# Timing and Synchronization Configuration Guide for Cisco 8000 Series Routers, Cisco IOS XR Releases

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CHAPTER 1

# About Timing and Synchronization Documentation

Introducing the updated *Timing and Synchronization Configuration on Cisco 8000 Series Routers*, Cisco IOS XR Releases.

### Release-agnostic Document

This document for the Cisco 8000 Series Router features a single version that will be consistently kept up to date with the latest features and releases. Our goal is to make it easier for you to bookmark a single link and find one comprehensive version of the Timing and Synchronization Configuration for the 8000 Series Routers, rather than sift through multiple versions that are specific to each IOS XR release.

### Where to begin

To get started with the Timing and Synchronization implementation, we recommend referring to the Feature, Release, and Platform Matrix for Timing and Synchronization. This section offers insights into Timing and Synchronization features introduced not only for the 8000 Series Routers but also for all other IOS XR Routing platforms. Our aim is to simplify your access to our documentation and help you develop a comprehensive understanding.



# Releases Supported

The document is relevant for the following releases:

- IOS XR Release 24.1.1
- IOS XR Release 7.11.1
- IOS XR Release 7.10.1
- IOS XR Release 7.9.2
- IOS XR Release 7.9.1
- IOS XR Release 7.8.2
- IOS XR Release 7.8.1

- IOS XR Release 7.7.2
- IOS XR Release 7.7.1
- IOS XR Release 7.5.3
- IOS XR Release 7.5.2
- IOS XR Release 7.5.1
- IOS XR Release 7.3.4
- IOS XR Release 7.3.3
- IOS XR Release 7.3.2
- IOS XR Release 7.3.15
- IOS XR Release 7.3.1

Cisco IOS XR Releases prior to those listed here have reached the End of Extended SW Maintenance Date. To access the notification, please visit the End-of-Life and End-of-Sale Notices page.

# Bias-free Language

This document uses the "Master/Client" terminology in its descriptive text and illustrations, while retaining "slave" in code and output. Once a consensus is reached within the standards bodies such as IEEE1588v2, this notification will be removed, and the book will be revised to incorporate the mutually agreed-upon terms.

CHAPTER 2

# Features Introduced in Cisco IOS XR Products and Releases

This table summarizes the features enhanced and introduced for Timing and Synchronization.



# Feature, Release, and Platform Matrix for Timing and Synchronization

*Table 1: Feature, Release, and Platform Matrix*

| Feature Name | 8000 Series Routers | Other IOS XR Routing Platforms |
|---|---|---|
| PTP Support on 88-LC1-12TH24FH-E and 88-LC1-52Y8H-EM | Timing Profile and Class Support Matrix | — |
| PTP on Cisco 8608 Router | Timing Profile and Class Support Matrix | — |
| Synchronous Ethernet (SyncE) Support on Cisco 8711-32FH-M Router | SyncE Profiles Support Matrix | — |
| Precision Time Protocol (PTP) Support on Cisco 8711-32FH-M Router | Timing Profile and Class Support Matrix | — |
| Global Navigation Satellite System (GNSS) Support on Cisco 8711-32FH-M Router | Class Support Matrix | — |
| PTP on 88-LC0-36FH-M and 8800-LC-36FH | Timing Profile and Class Support Matrix | — |
| PTP on Route Processor 8000-RP2 | Timing Profile and Class Support Matrix | — |

| Feature Name | 8000 Series Routers | Other IOS XR Routing Platforms |
| --- | --- | --- |
| NTP-PTP Interworking | 8000, R7.11.1 | NCS 5500, R24.1.1<br>NCS 560, R24.1.1<br>NCS 5500, R24.1.1 |
| Synchronous Ethernet (SyncE) on Cisco 8011-2X2XP4L PLE Service Endpoint Routers | SyncE Profiles Support Matrix | — |
| Precision Time Protocol (PTP) on Cisco 8011-2X2XP4L PLE Service Endpoint Routers | Timing Profile and Class Support Matrix | — |
| FQDN for NTP Server on Non-default VRF | 8000, R7.9.1 | ASR 9000, R7.9.1<br>NCS 5500, R7.9.1 |
| Synchronous Ethernet (SyncE) on 8202-32FH-M Routers and 88-LC0-36FH-M Line cards | SyncE Profiles Support Matrix | — |
| Precision Time Protocol (PTP) on 8202-32FH-M Routers and 88-LC0-36FH-M Line cards | Timing Profile and Class Support Matrix | — |
| PTP Delay Asymmetry | 8000, R7.3.2 | NCS 560, R7.6.1<br>NCS 5500, R7.6.1<br>ASR 9000, R7.3.1<br>NCS 560, R7.3.1<br>NCS 5500, R7.3.1 |
| Frequency Synchronization | 8000, R7.3.1 | — |
| Ethernet Synchronization Message Channel (ESMC) | 8000, R7.3.1 | — |
| Precision Time Protocol (PTP) | 8000, R7.3.1 | — |
| ITU-T G.8263 standard for secondary clock with ITU-T G.8265.1 profile | 8000, R7.3.1 | — |
| ITU-T G.8275.1 profile | 8000, R7.3.1 | — |
| Support for ITU-T G.8264 Standard | 8000, R7.3.1 | — |
| ITU-T G.8275.2 and Default PTP profiles over IPv6 | — | NCS 5500, R7.8.1<br>NCS 540, R7.7.1 |

| Feature Name | 8000 Series Routers | Other IOS XR Routing Platforms |
| --- | --- | --- |
| PTP Double Failure Clock Class | — | NCS 5500, R7.7.1<br>ASR 9000, R7.7.1 |
| Use PTP Virtual Port to Select Timing Source | — | NCS 5500, R7.7.1 |
| Use APTS to Select Timing Source | — | NCS 5500, R7.7.1 |
| PTP Holdover Traceability Suppression | — | NCS 5500, R7.4.1<br>ASR 9000, R7.3.1<br>NCS 540, R7.4.1<br>NCS 560, R7.4.1 |
| SyncE Support on 5th Generation 10-Port 400 Gigabit Ethernet Line Cards:<br>• A99-10X400GE-X-SE<br>• A99-10X400GE-X-TR | — | ASR 9000, R7.3.2 |
| Class C Timing Mode | — | ASR 9000, R7.6.2 |
| Precision Time Protocol on 12-port 100 Gigabit Ethernet line cards, ASR 9000 5th generation 400G line cards, ASR 9902 Series Routers, and 0.8T PEC | — | ASR 9000, R7.4.1 |
| PTP support on 5th Generation 10-Port 400 Gigabit Ethernet Line Cards:<br>• A99-10X400GE-X-SE<br>• A99-10X400GE-X-TR | — | ASR 9000, R7.3.2 |
| Enhanced SyncE and extended ESMC | — | NCS 540, R7.11.1<br>NCS 560, R7.8.1 |
| Synchronous Ethernet ESMC and SSM on N540X-16Z4G8Q2C-A/D | — | NCS 540, R7.7.1 |
| Synchronous Ethernet ESMC and SSM on N540-6Z14S-SYS-D | — | NCS 540, R7.5.2 |
| Synchronous Ethernet ESMC and SSM, and ITU-T G.8262.1 | — | NCS 540, R7.6.1 |

| Feature Name | 8000 Series Routers | Other IOS XR Routing Platforms |
|---|---|---|
| Frequency Synchronization on the N540X-4Z14G2Q-SYS-A/D routers. | — | NCS 540, R7.4.1 |
| TSoP Smart SFP for SDH and SONET Encapsulation | — | NCS 540, R7.11.1 |
| PTP and SyncE support on breakout ports for N540-24Q8L2DD-SYS and N540X-16Z4G8Q2C-A/D Routers | — | NCS 540, R7.11.1 |
| PTP Profiles Support for N540-6Z14S-SYS-D | — | NCS 540, R7.5.2 |
| PTP Profiles Support for N540-24Q8L2DD-SYS | — | NCS 540, R7.4.1 |
| PTP Profiles Support for N540X-16Z4G8Q2C-A/D | — | NCS 540, R7.0.1 |
| Assisted Partial Timing Support | — | NCS 540, R7.7.1 |
| PTP Holdover Traceability Suppression for T-GM and T-GM with VP/APTS modes | — | NCS 540, R7.8.1 |
| Support for Frequency Synchronization on the Cisco N560-IMA8Q interface module | — | NCS 560, R7.4.1 |
| Assisted Partial Timing Support on this routers | — | NCS 560, R7.9.1 |

CHAPTER 3

# What is Timing and Synchronization?

Timing and synchronization is critical for network services that depend on precise, synchronized timing on network devices. Accurate and reliable synchronization of any network device helps manage the security, availability, and efficiency of the network devices. You can configure and synchronize the clocks on the routers so that the network displays accurate time.



# Basic Concepts of Timing and Synchronization

## Synchronization

Synchronization is the alignment of clocks to the same time/phase and frequency and is categorized into frequency synchronization, phase synchronization, and time synchronization.

- **Frequency Synchronization**—ensures that all the Networking Equipments (NEs) operate at the same clock rate or frequency. Different NEs each have their own internal clocks. If NEs operate at varying frequencies, it could result in data loss, corruption, or misinterpretation, leading to dropped calls or reduced call quality in telecommunications networks. Frequency synchronization ensures all NEs operate in unison by matching the frequency of their clock to a source clock.

  There are four types of sources for frequency synchronization:

  - **Line interfaces** include Synchronous Ethernet (SyncE) interfaces.
  - **Clock interfaces** are external connectors for connecting other timing signals, such as BITS and GPS.
  - **PTP clock** If IEEE 1588 version 2 is configured on the router, a Precision Time Protocol (PTP) clock may be available to frequency synchronization.
  - **Internal oscillator** This is a free-running internal oscillator chip.

- **Phase Synchronization**—ensures that the phase of the signal is consistent throughout the network. Phase refers to a specific point in time on a waveform cycle. Phase synchronization ensures that all NEs agree on the timing of the "start" and "end" of each bit in a data stream. This is critical in applications where data from multiple sources have to be combined or compared. For instance, in a mobile network, phase synchronization ensures seamless handover between different base stations as a user moves.

  PTP is used to achieve phase synchronization across the network.

- **Time Synchronization**—also called Time of Day (ToD), ensures that all NEs agree on the current time, which is critical in applications where timing is crucial. For example, in financial transactions, it's vital to know the exact order in which trades occurred.

  Network Time Protocol (NTP) and PTP are used for time synchronization in the network. While NTP provides millisecond accuracy, PTP provides nanosecond accuracy, and also achieves phase synchronization.

# Synchronous Ethernet (SyncE)

Synchronous Ethernet (SyncE) is an ITU-T standard that uses the physical layer (Ethernet interfaces) to provide frequency synchronization.

It's a reliable source of frequency synchronization with a high precision. It integrates synchronization into the physical layer, eliminating the need for separate cabling or equipment. Since SyncE operates at the physical layer, it's less susceptible to packet delays and jitter, making it robust and reliable, especially in heavy traffic networks.

However, SyncE only offers frequency synchronization. For applications requiring time or phase synchronization, another protocol, such as PTP, is needed. Also, SyncE requires support from both ends of a link. Therefore, every NE between the source clock and the edge needs to support SyncE to deliver frequency synchronization to the edge.

## ESMC

Ethernet Synchronization Messaging Channel (ESMC) is a protocol defined in the ITU-T G.8264 standard and used to communicate Synchronization Status Messages (SSM) in SyncE networks. ESMC provides a way for nodes in a SyncE network to exchange information about the quality level of their synchronization source. This information can optimize network performance and facilitate switching to a different source if needed. By enabling nodes to select the best available synchronization source, ESMC enhances network resilience. If the current source fails, nodes can quickly switch to another source, minimizing the impact on network performance.

## Enhanced ESMC

Enhanced ESMC and Enhanced SyncE is an extension of the standard ESMC protocol. It incorporates features and improvements to augment the functionality and effectiveness of frequency synchronization in Ethernet networks. It introduces extra synchronization quality level indicators, providing more detailed and accurate information about the quality of the synchronization source. Enhanced ESMC enhances the ability of the network to respond to changes or failures in the synchronization source, which allows for faster and more precise switching to alternative sources when required.

# GPS, an external Clock Interface

Global Positioning System (GPS) for frequency synchronization refers to the use of GPS signals to provide an accurate frequency reference for devices in a network. GPS satellites carry highly stable atomic clocks that provide precise time signals, which can be converted into frequency references by a GPS receiver.

Due to the atomic clocks on GPS satellites, GPS provides highly precise time and frequency information. As long as there's a clear view of the sky, GPS signals can be received almost anywhere worldwide, making it ideal for synchronizing geographically dispersed devices. Also, because GPS synchronization doesn't rely on network infrastructure, it's less prone to network-related issues like congestion or failures.

However, factors like weather conditions or indoor locations can cause loss or degradation of GPS signals, which would mean losing synchronization. Implementing GPS synchronization also requires GPS receivers and antennas, which can increase setup cost and complexity.

Configure GPS, an external Clock Interface for Frequency Synchronization, on page 19 section details the configuration steps involved for frequency synchronization using GPS.

# BITS, an external Clock Interface

Building Integrated Timing Supply (BITS) uses a centralized clock to generate a timing signal, which is then distributed to the equipment in the network to ensure they operate in sync. It's typically used in single buildings, campuses, or data centers where there's a need to synchronize many NEs within a confined area. However, it's less suitable for wide-area or geographically distributed networks.

BITS systems typically use high-quality oscillators, providing a stable and accurate reference frequency. In contrast to GPS, BITS doesn’t rely on external systems, making it less susceptible to external disruptions or control.

BITS systems require dedicated infrastructure and regular maintenance to ensure their accuracy and reliability. As BITS relies on a centralized clock, any failure or issue with this clock can disrupt synchronization throughout the entire network.

Configure BITS, an external Clock Interface for Frequency Synchronization, on page 22 section details the configuration steps involved for frequency synchronization using BITS.

# Precision Time Protocol (PTP)

Precision Time Protocol (PTP) delivers time synchronization services with precise time and frequency over packet-based networks. PTP can synchronize the real-time clocks of NEs with nanosecond accuracy. It’s not tied to specific hardware or physical layer protocols, making it flexible and broadly applicable across various network types and architectures. It can scale to large networks and support many devices, making it suitable for large industrial, scientific, or telecommunications networks.

PTP messages can create a significant load on the network, potentially affecting network performance, particularly in large, or high-traffic networks. Network conditions such as latency, jitter, and packet loss can affect the accuracy of PTP. While PTP includes mechanisms to compensate for these factors, they can still impact the synchronization accuracy.

PTP lets you define separate profiles to adapt itself for use in different scenarios. G.8265.1 profile fulfills the frequency synchronization requirements in telecom networks, while G.8275.1 profile fulfills the ToD and phase synchronization requirements.

# Network Time Protocol (NTP)

Network Time Protocol (NTP) provides time synchronization to all devices on a network. The primary NTP servers are synchronized to a reference clock, such as GPS receivers and telephone modem services. An NTP server receives the time service from a time source, a clock that is attached to a time server, and then distributes and synchronizes the time across all devices on a network. NTP provides millisecond accuracy in synchronizing network device clocks.

NTP is a versatile protocol that operates independently of specific hardware or network architectures. It can be applied to a range of network environments, from small local networks to large, geographically dispersed ones.

NTP is less precise than PTP, making it unsuitable for applications needing extreme precision. Furthermore, since NTP is an older protocol, it has been targeted by various types of attacks. While security measures exist, managing NTP security can be a concern.

CHAPTER 4

# Frequency Synchronization



## What is Frequency Synchronization?

Frequency synchronization is the ability to distribute precision frequency around a network. In this context, timing refers to precision frequency, not an accurate time of day. Precision frequency is required in next generation networks for applications such as circuit emulation.

***Table 2: Feature History Table***

| Feature name | Release Information | Feature Description |
|---|---|---|
| Frequency Synchronization | Release 7.3.1 | Based on the ITU-T G.8262 recommendations, precision frequency is enabled on timing devices to deliver frequency synchronization for bandwidth, frequency accuracy, holdover, and measure noise generation. This allows for correct network operations when synchronous equipment is timed from either another synchronous equipment clock or a higher-quality clock. |

# Frequency Synchronization Timing Concepts

## Source and Selection Points

Frequency Synchronization implementation involves Sources and Selection Points.

### Source

A Source inputs frequency signals into a system or transmits them out of a system. There are four types of sources:

- **Line interfaces**: This includes SyncE interfaces.
- **Clock interfaces**: These are external connectors for connecting other timing signals, such as BITS and GPS.
- **PTP clock**: If IEEE 1588 version 2 is configured on the router, a PTP clock may be available to frequency synchronization as a source of the time-of-day and frequency.
- **Internal oscillator**: This is a free-running internal oscillator chip.

Each source has a Quality Level (QL) associated with it which gives the accuracy of the clock. This provides information about the best available source the devices in the system can synchronize to. To define a predefined network synchronization flow and prevent timing loops, you can assign priority values to the sources on each router. The combination of QL information and user-assigned priority levels allow each router to choose a source to synchronize its SyncE interfaces, as described in the ITU standard G.781.

### Selection Point

A Selection Point is any point where a choice is made between several frequency signals and possibly one or many of them are selected. Selection points form a graph representing the flow of timing signals between different cards in a router running Cisco IOS XR software. For example, there can be one or many selection points between different Synchronous Ethernet inputs available on a single-line card. This information is forwarded to a selection point on the router, to choose between the selected source from each card.

The input signals to the selection points can be:

- Received directly from a source.
- Received as the output from another selection point on the same card
- Received as the output from a selection point on a different card

The output of a selection point can be used in several ways, like:

- To drive the signals sent out of a set of interfaces.
- As input into another selection point on a card
- As input into a selection point on another card

Use the **show frequency synchronization selection** command to see a detailed view of the different selection points within the system.

