



7450 Ethernet Service Switch  
7750 Service Router  
7950 Extensible Routing System  
Virtualized Service Router  
Releases up to 25.7.R2

## Basic System Advanced Configuration Guide for Classic CLI

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# Preface

## About This Guide

Each Advanced Configuration Guide is organized alphabetically and provides feature and configuration explanations, CLI descriptions, and overall solutions. The Advanced Configuration Guide chapters are written for and based on several Releases, up to 25.7.R2. The Applicability section in each chapter specifies on which release the configuration is based.

The Advanced Configuration Guides supplement the user configuration guides listed in the *7450 ESS*, *7750 SR*, and *7950 XRS Guide to Documentation*.

## Audience

This manual is intended for network administrators who are responsible for configuring the routers. It is assumed that the network administrators have a detailed understanding of networking principles and configurations.

# IEEE 1588 for Frequency, Phase, and Time Distribution

This chapter provides information about IEEE 1588 for frequency, phase, and time distribution.

Topics in this chapter include:

- [Applicability](#)
- [Overview](#)
- [Configuration](#)
- [Conclusion](#)

## Applicability

The information and configuration in this chapter are based on SR OS Release 12.0.R2. The only software prerequisites are IP reachability between the node and neighboring IEEE 1588 clocks.

IEEE 1588 has several hardware dependencies both for the basic functionality as well as the IEEE 1588 port based timestamping necessary for high accuracy time distribution. Please consult the related Nokia documentation for the details of all the hardware requirements.

## Overview

Defined in IEEE Std 1588™-2008 (1588v2), Precision Time Protocol (PTP) is a protocol that distributes frequency, phase and time over packet based networks.



**Note:**

Many applications do not need time alignment but only phase alignment. However, phase is derived from time and so, for the remainder of the document, discussion refers to time but those references imply both time and phase.

The IEEE 1588 protocol has become the standard for distribution of high accuracy time. Following guidelines for specific network architectures allows the delivery of time to accuracies of one microsecond. This level of accuracy is required for mobile base stations using either Time Division Duplex technology and/or advanced LTE functions, as well as in the power industry for intelligent electronic device alignment.

More lenient architectures can still achieve 100 microseconds or better accuracies which can greatly enhance the usefulness of event logging and network one way delay measurements.

In addition, IEEE 1588 has been used to deliver a frequency reference for T1/E1 ports or for mobile base station frequency alignment. This is useful in environments where the transport network does not provide physical layer synchronization services.

The following IEEE 1588 capabilities are provided within the 7750 SR and 7450 ESS nodes:

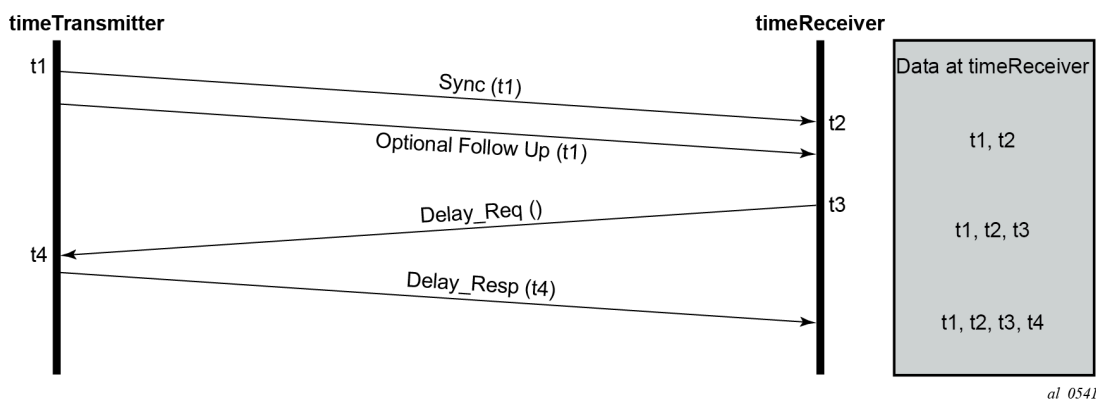
- CPM/CFM based IEEE 1588 timeTransmitter, boundary, and timeReceiver clock functionality
- Transport over Unicast UDP/IPv4 packets

- Access to IEEE 1588 process through base routing, IES, and VPRNs
- Port based timestamping of IEEE 1588 packets
- IEEE 1588 Profiles: 2008 standard default and ITU-T G.8265.1
- Utilization of IEEE 1588 derived time for NTP and System time.

