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.

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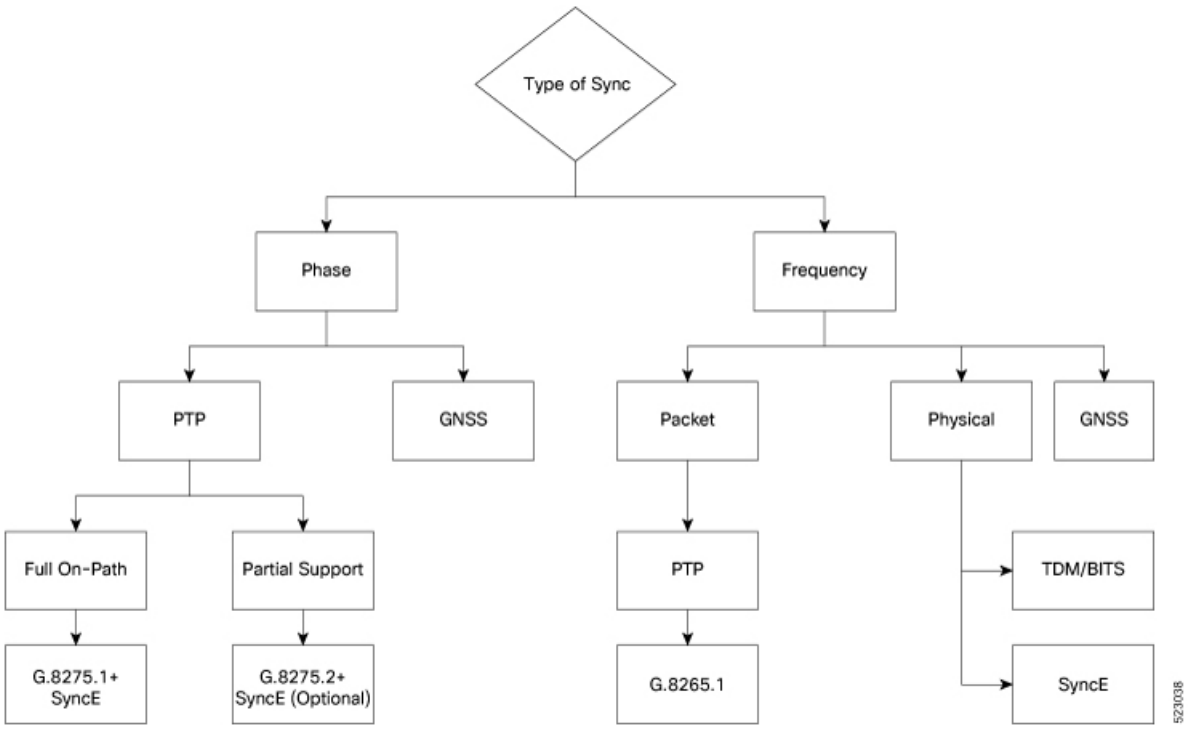
Network Synchronization Decision Tree

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 on SyncE and PTP, refer to *Network Synchronization Configuration Guide for Cisco NCS 540 Series Routers*.
- 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 on PTP Hybrid Mode, refer to *Network Synchronization Configuration Guide for Cisco NCS 540 Series Routers*.
- 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, refer to Verifying the Frequency Synchronization Configuration in the *Network Synchronization Configuration Guide for Cisco NCS 540 Series Routers*.
- 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 the *Network Synchronization Configuration Guide for Cisco NCS 540 Series Routers*.

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.

For more information, refer to G.8275.2 in the *Network Synchronization Configuration Guide for Cisco NCS 540 Series Routers*.

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)

Feature	G.8275.1 PTPoE	G.8275.2 PTPoIP
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.