# Synchronous Ethernet (SyncE)

SyncE is an ITU-T standard for computer networking that facilitates the transfer of clock signals over the Ethernet physical layer. It uses the physical layer (Ethernet interfaces) to distribute frequency from the primary reference clock (PRC) to downstream devices. It supports frequency transfer from hop to hop and is used to provide frequency synchronization in networks.

SDH equipment are widely replaced by Ethernet equipment and synchronized frequency is required over such Ethernet ports. SyncE is used to accurately synchronize frequency in devices connected by Ethernet in a network. SyncE provides a level frequency distribution of known common precision frequency references to a physical layer Ethernet network.

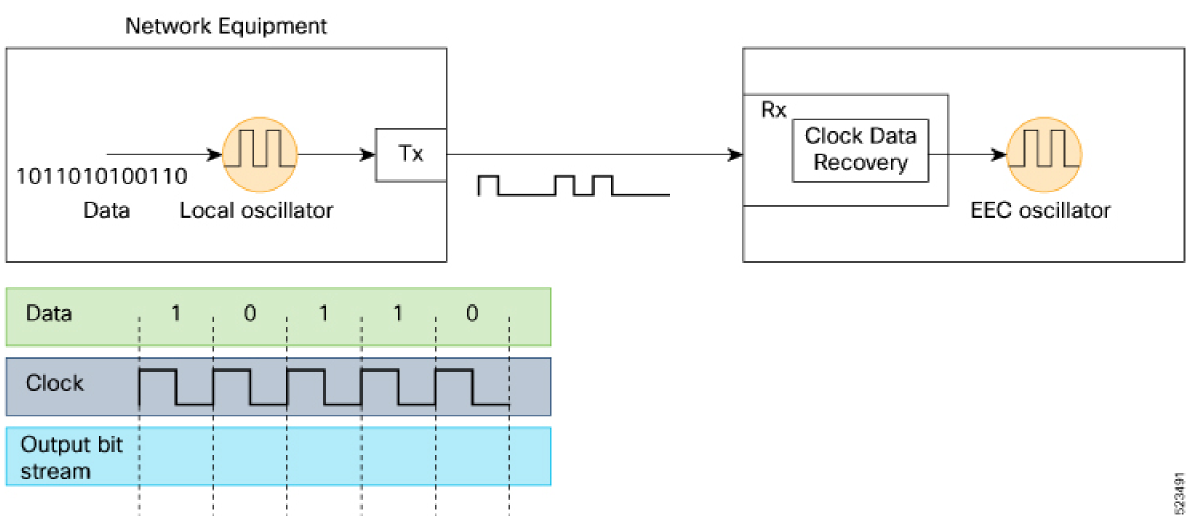
To maintain SyncE links, a set of operational messages are required. These messages ensure that a node is always deriving timing information from the most reliable source and then transfers the timing source quality information to clock the SyncE link. In SDH networks, these are known as Synchronization Status Messages (SSMs). SyncE uses an Ethernet Synchronization Message Channel (ESMC) to provide transport for SSMs.

## How SyncE Works?

SyncE operates on the fundamental principle of extracting clock frequency from the data received on a port.

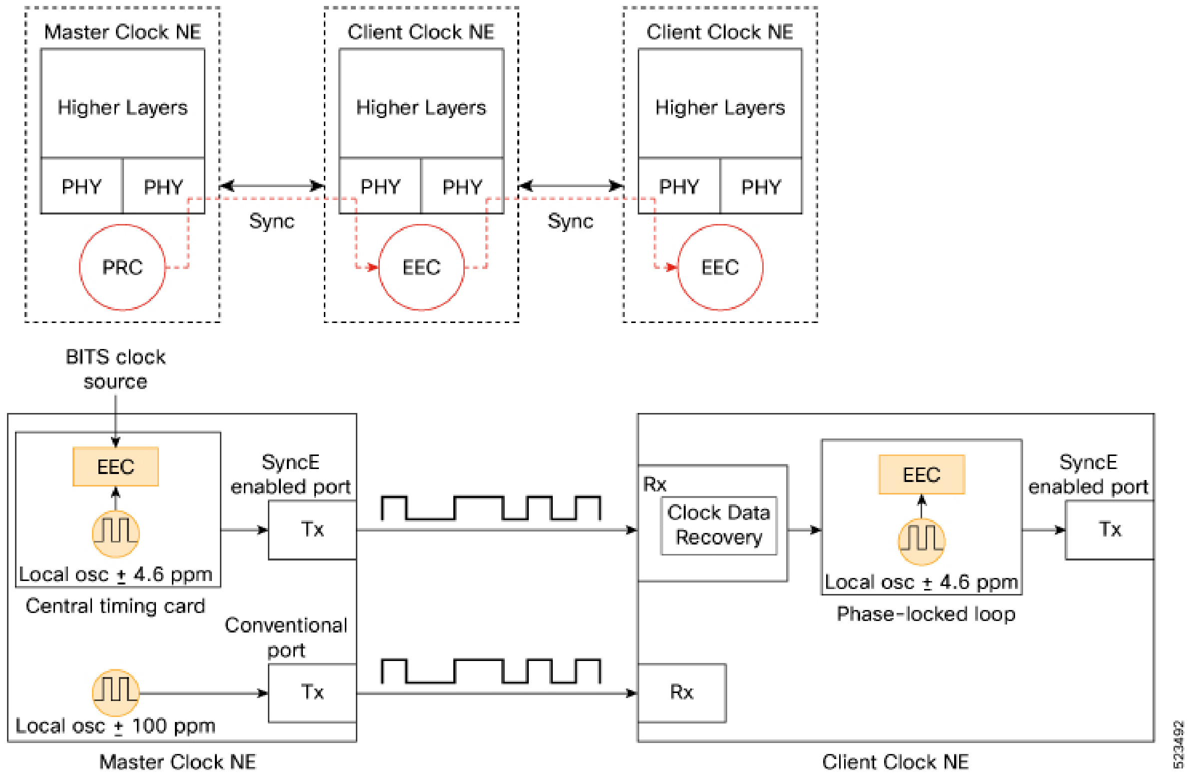
Here's an example. The local oscillator processes the data signal and the Tx port transmits the resulting output. You can observe that the clock frequency is present in the data signal transmitted on the port. SyncE functions by reverse-processing the signal received on the Rx port and obtains the frequency information of the transmitted clock.

***Figure 1: Clock Frequency Extraction for SyncE***




Per recommendation, the frequency from the bitstream is recovered in the physical layer. A clock known as the primary reference clock (PRC), is distributed in the chain and all the network clocks must be traceable back to this PRC. To ensure traceable clocks, all nodes within the chain connecting the Main Clock and the end device must actively adopt a synchronous Ethernet Equipment Clock (EEC), in accordance with SyncE recommendations. The performance of the recovered clock remains unaffected by network load as it doesn't synchronize with specific packets.

*Figure 2: Clock Deployment for SyncE*




The Master Clock NE receives external timing references from the network clock (SSU or BITS), which are then used as inputs to the EEC clock, typically located on the central timing card of the NE. The output timing reference from the EEC is used to sample data and transmit traffic on the SyncE-enabled Tx port.

At the Client Clock NE, the clock is recovered within the transceiver clock data recovery (CDR). In some cases where the RX clock isn't available at the transceiver, the use of an external CDR might be required to recover the clock. The clock is then sent through the backplane to reach the Client Clock's central timing card. This timing reference then becomes a reference to the EEC (also known as a line-timing reference). As shown in the Client Clock NE, an EEC can accept line and external references, as well as the input of a ±4.6 ppm local oscillator (used in situations where there are no line or external references available). From this point on, the Client Clock NE then becomes the Master Clock NE for the next downstream NE, and synchronization is transported on a node-to-node basis, where each node participates in recovery and distribution.

In the case of the Client Clock NE, the clock recovery occurs within the transceiver's clock data recovery (CDR). In situations where the RX clock is unavailable at the transceiver, the use of an external CDR may be necessary for clock recovery. The recovered clock is then transmitted through the backplane to reach the Client Clock's central timing card, which then becomes a reference for the EEC (also known as a line-timing reference). As depicted in the Client Clock NE, an EEC can accept line and external references, and the input of a ±4.6 ppm local oscillator (used when no line or external references are available). From this point onward, the Client Clock NE becomes the Master Clock NE for the subsequent downstream NE, and synchronization is conveyed on a node-to-node basis, with each node participating in recovery and distribution.

# SyncE Profiles Support Matrix

This table provides information on the SyncE profiles that are supported on the Cisco 8000 series routers and line cards.

*Table 3: SyncE Profiles Support Matrix*

| Hardware Module | Supported SyncE profiles | Cisco IOS XR Release |
|---|---|---|
| 8711-32FH-M router | G.8262<br>G.8262.1 | Release 24.3.1 |
| 8000-RP2 Route Processor | G8275.1<br>G8273.2 | Release 7.11.1 |
| 88-LC0-36FH-M | G8275.1<br>G8273.2 | Release 7.11.1 |
| 8800-LC-36FH | G8275.1<br>G8273.2 | Release 7.11.1 |
| • 88-LC0-36FH-M line card<br>• 8202-32FH-M router | G.8262 | Release 7.5.2 |
| | G.8264 | |
| • 8201-32FH router<br>• 88-LC-34H14FH line card<br>• 88-LC0-36FH line card | G.8262 | Release 7.3.3 |
| | G.8264 | |
| • 8201 router<br>• 8202 router<br>• 8800-LC-36FH line card<br>• 8800-LC-48FH line card | G.8262 | Release 7.3.1 |
| | G.8264 | |

# SyncE Restrictions

1. SyncE isn’t supported on 8800-RP 1588 ports.
2. We recommend that you configure and enable Frequency Synchronization selection input on two interfaces per line card.
3. For link aggregation, configure and enable Frequency Synchronization selection input on a single bundle member.

# Enhanced ESMC and Enhanced SyncE

The Ethernet Synchronization Message Channel (ESMC) protocol is specified in the ITU-T G.8264. It enables frequency synchronization across a network over Ethernet ports with the ability to select enhanced quality levels. Enhanced quality levels lead to improved bandwidth, frequency accuracy, and holdover along with reduced noise generation in a network.

As part of the ESMC protocol, Synchronization Status Messages (SSMs) distributes the Quality Level (QL) of timing signals. The updated G.8264 standard provides a new and enhanced Quality Level (QL) of Type Length Value (TLV) that allows more precise quality to provide accurate clocks.

The new and enhanced QL of TLV that is part of the updated G.8264 standard is known as **enhanced SyncE (eSyncE)**. The enhanced QL of TLV enables support for more QL values. You can configure a router to send or receive the enhanced TLV. The enhanced QL of TLV results in more precise synchronization of clocks across a network. To enable this feature, the local clock ID is configured. The clock ID is used, when appropriate, in the extended QL TLVs.

***Table 4: Feature History Table***

| Feature name | Release Information | Feature Description |
| --- | --- | --- |
| Ethernet Synchronization Message Channel (ESMC) | Release 7.3.1 | The ITU-T G.8264 performance compliance standard specifies the ESMC protocol, offering recommendations on synchronizing clock frequency across a network via an Ethernet port and enabling the selection of quality levels. Within the G.8264 standard, a new extended Quality Level (QL) in the form of Type Length Value (TLV) is provided. As networks progressively adopt Ethernet equipment instead of SONET and SDH equipment, frequency synchronization actively delivers high-quality clock synchronization over Ethernet ports. |

**Note** The default clock ID is based on the MAC address of the chassis.

# ESMC Restrictions

There may be devices in a network that do not support eSyncE and also do not support enhanced ESMC. If a router does not support eSyncE, it ignores any enhanced TLVs it receives and does not support enhanced quality to provide accurate clocks. Such routers at ingress nodes drop the QL TLV received from the previous node supporting eSyncE. If the next node supports enhanced ESMC, then the extended QL TLV is applied afresh to that node.

# Configure Frequency Synchronization

This section details the various ways for configuring frequency synchronization. First frequency synchronization needs to be enabled on the router which is detailed in *Enable Frequency Synchronization on the Router* section.

If SyncE is selected as the source for frequency synchronization, the configuration steps are detailed in the section *Configure Frequency Synchronization on an Interface*. For frequency synchronization using external clock interfaces (GPS or BITS), the configuration steps involved are detailed in the sections *Configure GPS, an external Clock Interface for Frequency Synchronization* and *Configure BITS, an external Clock Interface for Frequency Synchronization*.

Frequency synchronization using PTP is detailed in the section G.8265.1 of the *Precision Time Protocol (PTP)* module of this document.

## Enable Frequency Synchronization on the Router

This task describes the router-level configuration required to enable frequency synchronization.

**Step 1** Configure the type of timing sources that can be used to drive the output from a clock interface.

```
Router# config
Router(config)# frequency synchronization
Router(config-freqsync)# clock-interface timing-mode system
```

**Note** If the timing mode system isn't configured, the major alarm `T4 PLL is in FREERUN mode` is raised. This alarm has no functional impact to the system behavior.

**Step 2** (Optional) Configure the ITU-T quality level (QL) options.

```
Router(config-freqsync)# quality itu-t option 2 generation 1
```

**Note** The quality option configured here must match the quality option specified in the **quality receive** and **quality transmit** commands in interface frequency synchronization configuration mode.

**Step 3** Enable logging of changes or errors.

```
Router(config-freqsync)# log selection changes
Router(config-freqsync)# commit
```

#### What to do next

Configure frequency synchronization on any interfaces that should participate in frequency synchronization.

## Configure Frequency Synchronization on an Interface

### Configure SyncE

By default, there's no frequency synchronization on line interfaces. Use this task to configure an interface to participate in frequency synchronization.

**Before you begin**

You must enable frequency synchronization globally on the router.

**Step 1** Enter the interface frequency synchronization mode using **frequency synchronization** and **interface** commands.

```
Router# config
Router(config)# interface HundredGigE 0/1/1/0
Router(config-if)# frequency synchronization
Router(config-if-freqsync)#
```

**Step 2** (Optional) Define the parameters for frequency synchronization.

```
Router(config-if-freqsync)# selection input
Router(config-if-freqsync)# priority 100
Router(config-if-freqsync)# wait-to-restore 10
Router(config-if-freqsync)# ssm disable
Router(config-if-freqsync)# time-of-day-priority 50
Router(config-if-freqsync)# quality transmit highest itu-t option 1 prc
```

The quality option specified in this command must match the globally configured quality option in the **quality itu-t option** command.

**Note** For clock interfaces that don’t support SSM, only the lowest QL can be specified. In this case, rather than sending DNU, the output is squelched, and no signal is sent.

**Step 3** (Optional) Configure the SSM quality levels for the frequency source from the receive interface.

```
Router(config-if-freqsync)# quality receive highest itu-t option 1 prc
Router(config-if-freqsync)# commit
```

The quality option specified in this command must match the globally configured quality option in the **quality itu-t option** command.

**Note** For clock interfaces that don’t support SSM, only the exact QL can be specified.

## Configure eSyncE

**Step 1** Configure the MAC address of the device clock that can transmit the enhanced QL TLV in the network.

```
Router# configure
Router(config)# frequency synchronization
Router(config-freqsync)# clock-id mac-address aaaa.bbbb.cccc
Router(config-freqsync)# commit
Router(config-freqsync)# exit
```

**Step 2** Configure the quality level options to be transmitted by the device clock.

```
Router(config)# interface HundredGigE 0/1/0/0
Router(config-if)# frequency synchronization
Router(config-if-freqsync)# quality transmit exact itu-t option 1 ePRTC
Router(config-if-freqsync)# end
```

**Step 3** Verify eSyncE configuration.

```
Router# show frequency synchronization interfaces
Interface HundredGigE 0/11/0/1 (up)
```

```
Assigned as input for selection
Wait-to-restore time 0 minutes
SSM Enabled
  Peer Up for 00:00:54, last SSM received 0.741s ago
  Peer has come up 1 times and timed out 0 times
  ESMC SSMs        Total  Information     Event    DNU/DUS
    Sent:             55           53         2         45
    Received:         55           55         0          0
Input:
  Up
  Last received QL: Opt-I/ePRTC
  Effective QL: Opt-I/ePRTC, Priority: 30, Time-of-day Priority 100
  Originator clock ID: aaaabbfffebbcccc
  SyncE steps: 1, eSyncE steps: 1
  All steps run eSyncE; Chain of extended ESMC data is complete
  Supports frequency
Output:
  Selected source: HundredGigE 0/11/0/1
  Selected source QL: Opt-I/ePRTC
  Effective QL: DNU
  Originator clock ID: aaaabbfffebbcccc
  SyncE steps: 2, eSyncE steps: 2
  All steps run eSyncE; Chain of extended ESMC data is complete
Next selection points: ETH_RXMUX
```

# Configure GPS, an external Clock Interface for Frequency Synchronization

## Setting GPS

The router can receive 1PPS, 10 MHz, and ToD signals from an external clocking and timing source. The three inputs are combined as a Sync-2 interface to form the external timing source or the GPS input.

The GPS front panel connector details are:

- ToD—RS422 format as input
- 1PPS—RS422 or DIN connector as input
- 10MHz—DIN connector as input

GPS input starts only when all the three signals – 1PPS, 10MHz, and ToD are UP.

**Note** Unlike the Ethernet interface, the Sync-2 interface can't receive or transmit QL. Ensure that you assign a QL value to the Sync-2 interface.

By default, 1PPS and 10MHz are in output mode. ToD output mode isn't configurable.

For the variant, 8800-RP, 10MHZ and 1PPS can operate in output mode only when PTP Slave or BC mode are configured.

When the front panel timing LED is Green, it indicates that the GPS is configured and 1PPS, ToD, and 10M inputs are valid.

Timing GPS LED Behavior:

- Timing GPS LED is off: Indicates that no GPS is configured or the GPS port is down.
- Timing GPS LED is green: Indicates that the GPS port is up.