## PTP Basics

PTP uses an exchange of four timestamps between a reference clock (timeTransmitter port) and the clock to be synchronized (timeReceiver port). A simplified illustration of this mechanism is shown in [Figure 1: PTP Messages and Timestamp Exchange](#).

Figure 1: PTP Messages and Timestamp Exchange



The timeTransmitter sends a PTP Sync message containing a timestamp of when the Sync message is transmitted (t1) to the timeReceiver. In a two-step timeTransmitter clock, the t1 timestamp is sent in a Follow\_Up message. The timeReceiver records the time it receives the Sync message (t2). At some point after receiving the Sync message, the timeReceiver sends a Delay\_Req message back to the timeTransmitter. The timeReceiver records the time of transmission of the Delay\_Req message (t3) locally. The timeTransmitter records the time it receives the Delay\_Req message (t4) and sends this timestamp back to the timeReceiver in a Delay\_Resp message.



### Note:

The Follow\_Up message was defined to allow for implementations to generate a timestamp for the transmission of the Sync message but not have to try to insert that timestamp into the Sync message and update any frame checksums on the fly as it is in the process of transmission. While many recent implementations can perform the timestamping, update and checksum calculation on the fly, not all devices could perform this three step process with the desired accuracy. By using the Follow\_Up message to transmit the timestamp of the Sync message, the timeTransmitter port can still provide extremely accurate timestamps for the transmission of the Sync message to the timeReceiver port. Apart from the extra message required, there is no detriment to a timeTransmitter port using one-step clock versus a two-step clock procedures. All PTP clocks that have timeReceiver port capability must accept timing information from both types of timeTransmitter port. There is no requirement to force a clock that is a one-step clock to use two-step clock procedures on its timeTransmitter ports. The nodes covered by this example all support one-step clock timeTransmitter port procedures.



After the four timestamp exchange the timeReceiver can calculate the mean path delay and the clock offset from timeTransmitter using the following two equations:

- $\text{mean\_path\_delay} = [(t_4 - t_1) - (t_3 - t_2)] / 2$
- $\text{offset\_from\_timeTransmitter} = [(t_2 - t_1) - \text{mean\_path\_delay}]$

These calculations can occur on every message exchange or some initial packet selection can be performed so that only optimal message exchanges are used. The latter is useful if there is variable delay between the timeTransmitter and timeReceiver ports.

If only frequency is necessary, then the timeReceiver may use one or both pairs of timestamps ( $t_1, t_2$ ) and ( $t_3, t_4$ ). The timeReceiver can monitor the change in the perceived delay timeTransmitter-to-timeReceiver ( $t_2 - t_1$ ) or timeReceiver-to-timeTransmitter ( $t_4 - t_3$ ) over time. If the delay ( $t_2 - t_1$ ) decreases over time, it means the  $t_2$  timestamps are not progressing quickly enough and the timeReceiver clock frequency needs to be increased.

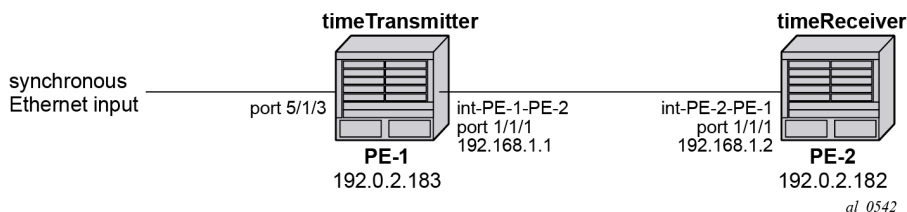
If time is necessary, then all four timestamps must be used. It is also important to note how the equation for offset uses the mean\_path\_delay. If the delays in the two directions are actually different, then the equation will introduce an error in the offset\_from\_timeTransmitter that is half of the difference of the two delays. The IEEE 1588 standard includes procedures to compensate for this asymmetry, if it is known, but if it is uncompensated, it does introduce time error.

## PTP Deployment Architectures

It is important to understand that there are very different topologies recommended for using IEEE 1588 for frequency distribution and using IEEE 1588 for time distribution.

Frequency distribution was developed for an architecture where there are mobile providers who have points of presence at the mobile telephony switching offices (MTSOs) and the cell site locations which depend on other parties for the connectivity between the MTSOs and the cell site locations. The mobile providers wanted a solution that could span the transport networks with minimal dependence on that network. This can be achieved by placing an IEEE 1588 grandmaster at the MTSO and a timeReceiver in a cell site router or directly in the base station and distributing the timestamped packets between the two, as shown in [Figure 2: IEEE 1588 Topology for Frequency Distribution](#). The transport network does introduce packet delay variation (PDV) to the IEEE 1588 messages which makes it more difficult to track the frequency of the grandmaster's clock. However, the timeReceivers have been designed to perform packet selection and noise filtering to allow for the recovery of a frequency within the required accuracies of the mobile base stations. This architecture and the performance requirements are covered by the ITU-T G.826x series of recommendations.

