: port number: 39
  PTP version: 2
  Port state: MASTER
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 0
  Sync interval(log mean): 0
  Delay Mechanism: End to End
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000

Device# show ptp port tengigabitethernet 1/0/44
PTP PORT DATASET: TenGigE1/0/44
  Port identity: clock identity: 0x0:A7:42:FF:FE:8A:84:C0
  Port identity: port number: 44
  PTP version: 2
  Port state: MASTER
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 0
  Sync interval(log mean): 0
  Delay Mechanism: End to End
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000

Device# show ptp port tengigabitethernet 1/0/48
PTP PORT DATASET: TenGigE1/0/48
  Port identity: clock identity: 0x0:A7:42:FF:FE:8A:84:C0
```

```
  Port identity: port number: 48
  PTP version: 2
  Port state: MASTER
 Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 0
  Sync interval(log mean): 0
  Delay Mechanism: End to End
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000
```

Slave Clock

The following command can be used to verify the PTP state on the interfaces:

```
Device# show ptp brief | exclude FAULTY
Interface                       Domain    PTP State
tenGigE1/0/12                     0         SLAVE
TenGigE1/0/20                     0         PASSIVE
TenGigE1/0/23                     0         PASSIVE
```

The following command verifies if interface configured on each port is an EtherChannel interface:

```
Device# show etherchannel 1 summary
Flags:  D - down        P - bundled in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator

        M - not in use, minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port
        A - formed by Auto LAG


Number of channel-groups in use: 1
Number of aggregators:           1

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------------------------------
1      Po1(SU)         LACP        Hu1/0/12(P)     Hu1/0/20(P)
                                   Hu1/0/23(P)
```

The following command verifies port state of each interface:

```
Device# show ptp port tengigabitethernet 1/0/12
PTP PORT DATASET: TenGigE1/0/12
  Port identity: clock identity: 0x0:A7:42:FF:FE:9B:DA:E0
  Port identity: port number: 12
  PTP version: 2
  PTP port number: 12
  PTP slot number: 0
  Port state: SLAVE
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 0
  Sync interval(log mean): 0
  Delay Mechanism: End to End
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000

Device# show ptp port tengigabitethernet 1/0/20
PTP PORT DATASET: TenGigE1/0/20
  Port identity: clock identity: 0x0:A7:42:FF:FE:9B:DA:E0
```

```
  Port identity: port number: 20
  PTP version: 2
  PTP port number: 20
  PTP slot number: 0
  Port state: PASSIVE
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 0
  Sync interval(log mean): 0
  Delay Mechanism: End to End
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000

Device# show ptp port tengigabitethernet 1/0/23
PTP PORT DATASET: TenGigE1/0/23
  Port identity: clock identity: 0x0:A7:42:FF:FE:9B:DA:E0
  Port identity: port number: 23
  PTP version: 2
  PTP port number: 23
  PTP slot number: 0
  Port state: PASSIVE
  Delay request interval(log mean): 0
  Announce receipt time out: 3
  Announce interval(log mean): 0
  Sync interval(log mean): 0
  Delay Mechanism: End to End
  Peer delay request interval(log mean): 0
  Sync fault limit: 500000000
```

Feature History for Precision Time Protocol

This table provides release and related information for features explained in this module.

These features are available on all releases subsequent to the one they were introduced in, unless noted otherwise.

Release	Feature	Feature Information
Cisco IOS XE Amsterdam 17.3.1	IEEE 1588v2, Precision Time Protocol (PTP) support	PTP was developed to synchronize the clocks in packet-based networks that include distributed device clocks of varying precisionand stability.
Cisco IOS XE Bengaluru 17.5.1	Port primary	Support was introduced to set a port permanently as primary (master) using the **ptp role primary** command.
Cisco IOS XE Cupertino 17.7.1	Audio Engineering Society: AES67 Timing Profile	AES67 timing profile support for high-performance streaming and audio-over-IP interoperability in audio devices was introduced.
Cisco IOS XE Cupertino 17.7.1	IEEE 1588v2, Precision Time Protocol (PTP) support	PTP was developed to synchronize the clocks in packet-based networks that include distributed device clocks of varying precisionand stability. This feature was implemented on supervisor modules C9400X-SUP-2 and C9400X-SUP-2XL, which were introduced in this release.

Release	Feature	Feature Information
Cisco IOS XE Cupertino 17.8.1	G8275.1 Telecom Profile	G8275.1 telecom profile support for interoperability for accurate delivery of phase and time synchronization. The G8275.1 specifies a profile for telecommunication applications based on IEEE 1588 PTP.
Cisco IOS XE Dublin 17.10.1	PTPv2 on Cisco StackWise Virtual	Cisco StackWise Virtual is a network system virtualization technology that pairs two switches into one virtual switch to simplify operational efficiency with a single control and management plane. PTPv2 is supported on Cisco StackWise Virtual.

Use Cisco Feature Navigator to find information about platform and software image support. To access Cisco Feature Navigator, go to http://www.cisco.com/go/cfn.