SYNC LED Behavior:

- SYNC LED is green: Indicates that the time core is synchronized to either external source, or SyncE or 1588.
- SYNC LED is amber: Indicates a Holdover or Acquiring state.
- SYNC LED is off: Indicates synchronization in a disable or free-running state.

The following table describes the implication of LED light status of GPS, BITS port, and SYNC LEDs.

***Table 5: LED Light States***

| LED Type | LED State | Description |
|---|---|---|
| GPS | Green | The GPS interface is provisioned and frequency, time of day, and phase input is operating accurately. |
| | Off | The GPS interface isn't provisioned or the GPS input isn't operating accurately. |
| BITS port | Green | The BITS interface is provisioned and the frequency is operating accurately. |
| | Off | The BITS interface isn't provisioned or the BITS input isn't operating accurately. |

| LED Type | LED State | Description |
|---|---|---|
| SYNC | Green | The frequency, time, and phase are synchronized to an external interface. The external interface can be:<br>• BITS<br>• GPS<br>• Recovered RX clock. |
| | Amber | The system is running in holdover or free-run mode and based on user configuration it's not synchronized to an external interface, as expected. |
| | Off | The centralized frequency or time and phase distribution isn't enabled. Therefore, all clocking is based on the local oscillator on the RSP. |

## Configuring GPS Settings for the Grandmaster Clock

**Step 1** Configure the clock interface to synchronize with a GPS.

```
Router# config
Router(config)# clock-interface sync 2 location 0/RP0/CPU0
Router(config-clock-if)# port-parameters
Router(config-clk-parms)# gps-input tod-format cisco pps-input ttl
Router(config-clk-parms)# exit
```

**Step 2** Define the parameters for frequency synchronization.

```
Router(config-clock-if)# frequency synchronization
Router(config-clk-freqsync)# selection input
Router(config-clk-freqsync)# wait-to-restore 0
Router(config-clk-freqsync)# quality receive exact itu-t option 1 PRC
Router(config-clk-freqsync)# exit
```

**Step 3** Configure the type of timing sources that can be used to drive the output from a clock interface.

```
Router(config-clock-if)# frequency synchronization
Router(config-clk-freqsync)# quality itu-t option 1
Router(config-clk-freqsync)# clock-interface timing-mode system
Router(config-clk-freqsync)# end
```

**Step 4** Verify the GPS input.

```
Router# show controllers timing controller clock

SYNCC Clock-Setting: -1 -1 6 -1
             Port 0    Port 1    Port 2    Port 3
Config :     No        No        Yes       No
Mode :       -         -         GPS       -
```

```
Submode1 :   -          -          CISCO      -
Submode2 :   -          -          UTC        -
Submode3 :   0          0          0          0
Shutdown :   0          0          0          0
Direction :  RX/TX      RX/TX      RX         RX/TX
Baud-Rate :  -          -          9600       -
QL Option :  O1         O1         -          -
RX_ssm(raw): -          -          -          -
TX_ssm :     -          -          -          -
If_state :   DOWN       DOWN       UP         DOWN  << Port 2 is UP when GPS input is valid.
```

# Configure BITS, an external Clock Interface for Frequency Synchronization

Your router supports the reception (Rx) and transmission (Tx) of frequency through the Building Integrated Timing Supply (BITS) interface. To enable the reception and transmission of BITS signals, you actively configure the clock-interface sync 0 on the route processor (RP).

## Configuring BITS

**Step 1** Prerequisite for BITS

- Frequency synchronization must be configured with the required quality level option at the global level.
- Both RP0 and RP1 should have identical configurations and should be connected to the same external reference for sync 0 and sync 2 to meet phase transient response compliance standards during RP failover.
- BITS-In and BITS-Out on the peer nodes must be configured with the same mode and format.
- Based on the quality level chosen in the global configuration, E1/T1 modes can be changed as required. But in all the cases, both TX and RX side modes and submodes must be the same.
- For non-CRC-4/D4 modes, SSM isn't present in BITS and the manual receive quality level must be configured.

**Step 2** Configure BITS-IN.

```
Router# config
Router(config)# clock-interface sync 0 location 0/RP0/CPU0
Router(config-clock-if)# port-parameters
Router(config-clk-parms)# bits-input e1 crc-4 sa4 ami
Router(config-clk-parms)# exit
Router(config-clock-if)# frequency synchronization
Router(config-clk-freqsync)# selection input
Router(config-clk-freqsync)# wait-to-restore 0
Router(config-clk-freqsync)# priority 1
Router(config-clk-freqsync)# end
```

**Step 3** Verify the BITS-IN configuration.

```
Router# show running-config clock-interface sync 0 location 0/RP0/CPU0
Wed Aug 21 12:31:43.350 UTC
clock-interface sync 0 location 0/RP0/CPU0
 port-parameters
  bits-input e1 crc-4 sa4 ami
 !
 frequency synchronization
  selection input
```

```
  priority 1
  wait-to-restore 0
 !
!
Router# show controllers timing controller clock
Wed Aug 21 12:38:20.394 UTC

SYNCC Clock-Setting: 1 -1 -1 -1

          Port 0          Port 1          Port 2          Port 3
Config     : Yes            No              No              No
Mode       : E1             -               -               -
Submode1   : CRC-4          -               -               -
Submode2   : AMI            -               -               -
Submode3   : 0              0               0               0
Shutdown   : 0              0               0               0
Direction  : RX             RX/TX           RX/TX           RX/TX
Baud-Rate  : -              -               -               -
QL Option  : O1             O1              -               -
RX_ssm(raw): 99             -               -               -
TX_ssm     : -              -               -               -
If_state   : UP           DOWN            DOWN            DOWN
```

**Step 4** Configure BITS-OUT.

```
Router# config
Router(config)# clock-interface sync 0 location 0/RP0/CPU0
Router(config-clock-if)# port-parameters
Router(config-clk-parms)# bits-output e1 crc-4 sa4 ami
Router(config-clk-parms)# end
```

**Step 5** Verify the BITS-OUT configuration.

```
Router# show running-config clock-interface sync 0 location 0/RP0/CPU0
Wed Aug 21 12:54:02.853 UTC
clock-interface sync 0 location 0/RP0/CPU0
 port-parameters
  bits-output e1 crc-4 sa4 ami
 !
!
Router# show controllers timing controller clock
Wed Aug 21 12:49:32.923 UTC
SYNCC Clock-Setting: 1 -1 -1 -1

          Port 0          Port 1          Port 2          Port 3
Config     : Yes            No              No              No
Mode       : E1             -               -               -
Submode1   : CRC-4          -               -               -
Submode2   : AMI            -               -               -
Submode3   : 0              0               0               0
Shutdown   : 0              0               0               0
Direction  : TX             RX/TX           RX/TX           RX/TX
Baud-Rate  : -              -               -               -
QL Option  : O1             O1              -               -
RX_ssm(raw): -              -               -               -
TX_ssm     : 22             -               -               -
If_state   : UP             DOWN            DOWN            DOWN
```

**Step 6** Verify quality level received and clock interfaces.

```
Router# show frequency synchronization clock-interfaces brief
Tue Feb 23 23:42:22.654 UTC
Flags: > - Up               D - Down                          S - Assigned for selection
d - SSM Disabled            s - Output squelched              L - Looped back
Node 0/RP0/CPU0:
```

```
==============
Fl      Clock Interface      QLrcv    QLuse    Pri   QLsnd    Output driven by
=====   ===================  ======   ======   ===   ======   ========================
D       Sync0                n/a      n/a      n/a   n/a      n/a
D       Sync1                n/a      n/a      n/a   n/a      n/a
>S      Sync2                None     PRC      100   n/a      n/a
>S      Internal0            n/a      SEC      255   n/a      n/a
Node 0/RP1/CPU0:
==============
Fl      Clock Interface      QLrcv    QLuse    Pri   QLsnd     Output driven by
=====   ===================  ======   ======   ===   ======    ========================
D       Sync0                n/a      n/a      n/a   n/a       n/a
D       Sync1                n/a      n/a      n/a   n/a       n/a
D       Sync2                n/a      n/a      n/a   n/a       n/a
>S      Internal0            n/a      SEC      255   n/a       n/a
```

# Verify the Frequency Synchronization Configuration

After performing the frequency synchronization configuration tasks, use this task to check for configuration errors and verify the configuration.

**Step 1** Display any configuration errors related to frequency synchronization using **show frequency synchronization configuration-errors** command.

```
Router# show frequency synchronization configuration-errors

Node 0/2/CPU0:
==============
  interface HundredGigE 0/2/0/0 frequency synchronization
    * Frequency synchronization is enabled on this interface, but isn't enabled globally.

  interface HundredGigE 0/2/0/0 frequency synchronization quality transmit exact itu-t option 2
generation 1 PRS
    * The QL that is configured is from a different QL option set than is configured globally.
```

Displays any errors that are caused by inconsistencies between shared-plane (global) and local-plane (interface) configurations. There are two possible errors that can be displayed:

- Frequency Synchronization is configured on an interface (line interface or clock-interface), but is not configured globally. Refer to Enable Frequency Synchronization on the Router, on page 17
- The QL option configured on some interfaces does not match the global QL option. Under an interface (line interface or clock interface), the QL option is specified using the **quality transmit** and **quality receive** commands. The value specified must match the value configured in the global **quality itu-t option** command, or match the default (option 1) if the global **quality itu-t option** command is not configured.

Once all the errors have been resolved, meaning there is no output from the command, continue to the next step.

**Step 2** Verify the configuration using **show frequency synchronization interfaces brief** and **show frequency synchronization clock-interfaces brief** commands.

```
Router# show frequency synchronization interfaces brief

Flags:  > - Up                D - Down              S - Assigned for selection
        d - SSM Disabled      x - Peer timed out    i - Init state
```

```
Fl  Interface                QLrcv QLuse Pri QLsnt Source
=== ======================== ===== ===== === ===== ========================
>Sx HundredGigE 0/2/0/0   Fail  Fail  100 DNU   None
Dd  HundredGigE 0/2/0/1   n/a   Fail  100 n/a   None

Router# show frequency synchronization clock-interfaces brief

Flags:  > - Up                D - Down              S - Assigned for selection
        d - SSM Disabled      s - Output squelched  L - Looped back

Node 0/0/CPU0:
==============
  Fl    Clock Interface     QLrcv  QLuse  Pri QLsnd  Source
  ===== =================== ====== ====== === ====== ========================
  >S    Sync0               PRC    Fail   100 SSU-B  Internal0 [0/0/CPU0]

  >S    Internal0           n/a    SSU-B  255 n/a    None

Node 0/1/CPU0:
==============
  Fl    Clock Interface     QLrcv  QLuse  Pri QLsnd  Source
  ===== =================== ====== ====== === ====== ========================
  D     Sync0               None   Fail   100 SSU-B  Internal0 [0/1/CPU0]

  >S    Internal0           n/a    SSU-B  255 n/a    None
```

Note the following points:

- All line interfaces that have frequency synchronization configured are displayed.
- All clock interfaces and internal oscillators are displayed.
- Sources that have been nominated as inputs (in other words, have **selection input** configured) have 'S' in the Flags column; sources that have not been nominated as inputs do not have 'S' displayed.

  **Note** Internal oscillators are always eligible as inputs.

- '>' or 'D' is displayed in the flags field as appropriate.

If any of these items are not true, continue to the next step.

**Step 3** Investigate issues within individual interfaces using **show frequency synchronization interfaces** and **show frequency synchronization clock-interfaces** commands.

```
Router# show frequency synchronization interfaces HundredGigE 0/2/0/2

Interface HundredGigE 0/2/0/2 (shutdown)
  Assigned as input for selection
  SSM Enabled
  Input:
    Down
    Last received QL: Failed
    Effective QL:     Failed, Priority: 100
  Output:
    Selected source:    Sync0 [0/0/CPU0]
    Selected source QL: Opt-I/PRC
    Effective QL:       Opt-I/PRC
  Next selection points: LC_INGRESS

Router# show frequency synchronization clock-interfaces location 0/1/CPU0

Node 0/1/CPU0:
```

```
==============
  Clock interface Sync0 (Down: mode not configured)
    SSM supported and enabled
    Input:
      Down
      Last received QL: Opt-I/PRC
      Effective QL:     Failed, Priority: 100
    Output:
      Selected source:    Internal0 [0/1/CPU0]
      Selected source QL: Opt-I/SSU-B
      Effective QL:       Opt-I/SSU-B
  Next selection points: RP_SYSTEM



  Clock interface Internal0 (Up)
    Assigned as input for selection
    Input:
      Default QL:   Opt-I/SSU-B
      Effective QL: Opt-I/SSU-B, Priority: 255
  Next selection points: RP_SYSTEM RP_CLOCK_INTF
```

If the clock interface is down, a reason is displayed. This may be because there is missing or conflicting platform configuration on the clock interface.

**Step 4** Verify that the fsyncmgr process is running on the appropriate nodes using **show processes fsyncmgr location** command.

```
Router# show processes fsyncmgr location 0/0/CPU0

                  Job Id: 134
                     PID: 30202
         Executable path: /pkg/bin/fsyncmgr
              Instance #: 1
              Version ID: 00.00.0000
                 Respawn: ON
           Respawn count: 1
  Max. spawns per minute: 12
            Last started: Mon Mar  9 16:30:43 2009
           Process state: Run
           Package state: Normal
       Started on config: cfg/gl/freqsync/g/a/enable
                    core: MAINMEM
               Max. core: 0
               Placement: None
            startup_path: /pkg/startup/fsyncmgr.startup
                   Ready: 0.133s
        Process cpu time: 1730768.741 user, -133848.-361 kernel, 1596920.380 total
  --------------------------------------------------------------------------------
```

CHAPTER 5

# Precision Time Protocol (PTP)

Precision Time Protocol (PTP) defines a method for distributing time across a network with its foundation based on the IEEE 1588-2008 standard.

This module describes the concepts around this protocol and details the various configurations involved.



# PTP Overview

The Precision Time Protocol (PTP), defined in the IEEE 1588 standard, achieves synchronization at nanosecond precision of real-time clocks across networked devices. These clocks are structured in a Master-Client hierarchy. PTP identifies the port connected to the device with the most accurate clock, known as the Master clock. All other devices within the network synchronize their clocks with the Master clock, and referred to as members. Ongoing exchange of timing messages ensures continual synchronization. PTP ensures the selection of the best available clock as the time source of the network (referred to as the grandmaster clock), with all other network clocks synchronized to this clock.

## Why PTP?

Smart grid power automation applications, such as peak-hour billing, virtual power generators, and outage monitoring and management, require 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 an IP address information contained in the packets. When the router attempts to send multiple packets simultaneously, the router buffers some packets so that they aren't 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.

More 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 Key Terms and Concepts section.

# Key Terms and Concepts

### PTP Clocks

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

- **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:
    - Master mode—Distributes timing information over the network to one or more client clocks, thus allowing the client to synchronize its clock to the master.
    - Slave mode—Synchronizes its clock to a master clock. You can enable the slave mode on up to two interfaces simultaneously in order to connect to two different master clocks.
- **Boundary Clock (BC)**—The device participates in selecting the best master clock and can act as the master clock if no better clocks are detected.

  The boundary clock starts its own PTP session with various downstream client clocks. The boundary clock mitigates the number of network hops and 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.

### Port State Machine and Best Master Clock Algorithm

This provides a method to determine the state of the ports in the network that remain passive (neither master nor client), run as a master (providing time to other clocks in the network), or run as secondaries (receiving time from other clocks in the network).

### Frequency and Time Selection

The selection of the source to synchronize the device clock frequency is made by frequency synchronization which is described in the Source and Selection Points section of the *Frequency Synchronization* module in this document. The Announce, Sync, and Delay-request frequencies must be the same on the master and client.

### Delay Request-Response Mechanism

The Delay Request-response mechanism (defined in section 11.3 of IEEE Std 1588-2008) lets a client 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 sent in the Sync message itself.
- Two-step mechanism - The timestamp for a Sync message is sent later in a Follow-up message.

When running a port in Client state, a router can 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.

### 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: BITS, 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 (BITS or 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. The ToD selection is controlled using the time-of-day priority configuration. This configuration is found under the clock 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 1–254 are allowed, with lower numbers indicating higher priority.

The steps involved are detailed in this section Configuring PTP Hybrid Mode of the topic G.8275.1.

### Time of Day (ToD) Support

The router receives GPS ToD messages in serial ASCII stream through the RS422 interface in one of the following configurable formats:

- NTP Type 4
- Cisco

### Port States for PTP

State machine indicates the behavior of each port. The possible states are:

| State | Description |
|---|---|
| INIT | Port isn’t ready to participate in PTP. |
| LISTENING | First state when a port becomes ready to participate in PTP: In this state, the port listens to PTP masters for a (configurable) period of time. |

| State | Description |
|---|---|
| PRE-MASTER | Port is ready to enter the MASTER state. |
| MASTER | Port provides timestamps for any Client or boundary clocks that are listening. |
| UNCALIBRATED | Port receives timestamps from a Master clock but, the router’s clock isn’t yet synchronized to the Master clock. |
| SLAVE | Port receives timestamps from a Master clock and the router’s clock is synchronized to the Master clock. |
| PASSIVE | Port is aware of a better clock than the one it would advertise if it was in MASTER state and isn’t a Client clock to that Master clock. |

# How PTP Works?

## Message-Based Synchronization

To ensure clock synchronization, PTP requires an accurate measurement of the communication path delay between the time source (master) and the receiver (client). PTP sends messages between the master 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 the path delay between devices on the network. The local clocks are adjusted for this delay using a series of messages sent between masters 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 don’t 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 master 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.

