

Network Synchronization Designs

A network synchronization design is a network design principle that

- ensures all devices in a network operate based on a common time reference,
- enables synchronized application behavior and accurate event correlation, and
- supports network reliability by minimizing timing discrepancies among devices.

Maintaining network synchronization is important for applications such as voice, video, and financial transactions that rely on precise timing. When designing synchronization, you must consider the network requirements, the timing budget, application needs, and the required level of synchronization accuracy.

Timing features implement timing concepts such as Packet Delay Variation (PDV), time error, and network asymmetry. These timing concepts directly affect the accuracy of synchronization technologies like PTP, SyncE, and NTP.

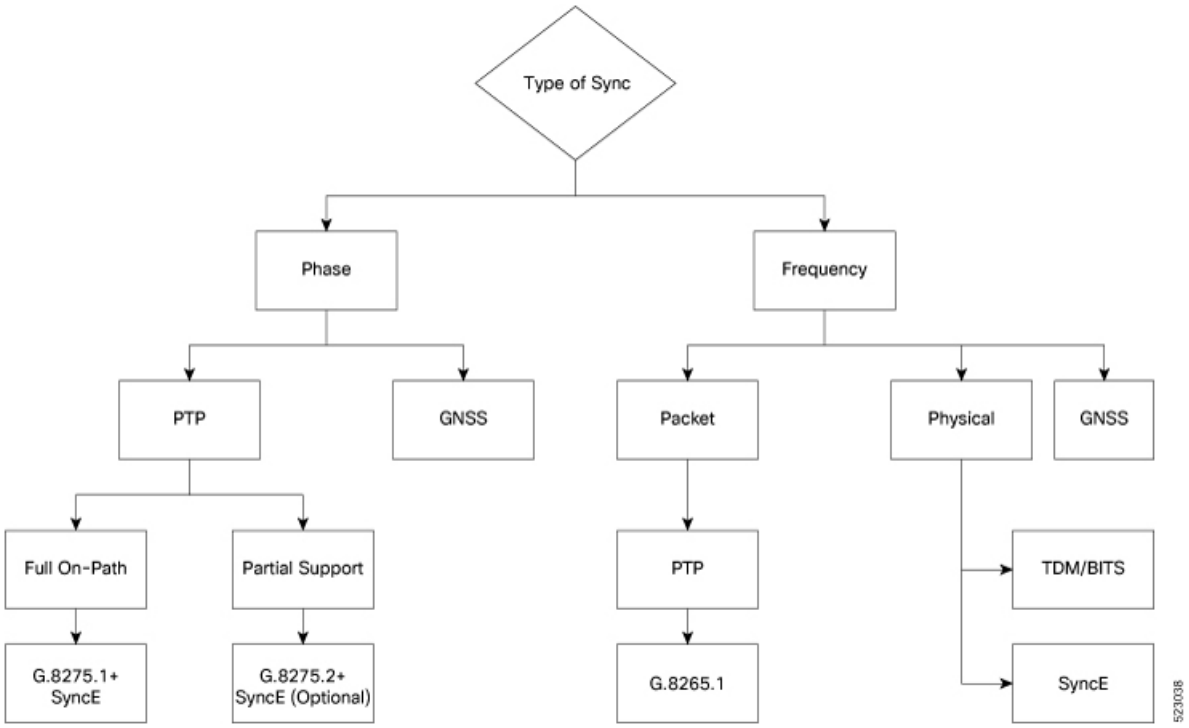
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Network Synchronization Decision Tree

A network synchronization decision tree is a decision-making tool that

- guides users through a series of yes/no or conditional questions,
- helps identify the most suitable synchronization solution for a specific network deployment, and
- streamlines the evaluation process to ensure accurate and synchronized network operation.

Figure 1: Network Synchronization Decision Tree



Network Synchronization is a timing technology domain that uses multiple synchronization technologies—such as Precision Time Protocol (PTP), Synchronous Ethernet (SyncE), Network Time Protocol (NTP), and Global Navigation Satellite System (GNSS)—to provide a common time reference, synchronized application behavior, and accurate event correlation.