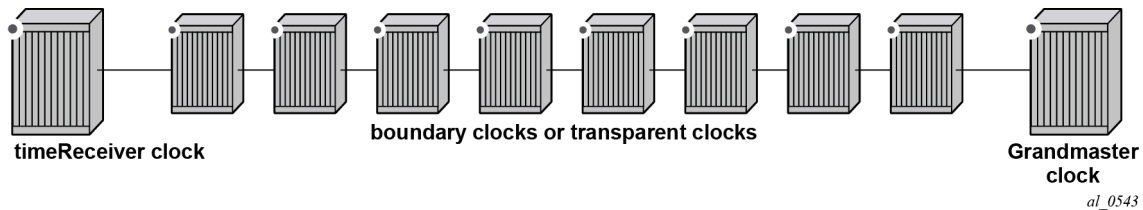
Figure 2: IEEE 1588 Topology for Frequency Distribution



For time distribution, it has been recognized that the architecture used above is extremely unlikely to be successful. The fundamental reason is that the performance requirement is much tighter and the network introduces not only PDV but also potentially asymmetric delay which causes time error in the timeReceiver. The topology recommended for time distribution is what is sometimes referred to as "Full On-Path Support

(OPS)". Full OPS means that every network element between the grandmaster clock and the timeReceiver clock is either an IEEE 1588 boundary clock or a IEEE 1588 transparent clock, as shown in [Figure 3: IEEE 1588 Topology for Time Distribution](#). Boundary clocks and transparent clocks process the IEEE 1588 messages and remove the PDV noise that would be present in a non IEEE 1588 network element. By using network elements that have very tight constraints on the time error they introduced, the network can be built to guarantee time accuracy under all network traffic conditions. This architecture and the performance requirements are covered by the ITU-T G.827x series of recommendations.

Figure 3: IEEE 1588 Topology for Time Distribution



## PTP Profiles

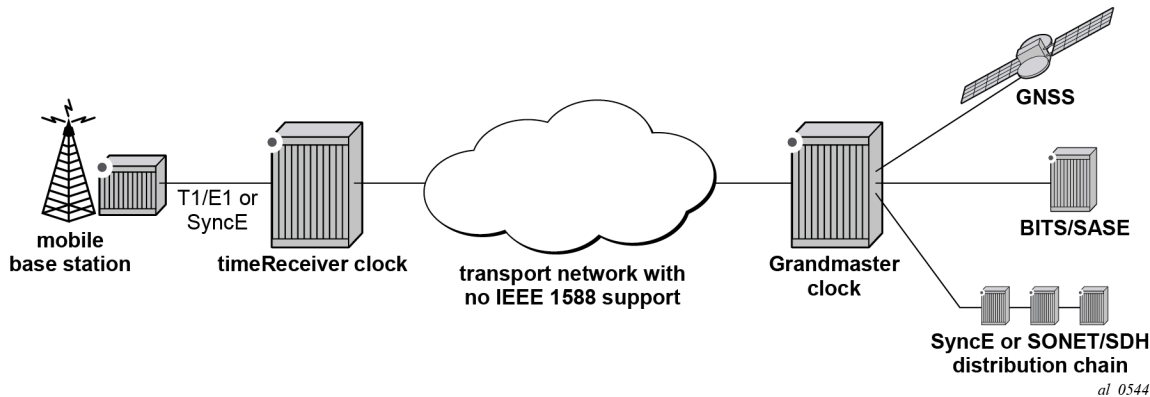
The IEEE 1588v2 standard includes the concept of a PTP profile. A PTP profile allows standardization bodies or industry groups to adapt the IEEE 1588v2 standard to a particular application. A profile defines which aspects of the IEEE 1588v2 standard are included or excluded, along with configurable ranges and defaults necessary for the application.

The IEEE 1588 standard itself includes a **default** profile that can be used for either time or frequency distribution. The default profile was defined principally for multicast operation. However, it can be used with the unicast sessions as described below. The default profile supports all IEEE 1588 clock types and includes the Best Master Clock Algorithm (BMCA) that automatically builds the synchronization distribution hierarchy amongst the PTP clocks. The SR OS only supports the unicast session version of the default profile.