## 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

- Follow_Up
- Delay_Req
- Delay_Resp

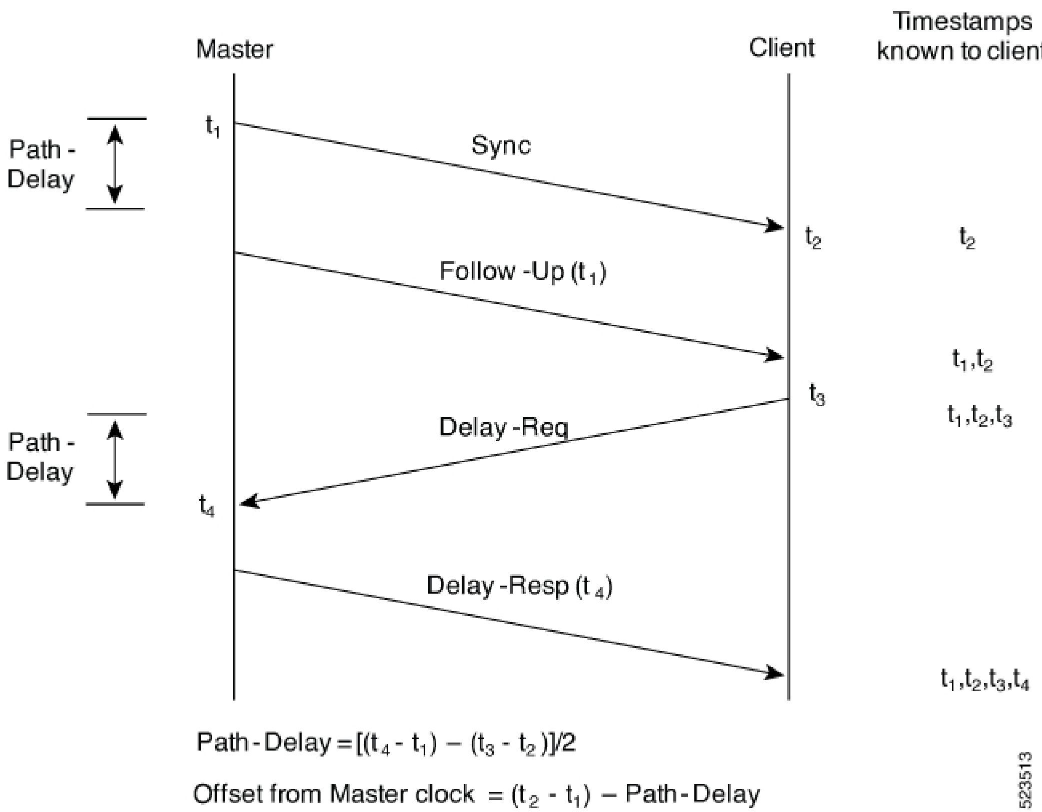
These messages are sent in the following sequence:

- The master 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 master 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 master and notes the time (t3) at which it was sent.
- The master receives the Delay_Req message and notes the time of reception (t4).
- The master 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 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 client is the same as the time required from client to master. This assumption isn't always valid on an Ethernet/IP network due to asymmetrical packet delay times.

*Figure 3: Detailed Steps—Boundary Clock Synchronization*




### Synchronizing the Local Clock

In an ideal PTP network, the master and client clocks operate at the same frequency. However, drift can occur on the network. Drift is the frequency difference between the master 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 master clock.

# PTP Support Information

This table lists different types of support information related to PTP:

| | |
|---|---|
| Transport Media | • UDP over IPv4<br>• UDP over IPv6<br>• Ethernet |

| | |
|---|---|
| Messages | • Signaling<br>• Announce<br>• Sync<br>• Follow-up<br>• Delay-request<br>• Delay-response<br>• Management |
| Transport Modes | • Unicast: This is the default mode. All packets are sent as unicast messages. Unicast is applicable only for PTP over IP profiles.<br>• Multicast: All packets are sent as multicast messages. Multicast is the only mode for PTP over ethernet profiles. |

# Timing Profile and Class Support Matrix

This table provides information about the timing profiles and class that are supported on the Cisco 8000 series routers and line cards.

*Table 6: Timing Profile and Class Support Matrix*

| Hardware Module | Supported Profile | Cisco IOS XR Release |
|---|---|---|
| 8711-32FH-M router | G.8265.1 | Release 24.3.1 |
| | G.8273.2 Class C | |
| | G.8275.1 | |
| | G.8275.2 | |
| 88-LC1-52Y8H-EM | G.8273.2 Class C | Release 24.3.1 |
| | G.8275.1 | |
| 88-LC1-12TH24FH-E | G.8273.2 Class C | Release 24.3.1 |
| | G.8275.1 | |
| 86-MPA-14H2FH-M | G.8265.1 | Release 24.3.1 |
| | G.8273.2 Class C | Release 24.1.1 |
| | G.8275.1 | |
| | G.8275.2 | Release 24.3.1 |

| Hardware Module | Supported Profile | Cisco IOS XR Release |
| --- | --- | --- |
| 86-MPA-24Z-M | G.8265.1 | Release 24.3.1 |
| | G.8273.2 Class C | Release 24.1.1 |
| | G.8275.1 | |
| | G.8275.2 | Release 24.3.1 |
| 86-MPA-4FH-M | G.8265.1 | Release 24.3.1 |
| | G.8273.2 Class C | Release 24.1.1 |
| | G.8275.1 | |
| | G.8275.2 | Release 24.3.1 |
| Cisco 8608 Router | G.8265.1 | Release 24.3.1 |
| | G.8273.2 Class C | Release 24.1.1 |
| | G.8275.1 | |
| | G.8275.2 | Release 24.3.1 |
| • 8000-RP2 Route Processor<br>• 88-LC0-36FH-M and 8800-LC-36FH line cards | G.8275.1 | Release 7.11.1 |
| | G.8273.2 Class C | |
| • 88-LC0-36FH-M line card<br>• 8202-32FH-M router | G.8273.2 Class C | Release 7.5.2 |
| | G.8275.1 | |
| • 88-LC0-36FH line card<br>• 88-LC0-34H14FH line card<br>• 8201-32FH router | G.8273.2 Class C | Release 7.3.3 |
| | G.8275.1 | |
| • 8201 router<br>• 8202 router<br>• 8800-LC-48H line card<br>• 8800-LC-36FH line card | G.8273.2 Class C | Release 7.3.1 |
| | G.8275.1 | |
| | G.8265.1 | |
| | G.8263 | |

# PTP Restrictions

The following PTP restrictions apply to the Cisco 8000 Series Router:

- Sync2 interface is supported only if 10 MHz, 1 Pulse per Second (PPS) and time-of-day (ToD) ports are configured.
- PTP isn't supported with global MACSec.
- PTP isn't supported with MACSec on the same interface.

  However, PTP is supported if MACSec isn't configured on the interface.
- PTP isn't supported with the global MACSec-FIPS-Post.

  MACSec-FIPS-Post isn't available per interface.
- Transparent Clock isn't supported. One-step clock is supported. It can receive follow-up PTP packets, that is, it can support a two-step peer primary but it can't send follow-up PTP packets.
- When a subinterface is configured with encapsulation default or untag configuration, you must configure PTP on that subinterface, instead of the main interface.
- PTP is configurable on Gigabit Ethernet interfaces (1G, 10G, 40G, and 100G), Bundle Ethernet interfaces, and subinterfaces. PTP isn't configurable on LAG Ethernet subinterfaces.
- PTP is supported over individual bundle member links and not supported on Bundle-Ether interfaces.

## PTP Best Practices

In a network that also uses Synchronous Ethernet (SyncE) for frequency synchronization, it's crucial to avoid timing loops. Timing loops can lead to network instability and erratic behavior, such as the flapping between PHASE-ALIGNED and FREQUENCY-LOCKED states. This can have a detrimental impact on the performance and reliability of the network synchronization.

- Configuring multiple redundant paths in a network can inadvertently create timing loops. This is particularly true when the paths are arranged in a ring topology.
- When a node receives synchronization from SyncE and then provides PTP synchronization back into the network, a loop is created.

Here are some best practices to avoid timing loops:

- Both PTP and SyncE should be traceable back to the same primary clock source. This ensures consistency in the synchronization of the network and prevents discrepancies between different synchronization protocols.
- Use PTP's local priority settings to align with the priority of SyncE inputs. By doing so, the network can maintain a uniform synchronization hierarchy, where the same clock source that is preferred for SyncE is also preferred for PTP.

# ITU-T Telecom Profiles for PTP

Cisco IOS XR software supports ITU-T Telecom Profiles for PTP as defined in the ITU-T recommendations. A profile is a specific selection of PTP configuration options that are selected to meet the requirements of a particular application.

PTP lets you define separate profiles to adapt itself for use in different scenarios. 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.

These are the G.8265.1 profile features:

- **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 aren't used.
- **Clock Selection**: G.8265.1 profile also defines an alternate Best Master Clock Algorithm (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 Master or Client instead of using state machines 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 the 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 4–23.
- **Port Numbers**: All PTP port numbers can only be one (1) because all clocks in this profile network are Ordinary Clocks.
- G.8261 class-specification standard is supported.

G.8265.1 profile defines an alternate algorithm to select between different master clocks based on the local priority given to each master clock and their quality levels (QL). This profile also defines Packet Timing Signal Fail (PTSF) conditions to identify the master clocks that don't qualify for selection. They are:

- **PTSF-lossSync condition**: Raised for master clocks that don't receive a reliable stream of Sync and Delay-Resp messages. Cisco IOS XR software requests Sync and Delay-Resp grants for each configured master clock to track the master clock with this condition.
- **PTSF-lossAnnounce condition**: Raised for master clocks that don't receive a reliable stream of Announce messages.

- **PTSF-unusable condition**: Raised for master clocks that receives a reliable stream of Announce, Sync, and Delay-Resp messages, but not usable by client clocks. Cisco IOS XR software doesn't use this condition.

## Configuring Global G.8265.1 Master Profile

The following configuration describes the steps involved creating a global configuration profile for a PTP interface that can then be assigned to any interface as required. It uses the G.8265.1 profile as an example:

**Step 1** Configure a G.8265.1 master profile.

```
Router# config
Router(config)# ptp
Router(config-ptp)# clock
Router(config-ptp-clock)# domain 4
Router(config-ptp-clock)# profile g.8265.1 clock-type master
Router(config-ptp-clock)# exit
```

**Step 2** Configure the specifics of the G.8265.1 master profile.

```
Router(config-ptp)# profile master
Router(config-ptp-profile)# transport ipv4
Router(config-ptp-profile)# sync frequency 32
Router(config-ptp-profile)# announce frequency 1
Router(config-ptp-profile)# delay-request frequency 32
Router(config-ptp-profile)# end
```

**Step 3** Verify the configured PTP profile details using the **show run ptp** command.

```
Router# show run ptp
Wed Feb 28 11:16:05.943 UTC
ptp
clock domain 4
profile g.8265.1 clock-type master
!
profile master
transport ipv4
sync frequency 32
announce frequency 1
delay-request frequency 32
!
```

## Configuring Global G.8265.1 Client Profile

The following configuration describes the steps involved creating a global configuration profile for a PTP interface that can then be assigned to any interface as required. It uses the G.8265.1 profile as an example:

**Step 1** Configure a global G.8265.1 client profile.

```
Router# config
Router(config)# ptp
Router(config-ptp)# clock
Router(config-ptp-clock)# domain 4
Router(config-ptp-clock)# profile g.8265.1 clock-type slave
Router(config-ptp-clock)# exit
```

**Step 2** Configure the specifics of the G.8265.1 client profile.

```
Router(config-ptp)# profile slave
Router(config-ptp-profile)# transport ipv4
Router(config-ptp-profile)# sync frequency 32
Router(config-ptp-profile)# announce frequency 1
Router(config-ptp-profile)# delay-request frequency 32
Router(config-ptp-profile)# end
```

**Step 3** Verify the configured PTP profile details using the **show run ptp** command.

```
Router# show run ptp

Wed Feb 28 11:16:05.943 UTC
ptp
clock domain 4
profile g.8265.1 clock-type slave
!
profile slave
transport ipv4
sync frequency 32
announce frequency 1
delay-request frequency 32
!
```

## Configuring the PTP Master Interface

The following configuration describes the steps involved in configuring a PTP interface to be a Master.

**Step 1** Configure the PTP interface to be a Master.

```
Router# config
Router(config)# interface HundredGigE 0/0/0/0
Router(config-if)# ipv4 address 18.1.1.1/24
Router(config-if)# ptp
Router(config-if-ptp)# profile master
Router(config-if-ptp)# port state master-only
Router(config-if-ptp)# end
```

**Step 2** Verify the port state details using the **show run interface** command.

```
Router# show run interface HundredGigE 0/0/0/0
interface HundredGigE0/0/0/0
ptp
 profile master
 port state master-only
!
```

## G.8263 Standard

G.8263 is the performance compliance standard for the clocks with the G.8265.1 profile configured. These clocks drive frequency synchronization based on the PTP packets that are received at the secondary devices from a traceable primary device. To handle excess PDV in the network, a special servo mode is enabled by configuring the **network-type high-pdv** command in the PTP configuration.

*Table 7: Feature History Table*

| Feature Name | Release Information | Feature Description |
|---|---|---|
| ITU-T G.8263 standard for client clock with ITU-T G.8265.1 profile | Release 7.3.1 | ITU-T G.8263 is a performance compliance standard for client clocks configured with ITU-T G.8265.1 profiles. These clocks drive frequency synchronization based on the PTP packets received at the secondary devices, from traceable primary devices. |

### Configuring High PDV Mode on the Client Clock

**Step 1** Configure telecom profile G.8265.1 and clock-type as client using the **profile** command.

```
Router# config
Router(config)# ptp
Router(config-ptp)# clock
Router(config-ptp-clock)# domain 4
Router(config-ptp-clock)# profile g.8265.1 clock-type slave
Router(config-ptp-clock)# commit
Router(config-ptp-clock)# exit
```

**Step 2** Configure the network type as high PDV using the **network-type high-pdv** command.

```
Router(config-ptp)# network-type high-pdv
Router(config-ptp)# end
```

**Step 3** Verify the configured PTP profile details using the **show run ptp** command.

```
ptp
 clock
  domain 4
  profile g.8265.1 clock-type slave
 !
 network-type high-pdv
 !
```

# G.8273.2

The G.8273.2 profile allows distribution of time and phase synchronization across packet-based networks. Cisco's implementation supports the enhanced Class C timing mode.

Class C mode enables highly accurate clock synchronization crucial for telecom networks with stringent timing requirements, including 5G networks. This mode significantly reduces the Maximum Absolute Time Error (Max|TE|) and improves the synchronization of Telecom Boundary Clocks (T-BC) and Telecom Time Secondary Clocks (T-TSC).

Class C timing support is available for both PTP and Frequency Synchronization, ensuring comprehensive synchronization capabilities for your network.

# 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 provides better frequency stability for the time-of-day and phase synchronization.

*Table 8: Feature History Table*

| Feature Name | Release Information | Feature Description |
|---|---|---|
| ITU-T G.8275.1 profile | Release 7.3.1 | This feature supports the architecture defined in ITU-T G.8275 for systems requiring accurate phase and time synchronization, phase or time-of-day synchronization is required, and where each network device participates in the PTP protocol. Support of this capability is extended on the Cisco 8000 Series router in this release. |

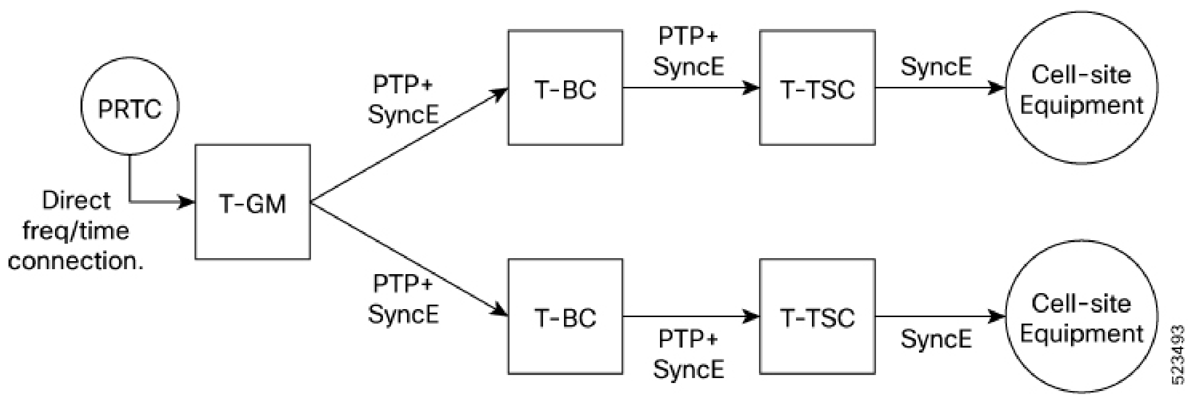
Features of the G.8275.1 profile are:

- **Synchronization Model**: G.8275.1 profile adopts a hop-by-hop synchronization model. Each network device in the path from master to client 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 master-only port state to enforce the port to be a master 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 the Ethernet PTP transport mechanism.

- **Mode**: G.8275.1 profile supports transport of data packets only in multicast mode. The forwarding is done based on a forwardable or nonforwardable multicast MAC address.
- **Clock Type**: G.8275.1 profile supports the following clock types:
  - **Telecom Grandmaster (T-GM)**: T-GM provides timing to all other devices on the network. It doesn't synchronize its local clock with any other network element other than the Primary Reference Time Clock (PRTC).
  - **Telecom Boundary Clock (T-BC)**: 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 to a T-BC to synchronize to, it may act as a grandmaster.
  - **Telecom Time Slave Clock (T-TSC)**: T-TSC synchronizes its local clock to another PTP clock (usually the T-BC), and doesn't provide synchronization through PTP to any other device.
- **Domain Numbers**: The domain numbers that can be used in a G.8275.1 profile network ranges 24–43. The default domain number is 24.