Best practices for successful synchronization deployments

To deploy successful network synchronization in your network, consider these guidelines.

- Use a standards-based solution for your network. Select the correct synchronization profile.
- Configure the clock source for your network. You can use one of these sources:
  - A Global Navigation Satellite System (GNSS) based source such as a GPS clock.
  - Use a Precision Time Protocol (PTP) grandmaster clock.
  - Frequency synchronization in networks uses Building Integrated Timing Supply (BITS) or synchronous Ethernet. Phase synchronization uses PTP or GNSS.
  - Use a combination of GNSS, which is delivered over the air, PTP, or synchronous Ethernet over transport. For more information, see SyncE and PTP .
- Set up the required synchronization protocols, such as PTP, Network Time Protocol (NTP), or synchronous Ethernet:
  - NTP uses the system clock for logging or to display clock output. PTP and GNSS work on the IEEE 1588 hardware clock.

- The NTP clock of a node cannot be used to synchronize the downstream network using PTP. However, a node can synchronize its NTP clock with an available PTP or GNSS clock.



Note Most NTP implementations are software-based. Software-based synchronization is less accurate than hardware-based solutions. However, it may provide sufficient accuracy for applications that can tolerate differences of 10 or 100 milliseconds.

- Use PTP for phase synchronization in the absence of GNSS.
- Synchronous Ethernet (SyncE) is a recommendation from ITU-T for delivering frequency in a network. If you require only frequency synchronization, use SyncE instead of PTP.

- Configure suitable synchronization profiles and preferences for your network. Evaluate parameters such as accuracy and priority to determine how synchronization events are managed.
- Design your network for phase synchronization so that it meets optimal time error budgets:
  - Use boundary clocks to reduce time error and reset packet delay variation (PDV).
  - Implement PTP awareness consistently, including in transport systems, and ensure boundary clocks accurately transmit time to minimize accumulated time error.
- For phase synchronization, use a hybrid clock incorporating both SyncE and PTP. For more information, see *PTP Hybrid Mode*.
- Reduce the number of network hops for time distribution:
  - Distribute time sources to meet accuracy budgets. If there are too many hops, install a GNSS receiver further out into the network.
  - Avoid centralizing two Primary Reference Time Clocks (PRTCs) and Telecom Grandmasters (T-GM) in different locations and attempting to run a synchronization signal accurately across the whole network.
- Minimize packet delay variation (PDV) and jitter. Ensure that technologies such as microwave, GPON, DSL, and DWDM are compatible with PTP.
- Monitor your synchronization deployment to ensure correct function and required accuracy. For more information, see *Verifying the Frequency Synchronization Configuration*.
- Be aware of relevant industry standards and practices when deploying synchronization.
- To reduce asymmetry in a PTP-unaware network, consider:
  - Implementing QoS to manage packet delays,
  - Using Telecom Boundary Clocks (T-BC) to handle node asymmetry.
- To avoid synchronization issues when you connect to other mobile networks:
  - 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.

- To correct transport asymmetry:
    - Ensure that your transport layer is Precision Time Protocol (PTP)-aware.

      If you use optical devices, apply wavelength division multiplexing (WDM) technologies, such as Optical Service Channel (OSC), to manage your fiber optic infrastructure effectively.

- To reduce Packet Delay Variation (PDV) and improve PTP clock recovery:
    - Install Telecom Boundary Clocks in nodes that do not support PTP to provide a time reference and enable synchronization.
    - Use a high-quality network connection between the Telecom Boundary Clock and the node that does not support the PTP. This minimizes PDV caused by network impairments.