In the telecommunications industry, the ITU-T is the body that develops these profiles. They have generated a profile for frequency distribution (G.8265.1) and a profile for time distribution (G.8275.1). The frequency profile permits only grandmaster and timeReceiver clocks and can be used to extend a traditional physical layer synchronization distribution (SONET/SDH, PDH, or SyncE) with a final leg of IEEE 1588 messages. The frequency source of the IEEE 1588 grandmaster could be a GPS receiver, a central office BITS or SASE device or it could use the frequency recovered from a Synchronous Ethernet or SONET/SDH interface. This is shown in [Figure 4: Frequency Distribution with IEEE 1588 as Last Mile](#)

Because an IEEE 1588 distribution system is significantly noisier than a physical layer distribution system, it should only be used as the final segment to connect the end application into the synchronization network. It should not be used to connect two Synchronous Ethernet or SONET/SDH islands.

Figure 4: Frequency Distribution with IEEE 1588 as Last Mile



The important features defined in the G.8265.1 profile are:

- Only timeTransmitter clocks and timeReceiver clocks are allowed.
- Unicast Message Negotiation using Signaling messages from the timeReceiver clocks toward the timeTransmitter clocks is used to establish communications.
- PTP messages are encapsulated over UDP over IPv4.
- PTP clock class values are based on a mapping of traditional quality levels from SSM/ESMC.



**Note:**

SSM stands for Synchronization Status Messages and ESMC stands for Ethernet Synchronization Messaging Channel. These are two capabilities in SDH/SONET and Synchronous Ethernet respectively for the relaying of source clock quality information.

The timeReceiver clock uses an alternate BMCA to select the grandmaster clock from the available timeTransmitter clocks based on:

- quality level
- relative priority

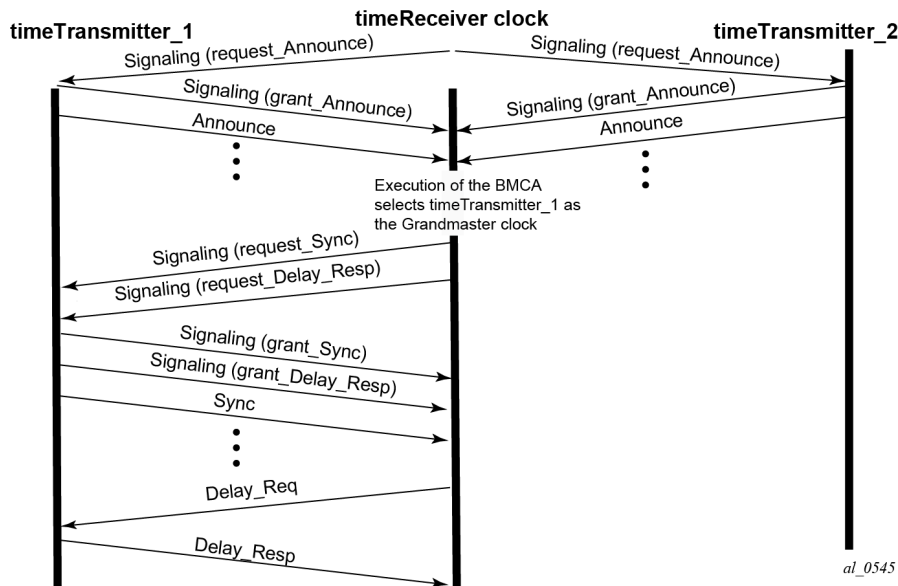
The ITU-T has defined the first time distribution profile in G.8275.1. It uses an architecture of a Global Navigation Satellite System (GNSS) based grandmaster clock distributing time through a chain of boundary clocks to a final timeReceiver device and end application. It includes the use of Synchronous Ethernet and IEEE 1588 at the same time for optimal performance. Physical layer Synchronous Ethernet is an excellent tool for the distribution of an accurate and stable frequency. This frequency can be used to advance time between offset adjustments made using the IEEE 1588 information.

## Unicast Message Negotiation

The initial IEEE 1588-2002 standard defined a multicast messaging model. IEEE 1588-2008 introduced the option of using unicast messaging with unicast discovery to establish a message exchange between a timeTransmitter and timeReceiver.

The typical unicast message flow between a timeTransmitter and timeReceiver is illustrated in [Figure 5: Unicast Message Negotiation](#).