The following figure describes a sample G.8275.1 topology.

*Figure 4: A Sample G.8275.1 Topology*




## Configuring Global 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.

The following configuration describes the steps involved creating a global PTP configuration profile that can be applied at an interface level. It uses the G.8275.1 profile as an example:

**Step 1** Configure the G.8275.1 clock type.

```
Router# config
Router(config)# ptp
Router(config-ptp)# clock
Router(config-ptp-clock)# domain 24
Router(config-ptp-clock)# profile g.8275.1 clock-type T-BC
Router(config-ptp-clock)# exit
```

**Step 2** Configure the G.8275.1 client profile.

```
Router(config-ptp)# profile slave
Router(config-ptp-profile)# multicast target-address ethernet 01-1B-19-00-00-00
Router(config-ptp-profile)# transport ethernet
Router(config-ptp-profile)# sync frequency 16
Router(config-ptp-profile)# announce frequency 8
Router(config-ptp-profile)# delay-request frequency 16
Router(config-ptp-profile)# exit
```

**Step 3** Configure the G.8275.1 master profile.

```
Router(config-ptp)# profile master
Router(config-ptp-profile)# multicast target-address ethernet 01-1B-19-00-00-00
Router(config-ptp-profile)# transport ethernet
Router(config-ptp-profile)# sync frequency 16
Router(config-ptp-profile)# announce frequency 8
Router(config-ptp-profile)# delay-request frequency 16
Router(config-ptp-profile)# exit
```

**Step 4** Enable the logging of servo events.

```
Router(config-ptp)# physical-layer-frequency
Router(config-ptp)# log
Router(config-ptp-log)# servo events
Router(config-ptp-log)# end
```

**Step 5** Verify the configured PTP profile details using the **show run ptp** command.

```
Router# show run ptp
Wed Feb 28 11:16:05.943 UTC
ptp
 clock
  domain 24
  profile g.8275.1 clock-type T-BC
 !
 profile slave
  multicast target-address ethernet 01-1B-19-00-00-00
  transport ethernet
  sync frequency 16
  announce frequency 8
  delay-request frequency 16
 !
 profile master
  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
 log
  servo events
!
```

## Configuring the PTP Master Interface

This procedure describes the steps involved in configuring a PTP interface to be a Master.

**Step 1** Configure the PTP interface to be a Master.

```
Router# config
Router(config)# interface HundredGigE 0/0/0/0
Router(config-if)# ptp
Router(config-if-ptp)# profile master
Router(config-if-ptp)# port state master-only
Router(config-if-ptp)# end
```

**Step 2** Verify the port state details using the **show run interface** command.

```
Router# show run interface HundredGigE 0/0/0/0
interface HundredGigE0/0/0/0
 ptp
  profile master
  port state master-only
 !
```

## Configuring the PTP Client Interface

This procedure describes the steps involved in configuring a PTP interface to be a Client.

**Step 1** Configure the PTP interface to be a Client.

```
Router# config
Router(config)# interface HundredGigE 0/0/0/1
Router(config-if)# ptp
Router(config-if-ptp)# profile slave
Router(config-if-ptp)# port state slave-only
outer(config-if-ptp)# end
```

**Step 2** Verify the port state details using the **show run interface** command.

```
Router# show run interface HundredGigE 0/0/0/1
interface HundredGigE0/0/0/1
 ptp
  profile slave
  port state slave-only
 !
```

## Configuring PTP Hybrid Mode

This procedure describes the steps involved in configuring the router in a hybrid mode. You can configure a hybrid mode by selecting PTP for phase and time-of-day (ToD) and another source for the frequency.

**Note**

- G.8275.1 PTP profile supports only the hybrid mode. It's mandatory to have a hybrid mode for the G8275.1 profile for T-BC and T-TSC clock types. By default, the hybrid mode is used, regardless of the physical-layer-frequency configuration.

**Step 1** Configure Frequency Synchronization for an Interface. The time-of-day-priority setting specifies that SyncE to be used as a ToD source if there's no source available with a lower priority.

```
Router# config
Router(config)# frequency synchronization
Router(config)# commit
Router(config)# interface HundredGigE 0/0/0/0
Router(config-if)# frequency synchronization
Router(config-if-freqsync)# selection input
Router(config-if-freqsync)# time-of-day-priority 100
Router(config-if-freqsync)# end
```

**Step 2** Verify PTP Hybrid Mode.

```
Router# show frequency synchronization selection location 0/RP0/CP$

Tue Feb  6 06:34:17.627 UTC
Node 0/RP0/CPU0:
==============
Selection point: T0-SEL-B (3 inputs, 1 selected)
Last programmed 00:01:04 ago, and selection made 00:00:24 ago
Next selection points
SPA scoped : None
Node scoped : CHASSIS-TOD-SEL
Chassis scoped: LC_TX_SELECT
Router scoped : None
Uses frequency selection
Used for local line interface output
S Input Last Selection Point QL Pri Status
== ======================== ======================== ===== === ===========
1 HundredGigE 0/0/0/0 0/2/CPU0 ETH_RXMUX 1 ePRTC 1 Locked
PTP [0/RP0/CPU0] n/a PRS 254 Available
Internal0 [0/RP0/CPU0] n/a ST3E 255 Available

Selection point: T4-SEL (3 inputs, 1 selected)
Last programmed 00:01:04 ago, and selection made 00:00:24 ago
Next selection points
SPA scoped : None
Node scoped : None
Chassis scoped: None
Router scoped : None
Uses frequency selection
Used for local clock interface output
S Input Last Selection Point QL Pri Status
== ======================== ======================== ===== === ===========
1 HundredGigE 0/0/0/0 0/2/CPU0 ETH_RXMUX 1 ePRTC 1 Locked
PTP [0/RP0/CPU0] n/a PRS 254 Available
Internal0 [0/RP0/CPU0] n/a ST3E 255 Available

Selection point: 1588-SEL (2 inputs, 1 selected)
Last programmed 00:01:04 ago, and selection made 00:00:24 ago
Next selection points
SPA scoped : None
Node scoped : None
Chassis scoped: None
Router scoped : None
Uses frequency selection
S Input Last Selection Point QL Pri Status
== ======================== ======================== ===== === ===========
1 HundredGigE 0/0/0/0 0/2/CPU0 ETH_RXMUX 1 ePRTC 1 Locked
Internal0 [0/RP0/CPU0] n/a ST3E 255 Available
```

```
Selection point: CHASSIS-TOD-SEL (2 inputs, 1 selected)
Last programmed 00:00:53 ago, and selection made 00:00:51 ago
Next selection points
SPA scoped : None
Node scoped : None
Chassis scoped: None
Router scoped : None
Uses time-of-day selection
S Input Last Selection Point Pri Time Status
== ======================== ======================== === ==== ===========
1 PTP [0/RP0/CPU0] n/a 100 Yes Available
HundredGigE 0/0/0/0 0/RP0/CPU0 T0-SEL-B 1 100 No Available

RP/0/RP0/CPU0:SF-D#
RP/0/RP0/CPU0:SF-D#
RP/0/RP0/CPU0:SF-D#show frequency synchronization selection location 0/RP0/CP$
Thu Jan 1 00:16:56.105 UTC
Node 0/RP0/CPU0:
==============
Selection point: T0-SEL-B (3 inputs, 1 selected)
Last programmed 00:01:09 ago, and selection made 00:00:29 ago
Next selection points
SPA scoped : None
Node scoped : CHASSIS-TOD-SEL
Chassis scoped: LC_TX_SELECT
Router scoped : None
Uses frequency selection
Used for local line interface output
S Input Last Selection Point QL Pri Status
== ======================== ======================== ===== === ===========
1 HundredGigE 0/0/0/0 0/2/CPU0 ETH_RXMUX 1 ePRTC 1 Locked
PTP [0/RP0/CPU0] n/a PRS 254 Available
Internal0 [0/RP0/CPU0] n/a ST3E 255 Available

Selection point: T4-SEL (3 inputs, 1 selected)
Last programmed 00:01:09 ago, and selection made 00:00:29 ago
Next selection points
SPA scoped : None
Node scoped : None
Chassis scoped: None
Router scoped : None
Uses frequency selection
Used for local clock interface output
S Input Last Selection Point QL Pri Status
== ======================== ======================== ===== === ===========
1 HundredGigE 0/0/0/0 0/2/CPU0 ETH_RXMUX 1 ePRTC 1 Locked
PTP [0/RP0/CPU0] n/a PRS 254 Available
Internal0 [0/RP0/CPU0] n/a ST3E 255 Available

Selection point: 1588-SEL (2 inputs, 1 selected)
Last programmed 00:01:09 ago, and selection made 00:00:29 ago
Next selection points
SPA scoped : None
Node scoped : None
Chassis scoped: None
Router scoped : None
Uses frequency selection
S Input Last Selection Point QL Pri Status
== ======================== ======================== ===== === ===========
1 HundredGigE 0/0/0/0 0/2/CPU0 ETH_RXMUX 1 ePRTC 1 Locked
Internal0 [0/RP0/CPU0] n/a ST3E 255 Available

Selection point: CHASSIS-TOD-SEL (2 inputs, 1 selected)
Last programmed 00:00:57 ago, and selection made 00:00:56 ago
```

```
Next selection points
SPA scoped : None
Node scoped : None
Chassis scoped: None
Router scoped : None
Uses time-of-day selection
S Input Last Selection Point Pri Time Status
== ======================= ======================= === ==== ===========
1 PTP [0/RP0/CPU0] n/a 100 Yes Available
HundredGigE 0/0/0/0 0/RP0/CPU0 T0-SEL-B 1 100 No Available
```

# 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 the ITU-T G.8275.2 documentation 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.

## Configure G.8275.2 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.

Global configuration for the telecom profile for Server clock:

```
ptp
 clock
  domain 44
  profile g.8275.2 clock-type T-GM
 !
 profile master
  transport ipv4
  sync frequency 64
  announce frequency 8
  unicast-grant invalid-request deny
  delay-request frequency 64
 !
!

interface GigabitEthernet0/0/0/11
 ptp
  profile master
 !
```

```
 ipv4 address 11.11.11.1 255.255.255.0
!
```

Global configuration for the telecom profile for Client clock:

```
ptp
 clock
  domain 44
  profile g.8275.2 clock-type T-TSC
 !
 profile slave
  transport ipv4
  port state slave-only
  sync frequency 64
  announce frequency 8
  delay-request frequency 64
 !
 log
  servo events
  best-master-clock changes
 !
!
interface GigabitEthernet0/0/0/12
 ptp
  profile slave
  master ipv4 10.10.10.1
   !
 !
 ipv4 address 10.10.10.2 255.255.255.0
!
```

Global configuration with clock type as T-Boundary Clock (T-BC) for the telecom profile:

```
ptp
 clock
  domain 44
  profile g.8275.2 clock-type T-BC
 !
 profile slave
  transport ipv4
  port state slave-only
  sync frequency 64
  announce frequency 8
  unicast-grant invalid-request deny
  delay-request frequency 64
 !
 profile master
  transport ipv4
  sync frequency 64
  announce frequency 8
  unicast-grant invalid-request deny
  delay-request frequency 64
 !
 log
  servo events
  best-master-clock changes
 !
!


interface GigabitEthernet0/0/0/11
 ptp
  profile master
 !
```

```
 ipv4 address 10.10.10.2 255.255.255.0
!

interface GigabitEthernet0/0/0/12
 ptp
  profile slave
  master ipv4 10.10.10.1
  !
 !
 ipv4 address 10.10.10.3 255.255.255.0
!
```

### Example: Configure G.8275.2 Profile in Hybrid Mode

This procedure provides the G.8275.2 profile configuration in hybrid mode.

---

**Step 1** Configure the T-GM with GNSS as source

If GNSS is the source, perform step a. If the server clock receives front panel inputs, skip to step b.

**Example:**

**a.** Enable GNSS

```
gnss-receiver 0 location 0/RP1/CPU0
no shut
constellation auto
frequency synchronization
selection input
wait-to-restore 0
quality receive exact itu-t option 1 PRC
```

**b.** Enable GPS for phase and frequency input

```
clock-interface sync 2 location 0/RP0/CPU0
         port-parameters
         gps-input tod-format ntp4 pps-input ttl baud-rate 9600
         !
         frequency synchronization
         selection input
         priority 1
         wait-to-restore 0
         quality receive exact itu-t option 1 PRC
         !
         !
```

**c.** Configure global frequency

```
frequency synchronization
        quality itu-t option 1
        clock-interface timing-mode system
        !
```

**d.** Configure global PTP

```
ptp
          clock
          domain 44
          profile g.8275.2 clock-type T-GM
         !
         profile 8275.2
        transport ipv4
        port state any
        sync frequency 64
```

```
        announce frequency 8
        delay-request frequency 64
         !
         physical-layer-frequency
        !
```

**e.** Configure PTP and SyncE output on port for T-GM

```
interface HundredGigE0/0/0/1
    ptp
    profile 8275.2
    !
    frequency synchronization
    !
```

**Step 2** Configure G.8275.2 on T-BC

**Example:**

**a.** Configure global SyncE

```
frequency synchronization
     quality itu-t option 1
     clock-interface timing-mode system
     !
```

**b.** Configure global PTP

```
ptp
clock
domain 44
profile g.8275.2 clock-type T-BC
!
profile 8275.2
  transport ipv4
  port state any
  sync frequency 64
  announce frequency 8
  delay-request frequency 64
!
physical-layer-frequency  <-- This is a mandatory command -->
!
```

**c.** Configure client port on Hybrid BC

```
interface HundredGigE0/0/0/0
ptp
profile 8275.2
!
frequency synchronization
selection input
priority 1
wait-to-restore 0
!
!
```

**d.** Configure server port on Hybrid BC

```
interface HundredGigE0/0/0/1
ptp
profile 8275.2
!
frequency synchronization
!
!
```

**Step 3** Configure G8275.2 on T-TSC

**Example:**

**a.** Configure global SyncE

```
frequency synchronization
     quality itu-t option 1
     clock-interface timing-mode system
     !
```

**b.** Configure global PTP

```
ptp
clock
domain 44
profile g.8275.2 clock-type T-TSC
!
profile 8275.2
  transport ipv4
  port state any
  sync frequency 64
  announce frequency 8
  delay-request frequency 64
!
physical-layer-frequency  <-- This is a mandatory command -->
!
```

**c.** Configure client port on Hybrid BC

```
interface HundredGigE0/0/0/0
ptp
profile 8275.2
!
frequency synchronization
selection input
priority 1
wait-to-restore 0
!
!
```

### Example: Configure G.8275.2 Profile in Non-Hybrid Mode

This procedure provides the G.8275.2 profile configuration in non-hybrid mode.

**Step 1** Configure the T-GM with GNSS as source

If GNSS is the source, perform step a. If the server clock receives front panel inputs, skip to step b.

**Example:**

**a.** Enable GNSS

```
gnss-receiver 0 location 0/RP1/CPU0
frequency synchronization
selection input
wait-to-restore 0
quality receive exact itu-t option 1 PRC
```

**b.** Enable GPS for phase and frequency input

```
clock-interface sync 2 location 0/RP0/CPU0
         port-parameters
         gps-input tod-format ntp4 pps-input ttl baud-rate 9600
         !

         selection input
         priority 1
         wait-to-restore 0
         quality receive exact itu-t option 1 PRC
         !
         !
```

**c.** Configure global PTP

```
ptp
          clock
          domain 44
          profile g.8275.2 clock-type T-GM
         !
         profile 8275.2
        transport ipv4
        port state any
        sync frequency 64
        announce frequency 8
        delay-request frequency 64
         !
        !
```

**d.** Configure PTP and SyncE output on port for T-GM

```
interface HundredGigE0/0/0/1
    ptp
    profile 8275.2
    !
    !
```

**Step 2** Configure G.8275.2 on T-BC

**Example:**

**a.** Configure global PTP

```
ptp
clock
domain 44
profile g.8275.2 clock-type T-BC
!
profile 8275.2
  transport ipv4
  port state any
  sync frequency 64
  announce frequency 8
  delay-request frequency 64
!
```

**b.** Configure client port on Hybrid BC

```
interface HundredGigE0/0/0/0
ptp
profile 8275.2
!
selection input
priority 1
wait-to-restore 0
```

```
!
!
```

c. Configure server port on Hybrid BC

```
interface HundredGigE0/0/0/1
ptp
profile 8275.2
!
!
```

**Step 3** Configure G8275.2 on T-TSC

**Example:**

a. Configure global PTP

```
ptp
clock
domain 44
profile g.8275.2 clock-type T-TSC
!
profile 8275.2
  transport ipv4
  port state any
  sync frequency 64
  announce frequency 8
  delay-request frequency 64
!
```

b. Configure client port on Hybrid BC

```
interface HundredGigE0/0/0/0
ptp
profile 8275.2
!
selection input
priority 1
wait-to-restore 0
!
!
```

# PTP Delay Asymmetry

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.

*Table 9: Feature History Table*

| Feature Name | Release Information | Description |
|---|---|---|
| PTP Delay Asymmetry | Release 7.3.2 | 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.<br>The **delay-symmetry** command is introduced for this feature. |

**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)

# PTP Delay Asymmetry 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.

# Configuring PTP Delay Asymmetry

**Step 1** Configure PTP delay asymmetry on the client side.

```
Router# configure
Router(config)# interface HundredGigE 0/1/0/0
Router(config-if)# ptp
Router(config-if-ptp)# delay-asymmetry 3 microseconds
Router(config-if-ptp)# end
```

**Step 2** 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
```

**Step 3** 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
```

CHAPTER 6

# Network Time Protocol (NTP)



## NTP Overview

NTP synchronizes timekeeping among a set of distributed time servers and clients. This synchronization allows events to be correlated when system logs are created and other time-specific events occur.