Guidelines for Phase Synchronization Deployments

- Set up your network infrastructure to support phase synchronization. Install timing devices such as GPS receivers, synchronous-Ethernet interfaces, and timing servers.
- Configure phase-synchronization protocols as needed. Set up Precision Time Protocol (PTP) to enable accurate timing distribution in your network.
- Use the G.8275.1 telecommunication profile standard with complete on-path support, including Layer 2 multicast in combination with Synchronous Ethernet (SyncE) for best results.
- To minimize phase time error:
    - Remove asymmetric routing issues.
    - Reduce the number of hops unless telecommunication grandmaster (T-GM) clocks are deployed in the pre-aggregation network.
    - Decrease packet delay variation (PDV) or jitter.

- If you use IP protocols for PTP, consider potential challenges such as rerouting, asymmetric routing, Equal Cost Multi-Path (ECMP), and bundles.
- For tight timing budgets over many hops, make sure your hardware supports the highest level of clock accuracy.
- For GNSS deployments:
    - Meet all requirements for cable installations and antenna installations.
    - Contact a professional if you are not experienced with GNSS installation and calibration.

- Confirm that your deployment works as intended and monitor it regularly to identify potential issues.
- Contact Cisco technical support if you experience 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 to 32 bytes in size. This process can lead to significant inconsistencies in the time delays between where the link is connected and where the egress timestamps are applied.

PTP over IP Network Design

In Precision Time Protocol networks, Packet Delay Variation (PDV) introduces time error, which directly degrades phase synchronization accuracy. To minimize Packet Delay Variation (PDV) and maintain precise frequency synchronization when using Precision Time Protocol over Internet Protocol (PTPoIP), follow these best practices:

- Place telecom grandmaster (T-GM) clocks in a centralized location if the network has a small number of hops. For larger networks with multiple hops, distribute T-GM clocks throughout the network. This ensures proper timing management at each hop.
- Use a dedicated frequency synchronization protocol such as Synchronous Ethernet or 1588v2 to maintain precise frequency synchronization between devices.
- Use the G.8265.1 standard to ensure multiple devices on the network operate at the same frequency for accurate and reliable communication.
- Configure Quality of Service (QoS) policies to prioritize network traffic and reduce delays. Use traffic shaping, traffic policing, and queue management as needed.

Selecting the Correct Profile For Network Synchronization

A network synchronization profile is a timing protocol profile that

- defines how time signals are distributed over a network,
- specifies the transport method, such as Ethernet or IP, and
- determines feature adaptability for precise synchronization.

There are two primary synchronization profiles that utilize the Precision Time Protocol (PTP), which is standardized for Ethernet and IP networks.

- G.8275.1 PTPoE: Used for multicast timing over layer 2 Ethernet networks.
- G.8275.2 PTPoIP: Used for packet-based timing over IP networks.

Table 1: Feature adaptability for G.8275.1 PTPoE and G.8275.2 PTPoIP profiles

Feature	G.8275.1 PTPoE	G.8275.2 PTPoIP
Network Model	Full on-path support	Partial on-path support

Feature	G.8275.1 PTPoE	G.8275.2 PTPoIP
IP Routing	Not applicable	IP routing can cause issues in rings and may introduce asymmetry.
Transit Traffic	Not allowed	Transit traffic can result in jitter and asymmetry.
Performance	Optimal	Variable
Configuration Model	Physical port	L3 device
PTP over Bundles	No issues	Development 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

A network asymmetry is a timing concept that

- increases Packet Delay Variation
- results in unequal forward and reverse delay, and
- leads to accumulated time error in PTP-based synchronization.

Network asymmetries in PTP-unaware networks can arise due to:

- routing in large or complex topologies such as rings or networks with Equal-cost multi-path (ECMP),
- use of transit nodes that do not recognize PTP and varying traffic patterns,
- or transport technologies like Passive Optical Network (PON), cable, or DWDM.

Note Every two seconds of asymmetry results in approximately one microsecond of time error.

To reduce asymmetry in a PTP-unaware network, consider:

- Implementing QoS to manage packet delays,
- Using Telecom Boundary Clocks (T-BC) to handle node asymmetry.