NTP uses the User Datagram Protocol (UDP) as its transport protocol. All NTP communication uses Coordinated Universal Time (UTC). An NTP network usually receives its time from an authoritative time source, such as a radio clock or an atomic clock attached to a time server. NTP distributes this time across the network. NTP is efficient; no more than one packet per minute is necessary to synchronize the two machines to within a millisecond of each other.

NTP uses the concept of a “stratum” to describe how many NTP “hops” away a machine is from an authoritative time source. A “stratum 1” time server typically has an authoritative time source (such as a radio or atomic clock, or a GPS time source) directly attached, a “stratum 2” time server receives its time via NTP from a “stratum 1” time server, and so on.

NTP avoids synchronizing to a machine whose time may not be accurate, in two ways. First, NTP never synchronizes to a machine that isn’t synchronized itself. Second, NTP compares the time reported by several machines and doesn’t synchronize to a machine whose time is significantly different than the others, even if its stratum is lower. This strategy effectively builds a self-organizing tree of NTP servers.

The Cisco implementation of NTP doesn’t support stratum 1 service; in other words, it’s not possible to connect to a radio or atomic clock (for some specific platforms, however, you can connect a GPS time-source device). We recommend that time service for your network be derived from the public NTP servers available in the IP Internet.

If the network is isolated from the Internet, the Cisco implementation of NTP allows a machine to be configured so that it acts as though it’s synchronized via NTP, when in fact it has determined the time using other means. Other machines can then synchronize to that machine via NTP.

Several manufacturers include NTP software for their host systems, and a publicly available version for systems running UNIX and its various derivatives is also available. This software also allows UNIX-derivative servers to acquire the time directly from an atomic clock, which would then propagate time information along to Cisco routers.

The communications between machines running NTP (known as *associations*) are statically configured; each machine is given the IP address of all machines with which it should form associations. Accurate timekeeping is made possible by exchanging NTP messages between each pair of machines with an association.

The Cisco implementation of NTP supports two ways that a networking device can obtain NTP time information on a network:

- By polling host servers
- By listening to NTP broadcasts

In a LAN environment, NTP can be configured to use IP broadcast messages. As compared to polling, IP broadcast messages reduce configuration complexity, because each machine can simply be configured to send or receive broadcast or multicast messages. However, the accuracy of timekeeping is marginally reduced because the information flow is one-way only.

An NTP broadcast client listens for broadcast messages sent by an NTP broadcast server at a designated IPv4 address. The client synchronizes the local clock using the first received broadcast message.

The time kept on a machine is a critical resource, so we strongly recommend that you use the security features of NTP to avoid the accidental or malicious setting of incorrect time. Two mechanisms are available: an access list-based restriction scheme and an encrypted authentication mechanism.

When multiple sources of time (VINES, hardware clock, manual configuration) are available, NTP is always considered to be more authoritative. NTP time overrides the time set by any other method.

# Preventing Issues due to GPS Week Number Rollover (WNRO)

- If there are no GPS sources in the NTP source chain or server chain, there's no impact of GPS Week Number Rollover (WNRO).
- GPS WNRO affects only the system clock and not user traffic.
- Contact your GPS manufacturer to fix the GPS source for this condition.

To mitigate the impact of GPS sources that are subject to GPS WNRO perform the following optional workarounds:

- If the GPS source has been identified to be a cause of potential disruption on April 6, 2019 (or after), configure ntp master in the Cisco that is device connected to this source, and its clock on the Stratum 1 device to isolate it. This configuration enables the device to present its own clock for synchronization to downstream NTP clients.

**Note** The usage of ntp master command as mentioned above is only a workaround to this condition. Use this command until the GPS source-related conditions are resolved, and to prevent the distribution of incorrect clock values throughout the network.

- Configure multiple NTP servers (ideally 4, but more than 3) at the Stratum 2 level of the network, to enable NTP clients at Stratum 2 level to get clock from more than one Stratum 1 server. This way, WNRO affected Stratum 1 servers are staged to be marked as 'false ticker' or 'outlier' clock sources as compared to other non-WNRO affected Stratum 1 servers.

# Configure NTP

## Choose the Method to Obtain NTP Time Information

### Configuring Poll-Based Associations

**Note** No specific command enables NTP; the first NTP configuration command that you issue enables NTP.

You can configure the following types of poll-based associations between the router and other devices (which may also be routers):

- Client mode
- Symmetric active mode

The client and the symmetric active modes should be used when NTP is required to provide a high level of time accuracy and reliability.

When a networking device is operating in the client mode, it polls its assigned time serving hosts for the current time. The networking device then picks a host from all the polled time servers to synchronize with. Because the relationship that is established in this case is a client-host relationship, the host doesn't capture or use any time information sent by the local client device. This mode is most suited for file-server and workstation clients that aren't required to provide any form of time synchronization to other local clients. Use the **server** command to individually specify the time-serving hosts that you want your networking device to consider synchronizing with and to set your networking device to operate in the client mode.

When a networking device is operating in the symmetric active mode, it polls its assigned time-serving hosts for the current time and it responds to polls by its hosts. Because this is a peer-to-peer relationship, the host also retains time-related information about the local networking device that it's communicating with. This mode should be used when there are several mutually redundant servers that are interconnected via diverse network paths. Most stratum 1 and stratum 2 servers on the Internet today adopt this form of network setup. Use the **peer** command to individually specify the time-serving hosts that you want your networking device to consider synchronizing with and to set your networking device to operate in the symmetric active mode.

When the router polls several other devices for the time, the router selects one device with which to synchronize.

**Note** To configure a peer-to-peer association between the router and another device, you must also configure the router as a peer on the other device.

You can configure multiple peers and servers, but you can't configure a single IP address as both a peer and a server at the same time.

To change the configuration of a specific IP address from peer to server or from server to peer, use the **no** form of the **peer** or **server** command to remove the current configuration before you perform the new configuration. If you don't remove the old configuration before performing the new configuration, the new configuration doesn't overwrite the old configuration.

**Step 1** Form a server association with another system.

```
Router# configure
Router(config)# ntp
Router(config-ntp)# server 172.19.69.1 minpoll 8 maxpoll 12
```

This step can be repeated as necessary to form associations with multiple devices.

**Step 2** Form a peer association with another system.

```
Router(config-ntp)# peer 192.168.22.33 minpoll 8 maxpoll 12
source hundredGigE 0/0/0/1
Router(config-ntp)# end
```

This step can be repeated as necessary to form associations with multiple systems.

**Note** To complete the configuration of a peer-to-peer association between the router and the remote device, the router must also be configured as a peer on the remote device.

**Step 3** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 server 172.19.69.1 minpoll 8 maxpoll 12
 peer 192.168.22.33 minpoll 8 maxpoll 12 source HundredGigE0/0/0/1
!
```

## Configuring Broadcast-Based NTP Associations

In a broadcast-based NTP association, an NTP server propagates NTP broadcast packets throughout a network. Broadcast clients listen for the NTP broadcast packets propagated by the NTP server and don’t engage in any polling.

Broadcast-based NTP associations should be used when time accuracy and reliability requirements are modest and if your network is localized and has many clients (more than 20). Broadcast-based NTP associations are also recommended for use on networks that have limited bandwidth, system memory, or CPU resources. Time accuracy is marginally reduced in broadcast-based NTP associations because information flows only one way.

Use the **broadcast client** command to set your networking device to listen for NTP broadcast packets propagated through a network. For broadcast client mode to work, the broadcast server and its clients must be located on the same subnet. The time server that is transmitting NTP broadcast packets must be enabled on the interface of the given device using the **broadcast** command.

Use the **broadcast** command to set your networking device to send NTP broadcast packets.

**Note** No specific command enables NTP; the first NTP configuration command that you issue enables NTP.

**Step 1** Configure the specified interface to receive NTP broadcast packets.

```
Router# configure
Router(config)# ntp
Router(config-ntp)# broadcastdelay 2
```

```
Router(config-ntp)# interface HundredGigE 0/2/0/0
Router(config-ntp-int)# broadcast client
```

**Note** Go to the next step to configure the interface to send NTP broadcast packets.

**Step 2** Configure the specified interface to send NTP broadcast packets.

```
Router(config-ntp-int)# broadcast destination 10.50.32.149
Router(config-ntp-int)# end
```

**Note** Go to the previous step to configure the interface to receive NTP broadcast packets.

**Step 3** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 interface HundredGigE0/2/0/0
  broadcast client
  broadcast destination 10.50.32.149
 !
 broadcastdelay 2
!
```

# Configuring NTP Access Groups

**Note** No specific command enables NTP; the first NTP configuration command that you issue enables NTP.

The access list-based restriction scheme allows you to grant or deny certain access privileges to an entire network, a subnet within a network, or a host within a subnet.

The access group options are scanned in the following order, from least restrictive to most restrictive:

1. **peer**—Allows time requests and NTP control queries and allows the system to synchronize itself to a system whose address passes the access list criteria.
2. **serve**—Allows time requests and NTP control queries, but doesn't allow the system to synchronize itself to a system whose address passes the access list criteria.
3. **serve-only**—Allows only time requests from a system whose address passes the access list criteria.
4. **query-only**—Allows only NTP control queries from a system whose address passes the access list criteria.

If the source IP address matches the access lists for more than one access type, the first type is granted. If no access groups are specified, all access types are granted to all systems. If any access groups are specified, only the specified access types are granted.

For details on NTP control queries, see RFC 1305 (NTP version 3).

**Step 1** Create an access group and apply a basic IPv4 or IPv6 access list to it.

```
Router# configure
Router(config)# ntp
```

```
Router(config-ntp)# access-group peer peer-acl
Router(config-ntp)# end
```

**Step 2** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 access-group ipv4 peer peer-acl
 broadcastdelay 2
!
```

# Configuring NTP Authentication

This task explains how to configure NTP authentication.

The encrypted NTP authentication scheme should be used when a reliable form of access control is required. Unlike the access-list-based restriction scheme that is based on IP addresses, the encrypted authentication scheme uses authentication keys and an authentication process to determine if NTP synchronization packets sent by designated peers or servers on a local network are deemed as trusted, before the time information that it carries along is accepted.

The authentication process begins from the moment that an NTP packet is created. A message authentication code (MAC) is computed using the MD5 Message Digest Algorithm and the MAC is embedded into an NTP synchronization packet. The NTP synchronization packet together with the embedded MAC and key number are transmitted to the receiving client. If authentication is enabled and the key is trusted, the receiving client computes the MAC in the same way. If the computed MAC matches the embedded MAC, the system is allowed to sync to the server that uses this key in its packets.

After NTP authentication is properly configured, your networking device only synchronizes with and provides synchronization to trusted time sources.

**Step 1** Define the authentication keys.

```
Router# configure
Router(config)# ntp
Router(config-ntp)# authenticate
Router(config-ntp)# authentication-key 3 md5 clear key1
```

Each key has a key number, a type, a value, and, optionally, a name. Currently the only key type supported is **md5**.

**Step 2** Define trusted authentication keys.

```
Router(config-ntp)# trusted-key 3
Router(config-ntp)# commit
```

If a key is trusted, this router only synchronizes to a system that uses this key in its NTP packets.

**Step 3** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 authentication-key 3 md5 encrypted 020D01425A
 authenticate
```

```
 trusted-key 3
 !
```

# Configuring the Source IP Address for NTP Packets

By default, the source IP address of an NTP packet sent by the router is the address of the interface through which the NTP packet is sent. Use this procedure to set a different source address.

**Step 1** Configure an interface from which the IP source address.

```
Router# configure
Router(config)# ntp
Router(config-ntp)# source HundredGigE 0/0/0/1
Router(config-ntp)# end
```

**Note** This interface is used for the source address for all packets sent to all destinations. If a source address is to be used for a specific association, use the **source** keyword in the **peer** or **server** command shown in Configuring Poll-Based Associations, on page 59.

**Step 2** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 authentication-key 3 md5 encrypted 020D01425A
 authenticate
 trusted-key 3
 source HundredGigE0/0/0/1
!
```

# Configuring the System as an Authoritative NTP Server

You can configure the router to act as an authoritative NTP server, even if the system isn't synchronized to an outside time source.

**Step 1** Make the router an authoritative NTP server.

```
Router# configure
Router(config)# ntp
Router(config-ntp)# master 9
Router(config-ntp)# end
```

**Note** Use the **master** command with caution. It's easy to override valid time sources using this command, especially if a low stratum number is configured. Configuring multiple machines in the same network with the **master** command can cause instability in time keeping if the machines don't agree on the time.

**Step 2** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 master 9
```

# Updating the Hardware Clock

On devices that have hardware clocks (system calendars), you can configure the hardware clock to be periodically updated from the software clock. This is advisable for devices using NTP, because the time and date on the software clock (set using NTP) is more accurate than the hardware clock. The time setting on the hardware clock has the potential to drift slightly over time.

**Step 1** Configure the router to update its system calendar from the software clock at periodic intervals.

```
Router# configure
Router(config)# ntp
Router(config-ntp)# update-calendar
Router(config-ntp)# end
```

**Step 2** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 update-calendar
```

# Verifying the Status of the External Reference Clock

This task explains how to verify the status of NTP components.

**Note** The commands can be entered in any order.

**Step 1** Display the status of NTP associations.

```
Router# show ntp associations
address         ref clock     st  when  poll reach  delay  offset    disp
 ~172.19.69.1      .AUTH.           16     -  1024    0    0.00   0.000   15937
 ~192.168.22.33    .AUTH.           16     -  1024    0    0.00   0.000   15937
*~127.127.1.1      .LOCL.            9    51    64   37    0.00   0.000  438.28
 * sys_peer, # selected, + candidate, - outlayer, x falseticker, ~ configured
```

**Step 2** Display the status of NTP.

```
Router# show ntp status
Clock is synchronized, stratum 10, reference is 127.127.1.1
nominal freq is 1000000000.0000 Hz, actual freq is 1000000000.0000 Hz, precision is 2**24
reference time is E8CE945C.8E2A8B07 (15:01:48.555 UTC Mon Oct  9)
clock offset is 0.000 msec, root delay is 0.000 msec
root dispersion is 63.52 msec, peer dispersion is 63.40 msec
loopfilter state is 'FREQ' (Drift being measured), drift is 0.0000000000 s/s
system poll interval is 64, last update was 9 sec ago
```

```
authenticate is enabled, panic handling is disabled,
hostname resolution retry interval is 1440 minutes.
```

# Disabling NTP Services on a Specific Interface

NTP services are disabled on all interfaces by default.

NTP is enabled globally when any NTP commands are entered. You can selectively prevent NTP packets from being received through a specific interface by turning off NTP on a given interface.

**Step 1** Disable NTP services on the specified interface using one of the following commands:

- **interface**
- **no interface**

```
Router# configure
Router(config)# ntp
Router(config-ntp)# interface HundredGigE 0/0/0/1 disable
Router(config-ntp)# end
```

or

```
Router# configure
Router(config)# ntp
Router(config-ntp)# no interface HundredGigE 0/0/0/1
Router(config-ntp)# end
```

**Step 2** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 interface HundredGigE0/0/0/1
  disable
 !
```

# FQDN for NTP Server

NTP on Cisco IOS XR Software supports configuration of servers and peers using their Fully Qualified Domain Names (FQDN). While configuring, the FQDN is resolved via DNS into its corresponding IPv4 or IPv6 address and is stored in the running-configuration of the system. NTP supports FQDN for both IPv4 and IPv6 protocols. You can configure FQDN on default VRF.

Starting Cisco IOS XR Software Release 7.9.1 you can configure FQDN in nondefault VRF also.

*Table 10: Feature History Table*

| Feature Name | Release Information | Feature Description |
|---|---|---|
| FQDN for NTP Server on Nondefault VRF | Release 7.9.1 | You can now specify a Fully Qualified Domain Name (FQDN) as the hostname for NTP server configuration over nondefault VRFs.<br>FQDNs are easy to remember compared to numeric IP addresses. Service migration from one host to another can cause a change in IP address leading to outages.<br>Prior releases allowed FQDN handling in only default VRFs. |

# Configure FQDN for NTP server

## Configuring FQDN on NTP Server on Default VRF

**Step 1** Use the **ntp server** command with the FQDN name to configure FQDN on default VRF. You don't need to specify the VRF name.

In the following example, *time.cisco.com* is the FQDN.

```
Router# configure
Router(config)# ntp server time.cisco.com
Router(config)# commit
```

**Step 2** Verify the configured NTP profile details.

```
Router# show running-config ntp
ntp
 server 192.0.2.1
!
```

**Step 3** Verify that an NTP association has come up using the **show ntp associations** command.

```
Router# show ntp associations

      address       ref clock     st  when  poll reach  delay  offset    disp
 ~192.0.2.1       173.38.201.67    2    42   128    3  196.06  -14.25  3949.4
 * sys_peer, # selected, + candidate, - outlayer, x falseticker, ~ configured
```

## Configuring FQDN on NTP Server on Nondefault VRF

### Before you begin

- Configuration must exist for DNS resolution over that specific VRF.

- The server must be reachable.

**Step 1** FQDN must be reachable from the router to configure it as an NTP server or peer. You can use the **ping** command and verify that FQDN is reachable.

In the following example, *time.cisco.com* is the FQDN and *vrf_1* is the VRF over which it's reachable.

```
Router# ping time.cisco.com vrf vrf_1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.0.2.1 timeout is 2 seconds:
```

**Step 2** When you have confirmed that FQDN is reachable, you can configure FQDN to be used as an NTP server/peer.

```
Router# configure
Router(config)# ntp server vrf vrf_1 time.cisco.com minpoll 4 maxpoll 4 iburst
Router(config)# commit
```

**Note** If the FQDN you're trying to configure isn't reachable, the CLI treats it as invalid input.

**Step 3** Verify the configured NTP profile details.

```
Router# show running-config ntp
 ntp
  server vrf vrf_1 192.0.2.1 minpoll 4 maxpoll 4 iburst
 !
```

**Step 4** Verify that an NTP association has come up using the **show ntp associations** command.

```
Router# show ntp associations
 address         ref clock     st  when  poll reach  delay  offset    disp
~192.0.2.1 vrf vrf_1
                173.38.201.115  2    14    16   37  179.10  13.492  16.680
* sys_peer, # selected, + candidate, - outlayer, x falseticker, ~ configured
```

# NTP-PTP Interworking

Starting Cisco IOS XR Software Release 7.11.1, NTP-PTP interworking provides the ability to use Precision Time Protocol (PTP), and other valid time of day (TOD) sources such as Data over Cable Service Interface Specification (DOCSIS) Timing Interface (DTI) and Global Positioning System (GPS), as the time source for the operating system in the units of nanosec level accuracy. PTP is capable of achieving nanosecond-level accuracy, while NTP is typically only accurate to within milliseconds. By using PTP as a reference clock, NTP can improve its accuracy and meet the needs of applications that require high precision timing.

Before the support of NTP-PTP interworking, only backplane time was supported for the operating system time of the router.

*Table 11: Feature History Table*

| Feature Name | Release Information | Feature Description |
|---|---|---|
| NTP-PTP Interworking | Release 7.11.1 | We have improved NTP synchronization and reliability to achieve nanosecond-level accuracy for applications that require high-precision timing. This is achieved by enabling NTP-PTP interworking which allows the use of PTP as the reference clock.<br><br>As in previous releases, the NTP client continues to support polling NTP protocol-based external time servers to synchronize the local system clock and achieve accuracy within the millisecond range. |

NTP-PTP interworking also provides the means to communicate status changes between PTP and NTP processes. It also supports the unambiguous control of the operating system time and backplane time in the event of bootup, switchovers, or card and process failures.

With NTP-PTP interworking, NTP is less likely to lose synchronization. As, PTP is more robust to network delays and disruptions than NTP. So, if there's a problem with the network, PTP can still maintain accurate synchronization.

# Configuring NTP-PTP Interworking

**Before you begin**

- Ensure that PTP is enabled, before configuring NTP-PTP Interworking.
- For PTP, the Grandmaster (GM) gets the clock from a GPS/GNSS reference clock:
  - If the PTP-NTP feature is enabled on a GM node, verify that the GM gets clock reference from the FPS/GNSS clock reference and then configure the CLI on the GM node.
  - If the PTP-NTP feature is enabled on a Boundary Clock (BC) node, ensure that the GM gets clock reference from the FPS/GNSS clock reference and then configure the CLI on the BC node.
  - If the PTP-NTP feature is enabled on a Transparent Clock (TC) node, ensure that the GM gets the clock reference from the FPS/GNSS clock reference, and the BC node gets the clock from that GM node, the TC node gets the clock from the BC node, and then configure the CLI on the TC node.
- If the GM isn't connected to any GPS/GNSS reference clock, the default PTP clock is set to Jan 1, 1970.

---

**Step 1** You can configure NTP-PTP Interworking in any of the following ways:

- Setting NTP Primary Reference Clock as PTP

```
Router# configure
Router(config)# ntp
Router(config-ntp)# master primary-reference-clock
Router(config-ntp)# commit
```

- Configuring NTP Server with IP address

  The following example shows an NTP configuration to allow the system clock to be synchronized by time server hosts at IP address 198.51.100.1. You can take the IP address of a neighboring PTP interface.

```
Router# configure
Router(config)# ntp server 198.51.100.1
Router(config-ntp)# commit
```

**Step 2** Verify the NTP status using the **show ntp status** command.

```
Router# show ntp status

Clock is synchronized, stratum 1, reference is 198.51.100.1
nominal freq is 1000000000.0000 Hz, actual freq is 101341889.2967 Hz, precision is 2**24
reference time is 8497CD13.A6AEB9DA (00:02:27.651 UTC Tue Jun 30 1970)
clock offset is -0.077 msec, root delay is 0.000 msec
root dispersion is 3937.89 msec, peer dispersion is 3937.74 msec
loopfilter state is 'CTRL' (Normal Controlled Loop), drift is 0.0000088676 s/s
system poll interval is 64, last update was 4 sec ago
authenticate is disabled, panic handling is disabled,
hostname resolution retry interval is 1440 minutes
```

**Step 3** Verify that an NTP association has come up using the **show ntp associations** command.

```
Router# Show ntp associations
  address         ref clock     st  when  poll reach  delay  offset    disp
*~198.51.100.1    .PTP.          0     -    64    0   0.00   0.000   16000
```

CHAPTER 7

# Global Navigation Satellite System (GNSS)

Global Navigation Satellite System (GNSS) is a satellite system which is used as a timing interface. GNSS receiver receives signals from GNSS satellites and decodes the information from multiple satellites to determine its distance from each satellite. Based on this data, the GNSS receiver identifies the location of each satellite.

The chassis uses a satellite receiver, also called the global navigation satellite system (GNSS), as a new timing interface.

In typical telecom networks, synchronization works in a hierarchal manner where the core network is connected to a stratum-1 clock. The stratum-1 clock is then distributed along the network in a tree-like structure. However, with a GNSS receiver, clocking is changed to a flat architecture, where access networks can directly take clock from satellites in sky by using an onboard GPS chip.

To optimize the GNSS system, it requires all the systems to share a common time scale and coordinated system. If all the systems do not have a common time, the receiver sees a time offset and selects only one constellation having common time scale. More satellites should be added to increase the coverage of the constellation itself.

This capability simplifies network synchronization planning, provides flexibility, and resilience in resolving network synchronization issues in the hierarchical network.

Cisco IOS XR routers now support onboard GNSS receiver to recover time.



# Overview of GNSS Modules and Operations

The GNSS module is present on the front panel of the Route Processor (RP) module and can be ordered separately with PID=. However, there is no license required to enable the GNSS module.

The GNSS LED on the front panel of the RP indicates the status of the module. This table provides the different LED statuses.

| LED Status | Description |
| --- | --- |
| Green | GNSS NormalState.Selfsurvey is complete. |

| LED Status | Description |
|---|---|
| Amber | All other states |

When connected to an external antenna, the module can acquire satellite signals and track up to 32 GNSS satellites, and compute location, speed, heading, and time. GNSS provides an accurate one pulse-per-second (PPS), a stable 10 MHz frequency output to synchronize broadband wireless, aggregation and pre-aggregation routers, and an accurate time-of-day (ToD).

**Note** We do not recommend that you configure both the front panel (10M, 1PPS and ToD) input configuration and the GNSS input configuration.

By default, anti-jamming is enabled on the GNSS module.

A GNSS module operates in one of these modes. Both modes acquire and provide timing signals to Cisco 8000 routers:

- **Self-survey mode** - When the router is reset, the GNSS module comes up in self-survey mode. It tries to lock on to a minimum of four different satellites and computes approximately 2000 different positions of the satellites to obtain a 3-D location (Latitude, Longitude, and Height) of its current position. This operation takes about 35 to 40 minutes. During this stage also, the module is able to generate accurate timing signals and achieve a Normal or Phase-locked state.
- **Over-determined clock mode** - The router switches to an over-determined (OD) mode when the self-survey mode is complete and the position information is stored in the non-volatile memory on the router. In this mode, the module only processes the timing information based on satellite positions captured in self-survey mode.

The router saves the tracking data. This tracking data is retained even after the router reload. If you want to change the tracking data, use the **no shutdown** command to set the GNSS interface to its default value.

The GNSS module stays in the OD mode until one of the following conditions occur:

- When the position relocation of the antenna of more than 100 meters is detected. This detection causes an automatic restart of the self-survey mode.
- When the self-survey mode is restarted manually.
- When the stored reference position is deleted.
- When a worst-case recovery scenario is considered after a jamming-detection condition that cannot be resolved with other methods.

You can configure the GNSS module to automatically track any satellite or explicitly use a specific constellation. However, the module uses configured satellites only in the OD mode.

**Note** GLONASS and BeiDou satellites cannot be enabled simultaneously.

When the router is reloaded, it always comes up in the OD mode unless:

- The router is reloaded when the self-survey mode is in progress.

- The physical location of the router is changed to more than 100 m from its pre-reloaded condition.

When the system restarts GNSS self-survey by using the default **gnss slot R0/R1** command in configuration mode, the 10MHz, 1PPS, and ToD signals are not changed and remain in the up state.

# Prerequisites

- 1PPS, 10 MHz, and ToD must be configured for netsync and PTP.
- The antenna must have a clear view of the sky. For accurate timing, a minimum of four satellites should be locked.

# Restrictions

- The GNSS module is not supported through SNMP; all configurations are performed through commands.
- The GNSS holdover performance is one microsecond in two hours of holdover after twelve hours of GNSS lock time.

# PRTC Mode with GNSS

A Cisco 8000 router can act in Primary Reference Time Clock (PRTC) mode, when GNSS is locked and no telecom profiles are configured. In PRTC mode, the router provides ToD + 1PPS output with ToD in UBX format.

Once the router is in PRTC mode, ordinary clock and transparent clocks are not supported under LAN profiles. All boundary clocks under LAN profiles will be in GMC-BC mode, which fetches timestamps and grandmaster clock details as per the GNSS input.

The GMS-BC master clock provides these clock quality values.

```
Clock Quality:
    Class: 6                        //----GNSS CLASS
    Accuracy: Within 250ns          //----GNSS Accuracy
    Offset (log variance): 20061    //----GNSS Variance
```

PRTC mode is supported on PTP Default and Power profile. The conversion takes place automatically when GNSS moves to locked state.

**Note** GNSS cannot be configured when the one of the following is configured:

- 802.1AS
- PTP TC mode
- GMC-BC options

# Class Support Matrix

This table provides information about the GNSS class supported on the Cisco 8000 series routers and line cards.

*Table 12: GNSS Class Support Matrix*

| Hardware Module | Supported GNSS Class | Cisco IOS XR Release |
|---|---|---|
| 8711-32FH-M router | PRTC-B | Release 24.3.1 |

# Configure GNSS

You can configure any of the these constellation options for a router:

- GPS
- Galileo
- GLONASS
- BeiDou
- QZSS

Based on your configuration, the output displays the status of the GNSS receiver on the router models.

This section describes how you can configure GNSS for a router.

```
/* Enable the GNSS receiver and enter the gnss-receiver submode */

Router(config)# gnss-receiver 0 location 0/0/CPU0
Router(config-gnss)# frequency synchronization
Router(config-gnss-freqsync)# selection input
```

### Optional Configuration

This is an optional configuration for GNSS.

```
Router(config)# gnss-receiver 0 location 0/0/CPU0
Router(config-gnss)# anti-jam disable
Router(config-gnss)# constellation GPS
Router(config-gnss)# snr threshold 10
Router(config-gnss)# frequency synchronization
Router(config-gnss-freqsync)# selection input
Router(config-gnss-freqsync)# priority 5
Router(config-gnss-freqsync)# wait-to-restore 0
```

### Running Configuration

This example provides the running configuration for GNSS.

```
gnss-receiver 0 location 0/RP0/CPU0
frequency synchronization
  selection input
  priority 1
```

```
  wait-to-restore 0
  quality receive exact itu-t option 1 PRC
 !
!
```

### Verification

These examples provide **show gnss-receiver** command output on the router models.

**Example: 1**

```
Router# show gnss-receiver
GNSS-receiver 0 location 0/RP0/CPU0
    Status: Available, Up
    Position: 741:12.12 N 4451:39.60 E 0.827km
    Time: 2019:01:17 14:43:08 (UTC offset: 18s)
    Firmware version: 1.4
    Lock Status: Phase Locked, Receiver Mode: 3D-fix
    Survey Progress: 100, Holdover Duration: 0
    Major Alarm: Not used
    Minor Alarm: Not used
    Anti-jam: Enabled, Cable-delay compensation: 0
    1PPS polarity: Positive
    PDOP: 6.000, HDOP: 0.000, VDOP: 0.000, TDOP: 1.000
    Constellation: GPS, Satellite Count: 10
```

**Example: 2**

```
Router# show gnss-receiver
Fri Jan 17 07:27:34.804 UTC
GNSS-receiver 0 location 0/RP0/CPU0
    Status: Available, Up
    Position: 12:56.18 N 77:41.77 E 0.823km
    Time: 2020:01:17 07:31:41 (UTC offset: 0s)
    Locked at: 2020:01:15 17:15:28
    Firmware version: TIM 1.10
    Lock Status: Phase Locked, Receiver Mode: Time fix only
    Survey Progress: 100, Holdover Duration: Unknown
    Major Alarms: Unknown
    Minor Alarms: Unknown
    Anti-jam: Enabled, Cable-delay compensation: 0
    1PPS polarity: Positive
    PDOP: 99.990, HDOP: 99.990, VDOP: 99.990, TDOP: 0.240
    Constellation: GPS, Satellite Count: 17
    Satellite Thresholds:
        SNR - 0 dB-Hz, Elevation - 0 degrees, PDOP - 0, TRAIM - 0 us
    Satellite Info:
        CHN: Channel, AQUN: Aquisition, EPH: Ephemeris
        PRN   CHN   AQUN   EPH    SV            Signal
        No.   No.   Flag   Flag   Type          Strength   Elevat'n   Azimuth
        ---   ---   ----   ----   -----------   --------   --------   --------
          1   n/a   On     On     GPS             44.000     19.000    220.000
          3   n/a   On     On     GPS             48.000     62.000    299.000
          4   n/a   On     On     GPS             46.000     30.000    338.000
          7   n/a   On     On     GPS             47.000      9.000    261.000
          8   n/a   On     On     GPS             41.000     17.000    172.000
          9   n/a   On     On     GPS             44.000      7.000    317.000
         11   n/a   On     On     GPS             42.000     10.000    202.000
         14   n/a   On     On     GPS             42.000     22.000     90.000
         16   n/a   On     On     GPS             46.000     66.000     59.000
         22   n/a   On     On     GPS             47.000     71.000    238.000
         23   n/a   On     On     GPS             46.000     27.000    332.000
         26   n/a   On     On     GPS             48.000     40.000     40.000
```

CHAPTER 8

# Network Synchronization Design Best Practices

The synchronization of a network is essential for ensuring that all devices in a network run on the same clock time. It also ensures that the applications in the network function correctly. To design your network synchronization accurately, you must have a clear understanding of your network requirements, timing budget, application requirements, and the desired level of synchronization accuracy. This section describes some best practices to follow when designing your network synchronization.

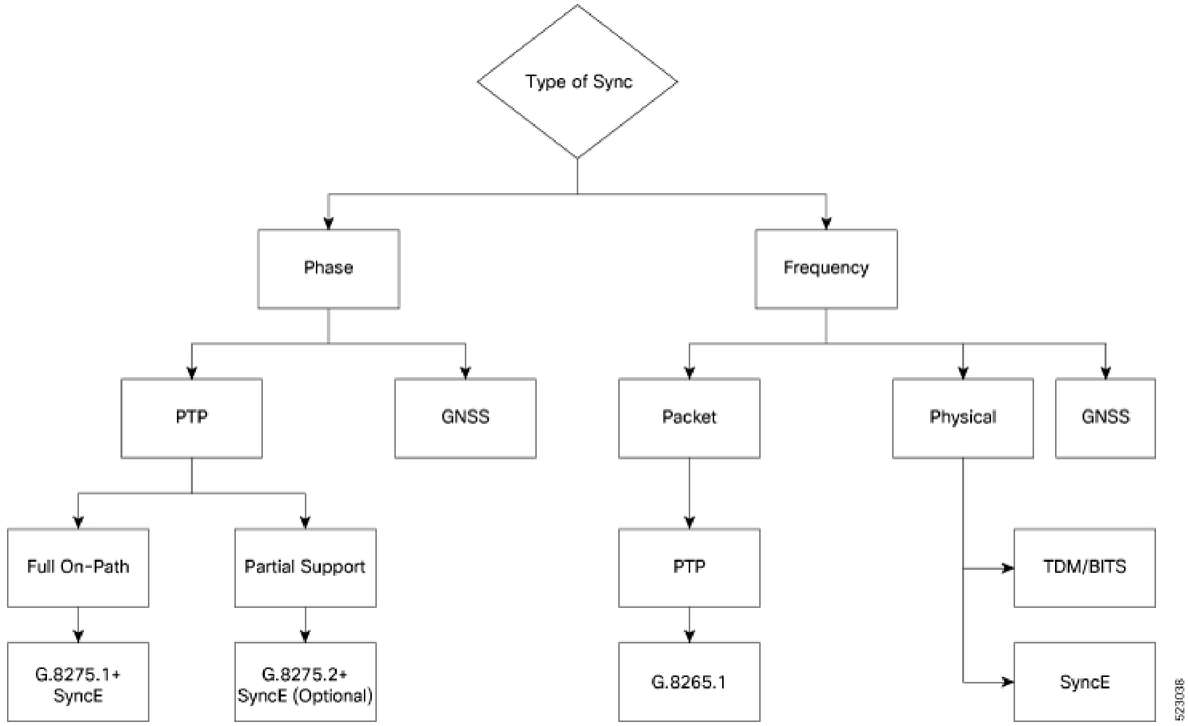


## Network Synchronization Design Best Practices


The synchronization of a network is essential for ensuring that all devices in a network run on the same clock time. It also ensures that the applications in the network function correctly. To design your network synchronization accurately, you must have a clear understanding of your network requirements, timing budget, application requirements, and the desired level of synchronization accuracy. This section describes some best practices to follow when designing your network synchronization.


### Network Synchronization Decision Tree

Use the network synchronization decision tree for determining the appropriate synchronization solution for your network deployment. Network synchronization helps in ensuring that the network operates with accurate and synchronized time.




# General Guidelines for Successful Synchronization Deployments

Network synchronization is crucial for maintaining reliable and efficient network operations, ensuring data integrity, complying with regulations, and facilitating troubleshooting and management tasks. The following guidelines help in deploying successful network synchronization for your network:

- Ensure that you use a standards-based solution designed for your need. For example, use the correct profile.
- Configure the appropriate clock source for your network. It can be Global Navigation Satellite System (GNSS) based such as a Global Positioning System (GPS) clock, or a Precision Time Protocol (PTP) grandmaster clock.
    - Frequency synchronization requires Building Integrated Timing Supply (BITS) or synchronous Ethernet, and Phase synchronization requires PTP and/or GNSS.
    - Use a combination of GNSS over the air and/or PTP or synchronous Ethernet over transport.

  For more information, see SyncE and PTP .
- Set up the synchronization protocols that are required, which includes PTP, Network Time Protocol (NTP), or synchronous Ethernet.
    - NTP uses the system clock for logging events in the system, or to show clock output, whereas PTP and GNSS work on the IEEE 1588 hardware clock in the system.
    - The NTP clock of a node can’t be used to synchronize the downstream network using PTP. However, a node can synchronize its NTP clock with the available PTP or GNSS clock.

> **Note** Most NTP implementations are software-based. Software-based time synchronization is less accurate than hardware-based synchronization, but it's still useful for applications where low levels of accuracy, such as 10's or 100's of milliseconds, are acceptable.

  - Use PTP for phase synchronization in the absence of a GNSS.
  - Synchronous Ethernet (SyncE) is a recommendation from ITU Telecommunication Standardization Sector (ITU-T) on how to deliver a frequency in a network. If you require a frequency-only synchronization solution, use SyncE instead of PTP.

- Configure the appropriate synchronization profiles and preferences for your network. It might include the accuracy, priority, and other parameters that determine how your network handles synchronization events.
- Design your network for phase synchronization with optimal time error budgets.
  - Use boundary clocks to reduce time error and to reset Packet Delay Variation (PDV).
  - Ensure that PTP awareness is implemented consistently throughout, including the transport system, and that boundary clocks accurately transmit time to minimize accumulated time error.
- For phase synchronization, use a hybrid clock that incorporates both SyncE and PTP.

  For more information, see *PTP Hybrid Mode*.
- Reduce the number of hops:
  - Distribute sources of time to meet the budget. If you have too many hops, install a GNSS receiver further out into the network.
  - Don't centralize two Primary Reference Time Clocks (PRTC) and Telecom Grandmasters (T-GM) in two different locations and try to run a synchronization signal accurately across the whole network.
- Minimize Packet Delay Variation (PDV) and jitter. Ensure that microwaves, Gigabit-capable Passive Optical Networks (GPON), Digital Subscriber Line (DSL), and Dense Wavelength Division Multiplexing (DWDM) are PTP aware.
- Monitor your synchronization deployment to ensure that it's functioning correctly and meeting your desired level of accuracy.

  For more information, see *Verifying the Frequency Synchronization Configuration*.
- Be aware of any relevant industry standards and practices when deploying synchronization.

# Guidelines for Phase Synchronization Deployments

Follow these guidelines for phase synchronization deployments.

- Set up the necessary network infrastructure to support phase synchronization. It includes installing timing devices such as GPS receivers, synchronous Ethernet interfaces, and timing servers.
- Configure the phase synchronization protocols such as setting up PTP as appropriate.

- As best practice, use the G.8275.1 telecommunication profile standard with complete on-path support, including Layer-2 multicast in combination with SyncE.
- Minimize phase time error by performing the following tasks:
  - Remove asymmetric routing issues.
  - Reduce the number of hops, unless telecommunication grandmaster (T-GM) clocks are deployed in the preaggregation network.
  - Decrease PDV or packet jitter.
- If you use IP protocols for PTP, you can run into issues with rerouting, asymmetric routing, Equal Cost Multi-Path (ECMP), bundles, and so on.
- If you need tight timing budgets over many hops, ensure that your hardware supports the highest levels of clock accuracy.
- For GNSS deployments:
  - Meet all the requirements for cable and antenna installations.
  - Consult with a professional if you don’t have experience with GNSS installation and calibration.
- Make sure that your deployment is working as intended. Monitor it regularly to identify any potential issues.
- Consult with Cisco technical support if you encounter any issues or have questions.

**Note** When PTP is used with MACsec, achieving high accuracy can be challenging. PTP requires exact timestamping to maintain tight network synchronization. MACsec affixes and detaches a header that is between 24–32 bytes in size. This process can lead to significant inconsistencies in the time delays between where the link is connected and the location where the egress timestamps are applied.

# PTP over IP Network Design

When using networks to carry frequency over Precision Time Protocol over Internet Protocol (PTPoIP), the goal is to minimize Packet Delay Variation (PDV) by reducing the number of hops. Use the following guidelines:

- The placement of the telecom grandmaster (T-GM) clock plays an important role in ensuring that the network operates within your timing budget. For example, place a pair of T-GM clocks in a centralized location only if the network has a small number of hops. In larger networks with multiple hops, it may be necessary to distribute T-GM clocks throughout the network to ensure proper timing management at each hop.
- Use a dedicated frequency synchronization protocol such as synchronous Ethernet or 1588v2, which is designed specifically to maintain precise frequency synchronization between devices.
- Use the G.8265.1 standard. Frequency synchronization using the G.8265.1 standard is a way to make sure multiple devices on a network are operating at the same frequency, allowing for more accurate and reliable communication.

- Configure Quality of Service (QoS) policies to prioritize network traffic and reduce delays. This can be done by using traffic shaping, traffic policing, and queue management.

# Selecting the Correct Profile For Network Synchronization

### G.8275.1 PTPoE

G.8275.1 is a technical specification standard for Precision Time Protocol over Ethernet (PTPoE). It defines how you can use the Precision Time Protocol (PTP) to synchronize clocks over Ethernet networks with layer 2 multicast. PTPoE is an extension of PTP that allows it to be used over Ethernet networks. It's used in applications where precise time synchronization is required.

For more information, refer to G.8275.1 in this guide.

### G.8275.2 PTPoIP

G.8275.2 is a technical specification standard for Precision Time Protocol over Internet Protocol (PTPoIP). It defines the use of the Precision Time Protocol (PTP) over packet-based networks such as Internet Protocol (IP) networks, to provide precise time synchronization of network devices.

### Feature Adaptability on Each Profile

The following table lists the adaptability of features on each profile:

| Feature | G.8275.1 PTPoE | G.8275.2 PTPoIP |
|---|---|---|
| Network Model | Full on-path support | Partial on-path support |
| IP Routing | Not applicable | Can cause issues in rings and asymmetry from a number of causes |
| Transit Traffic | Not allowed | Can result in jitter and asymmetry |
| Performance | Optimal | Variable |
| Configuration Model | Physical port | L3 device |
| PTP over Bundles | No issues | Work in progress for Telecom Boundary Clocks (T-BC) |
| Asymmetry | Reduced due to T-BC on every node | Optimal when deployed as a Partial Support Telecom Boundary Clock (T-BC-P) |
| PDV/Jitter | Reduced due to T-BC on every node | Optimal when deployed as a T-BC-P |

# Reducing Asymmetry

Asymmetry occurs in a PTP unaware network for the following scenarios:

- When routing large networks, complex topologies, rings, and Equal-cost multi-path (ECMP)
- When using PTP unaware transit nodes, especially with varying traffic patterns
- In the transport layer such as Passive Optical Network (PON), cable, DWDM, and complex optics

**Note** Every 2 seconds of asymmetry results in 1 microsecond of time error.

To reduce asymmetry in a PTP unaware network:

- Use QoS: QoS can help reduce asymmetry in an unaware network.
- Implement Telecom Boundary Clocks (T-BC): T-BCs can handle asymmetry in the nodes when implemented correctly.

# Reducing Packet Delay Variation

To reduce the effects of Packet Delay Variation (PDV) on PTP clock recovery, you must have a steady layer of packets that arrive in minimum time.

- Implement Telecom Boundary Clocks (T-BC) in the PTP unaware node. T-BC introduces a time reference to the PTP unaware node, which then synchronizes its clock with the T-BC.
- Use a high-quality network connection between the T-BC and the PTP unaware node. A high-quality network connection, such as a dedicated fiber link, can help reduce PDV due to network impairments.

# Remediating Transport Asymmetry

Transport asymmetry occurs when data is transported at varying rates in different directions over a communication link, leading to an imbalance in transport. To correct this issue:

- Ensure that your transport layer is PTP aware.

  In optical devices, use a wavelength division multiplexing (WDM) technology such as Optical Service Channel (OSC) for managing your fiber optic infrastructure effectively.

# Synchronizing Across Networks

To avoid synchronization issues when connecting to other mobile networks:

- Make sure to align all mobile networks to a common source of time. For example, align mobile networks to the Coordinated Universal Time (UTC) from a Global Navigation Satellite System (GNSS) such as Global Positioning System (GPS).
- Monitor your clocks at the interconnect points.

**Note** In 5G networks, using standalone GNSS receivers at every radio site may not provide the sub-100 nanosecond accuracy required for the timing requirements of Fronthaul radio systems.

CHAPTER 9

# YANG Data Models for Timing and Synchronization

In this section, you'll learn to use the YANG data models to configure and retrieve the operational status of Timing and Synchronization on Cisco 8000 Series Routers.

### What You'll Find in This Section

Cisco IOS XR supports configuring Timing and Synchronization using both traditional Command Line Interface (CLI) using commands as well as programmatically using YANG data models. In this section, you'll find references to supported YANG data models and an understanding about accessing and using these data models.

To get started with using these data models, see:


- List of YANG Data Models for Timing and Synchronization, on page 83
- Access Data Models, on page 84
- Get Started With IOS XR YANG Data Models, on page 86


# List of YANG Data Models for Timing and Synchronization

Here is a list of YANG data models that you can use to configure and manage Timing and Synchronization on the router:

*Table 13: Timing and Synchronization YANG Data Models*

| Cisco IOS XR Native Data Model | Unified Data Model | OpenConfig Data Model |
|---|---|---|
| Cisco-IOS-XR-freqsync-cfg<br>Cisco-IOS-XR-freqsync-oper | Cisco-IOS-XR-um-frequency-synchronization-cfg | |
| Cisco-IOS-XR-ptp-cfg<br>Cisco-IOS-XR-ptp-oper | Cisco-IOS-XR-um-ptp-cfg<br>Cisco-IOS-XR-um-ptp-log-servo-cfg | |
| Cisco-IOS-XR-ip-ntp-cfg<br>Cisco-IOS-XR-ip-ntp-oper | Cisco-IOS-XR-um-ntp-cfg | |

**Note** We recommend using Unified Data Models over Native Data Models

You can access the data models using one of these following options:

# Access Data Models

You can access the data models using one of these following options:

## Access Data Models From Router

To access data models directly from the router, you can follow these steps:

**Step 1** Enter the global configuration mode.

**Example:**

```
Router#configure
```

**Step 2** Configure the NETCONF network management protocol to remotely configure and manage the router using YANG data models.

**Example:**

```
Router(config)#netconf-yang agent ssh
```

**Step 3** Commit the configuration.

**Example:**

```
Router(config)#commit
```

**Step 4** Establish a NETCONF session with the device and retrieve the capabilities information.

**Example:**

```
Router#show netconf-yang capabilities
Tue Sep 19 22:03:26.305 UTC
[Netconf capabilities]

   D: Has deviations

 Capability                                                                  | Revision |D
-----------------------------------------------------------------------------+----------+-
urn:ietf:params:netconf:base:1.1                                             | -        |
urn:ietf:params:netconf:capability:candidate:1.0                             | -        |
urn:ietf:params:netconf:capability:confirmed-commit:1.1                      | -        |
urn:ietf:params:netconf:capability:interleave:1.0                            | -        |
urn:ietf:params:netconf:capability:notification:1.0                          | -        |
urn:ietf:params:netconf:capability:rollback-on-error:1.0                     | -        |
urn:ietf:params:netconf:capability:validate:1.1                              | -        |
http://cisco.com/ns/yang/Cisco-IOS-XR-8000-fib-platform-cfg                  |2019-04-05|
http://cisco.com/ns/yang/Cisco-IOS-XR-8000-lpts-oper                         |2022-05-05|
http://cisco.com/ns/yang/Cisco-IOS-XR-8000-platforms-npu-resources-oper      |2020-10-07|
http://cisco.com/ns/yang/Cisco-IOS-XR-8000-qos-oper                          |2021-06-28|
http://cisco.com/ns/yang/Cisco-IOS-XR-Ethernet-SPAN-act                      |2021-03-22|
http://cisco.com/ns/yang/Cisco-IOS-XR-Ethernet-SPAN-cfg                      |2022-07-13|
```

```
http://cisco.com/ns/yang/Cisco-IOS-XR-Ethernet-SPAN-datatypes                    |2021-10-06|
http://cisco.com/ns/yang/Cisco-IOS-XR-Ethernet-SPAN-oper                         |2022-09-05|
http://cisco.com/ns/yang/Cisco-IOS-XR-aaa-aaacore-cfg                            |2019-04-05|
http://cisco.com/ns/yang/Cisco-IOS-XR-aaa-ldapd-cfg                              |2022-06-22|
http://cisco.com/ns/yang/Cisco-IOS-XR-aaa-ldapd-oper                             |2022-05-20|
http://cisco.com/ns/yang/Cisco-IOS-XR-aaa-lib-cfg                                |2020-10-22|
http://cisco.com/ns/yang/Cisco-IOS-XR-aaa-lib-datatypes
----------------------------------   Truncated for brevity  --------------------------------------
```

By examining the capabilities, you can view the available data models for the software version installed on the router.

# Access Data Models From Cisco Feature Navigator

To access data models from Cisco Feature Navigator, you can follow these steps:

**Step 1** Go to Cisco Feature Navigator.

**Step 2** If you have a Cisco.com account, click on the **Login** button and enter your credentials. If you don't have an account, you can click **Continue as Guest**.

You will be directed to the Cisco Feature Navigator main page.

**Step 3** Click **YANG Data Models**.

**Step 4** Select the **Product** and **Cisco IOS XR Release** based on your requirement.

The data models are listed based on type—Cisco XR native models, Unified models and OpenConfig models.

You can use the search field to search for specific data model of interest.

**Step 5** Click the specific data model of interest to view more details.

The data model is displayed in a hierarchical tree structure making it easier to navigate and understand the relationships between different YANG modules, containers, leaves and leaf lists. You can apply filters to further narrow down the data model definitions for the selected platform and release based on status such as deprecated, obsolete and unsupported nodes.

You can also click the **Download** icon to export the data model information in Excel format.

This visual tree form helps you get insights into the nodes that you can use to automate your network.

The data models on Cisco Feature Navigator is regularly updated based on IOS XR release. If you encounter any problem or have suggestions for improvements, share your experience using Send us your feedback link.

# Access Data Models From GitHub

To access the data models from GitHub repository, you can follow these steps:

**Step 1** Go to the GitHub repository for data models.

On the repository page, you will find a list of folders based on IOS XR releases.

**Step 2** Navigate to the release folder of interest to view the list of supported data models and their definitions. For example, if you want to access the data models for IOS XR release 7.10.1, click on the folder named `7.10.1`.

Inside the folder, you will find a list of YANG files representing different data models.

**Step 3** Click on the YANG file you want to access to view its contents.

You can also click on the **Raw** button to see the raw code or use the **Download** button to download the file to your computer.

Each data model defines a complete and cohesive model, or augments an existing data model with additional XPaths. To view a comprehensive list of the data models supported in a release, navigate to the **Available-Content.md** file in the repository. The unsupported sensor paths are documented as deviations. For example, `openconfig-acl.yang` provides details about the supported sensor paths, whereas `cisco-xr-openconfig-acl-deviations.yang` shows the unsupported sensor paths for `openconfig-acl.yang` model.

**Step 4** Repeat the above steps for other versions or data models of interest.

The GitHub repository for IOS XR data models is regularly updated based on release. You can also contribute to the repository by submitting pull requests, opening issues if you encounter any problems or have suggestions for improvements.

# Get Started With IOS XR YANG Data Models

Here is a generic outline of the steps involved in programmatically configuring your router using YANG data models:

1. Enable network management protocol—Manage the router remotely using the protocols such as NETCONF or gRPC.
2. Install the necessary libraries and tools—Depending on the programming language you are using, you may need to install libraries or tools to programatically interact with the router. For example, if you are using Python, you might need to install the `ncclient` library.
3. Establish a session with the router—Use the programming language of your choice to establish a connection to the router using NETCONF or gRPC protocols. This involves providing connection parameters such as device IP address, username, password, and port number.
4. Retrieve the router capabilities—View the supported features and functionalities available on the router.
5. Create or modify configurations—Use YANG data models to create or modify the configuration on the router.
6. Apply the configuration—Push the updated configuration via the NETCONF or gRPC protocol to modify the router's running configuration to reflect the desired changes.
7. Validate the configuration—Verify that the changes are successfully applied. You can retrieve the running configuration or specific configuration parameters to ensure that the device is configured as intended.

For detailed instructions about using the data models, refer the *Programmability Configuration Guide for Cisco 8000 Series Routers*.

CHAPTER 10

# Command-line Interface (CLIs) for Timing and Synchronization

The Cisco Command Reference Guide serves as a comprehensive resource, offering a catalog of command-line interface (CLI) commands for configuring and verifying Timing and Synchronization implementation.

### What You'll Find in This Section

Cisco IOS XR supports configuring Timing and Synchronization using both traditional Command Line Interface (CLI) using commands as well as programmatically using YANG data models.

In this section, you'll find:



## Reference to Command Reference Guide

The Cisco Command Reference Guide serves as a comprehensive resource, offering a catalog of command-line interface (CLI) commands for configuring and verifying Timing and Synchronization settings.

To view the list of supported commands, refer System Management Command Reference for Cisco 8000 Series Routers.