Figure 5: Unicast Message Negotiation



A timeReceiver clock initiates unicast discovery by sending a Signaling message to one of its configured timeTransmitter clocks requesting the timeTransmitter send unicast Announce messages to the timeReceiver. The request includes the desired rate for the Announce messages and the duration over which the messages should be sent. If the timeTransmitter can support the request, it replies with a Signaling message indicating that the session for unicast Announce messages has been granted.

From this point on, the timeTransmitter sends unicast Announce messages to the timeReceiver at the rate requested. A timeReceiver will generally establish an Announce message session with at least two timeTransmitter clocks.

The timeReceiver then uses the Announce messages it receives from all timeTransmitters as input to the BMCA that determines which timeTransmitter clock is the best source for information. The selected timeTransmitter becomes the grandmaster clock to the timeReceiver. The timeReceiver then sends additional Signaling messages to the grandmaster to request unicast delivery of Sync and Delay\_Resp messages. Assuming the grandmaster clock has sufficient resources, the request is granted and unicast Sync and Delay\_Resp messages are sent from the grandmaster to the timeReceiver.

As with the Announce messages, the rate at which the Sync and Delay\_Resp messages are sent and the duration of the unicast sessions is requested by the timeReceiver in the initial Signaling messages.

The unicast sessions for Announce, Sync, and Delay Response messages have an expiry time. The timeReceiver renews all three sessions before this time is reached.

## Network Limits

A common concern around IEEE 1588 is whether it will work on or over a specific customer network. For time distribution using full OPS as shown in [Figure 3: IEEE 1588 Topology for Time Distribution](#), there are well defined limits on the number of network elements allowed in the distribution chain (see below). However, for the frequency distribution using the architecture shown in [Figure 2: IEEE 1588 Topology for Frequency Distribution](#), it is a more difficult question to answer. There are so many different types of network elements and inter-node links that a simple limit on the number of network elements is not

adequate. What has been specified is a limit to the noise that the network can introduce to the IEEE 1588 message flow between the grandmaster and timeReceiver clocks. This noise occurs as packet delay variation (PDV). The following sections provide some description of this PDV and a new metric that has been defined for PDV as well as the recommended limit to PDV for IEEE 1588 deployments.

## Packet Delay Variation

If the packet delay through the packet network is constant, then it is relatively easy to use a series of timestamp exchanges to remove the delay as an unknown and track the timeTransmitter clock frequency. However, in most network technologies, the packet delay will be different for each individual packet. This PDV makes it more difficult to track the timeTransmitter clock because observations have both the timeTransmitter information and PDV noise included.

PDV is introduced when packets get placed in queues before they are forwarded. The time each packet sits in any one queue is influenced by multiple factors:

- the speed of the interface toward which the queue drains, for example 100Mbps versus 100Gbps
- the traffic load on the interface, for example 20% versus 100% of line capacity
- the distribution of packet sizes and priorities in the traffic load toward the interface and
- the underlying physical technology used, xPON, xDSL, Ethernet, or microwave

In addition, the load and packet distribution within the load will vary over time so the distribution of the PDV can shift rapidly such as when a network event triggers congestion or slowly, for example, as end customers gradually come online over a period of several hours.

Also, there are pipeline effects that can occur in a chain of queuing devices, where the small timing packets can catch up to a large packets moving across the network. Once behind such a packet, the timing packet can remain stuck behind that packet on all subsequent transmit queues.

QoS prioritization of packets helps reduce PDV significantly during congestion periods, but does not remove the PDV effects during lighter loading. This is due to the fact that a timing packet may be delivered to the egress queue for an interface while the interface is busy transmitting a packet. Pre-emption of packet transmissions is not used in today's networks.

Having stated all of the above, most of the time, the network will still present a percentage of packets that get across the network with minimal queuing delays. These are often referred to as 'lucky' or 'fastest' packets. Because these lucky packets are never waiting in queues or have minimal wait times, their transit across the network is relatively consistent. By running a selection filter on all IEEE 1588 packets to find these lucky packets, a level of variation of network delay can be removed or reduced significantly. Then the timeReceiver clocks have a much easier time determining the frequency of the grandmaster.

However, there will always be a limit to the amount of PDV that can be tolerated. The ITU has defined a metric to quantify the PDV, the limit of the PDV for a compliant network, and the required tolerance of a timeReceiver clock.

## PDV Metrics

In order to know whether a particular timing-over-packet implementation will meet the performance targets in a given network deployment, it is desirable to both characterize the limits on the PDV that the implementation can tolerate and to measure the network against these limits. In 2012, the ITU-T published three documents that address these requirements:

- G.8260 defines the Floor Packet Percentage (FPP) metric.

- G.8261.1 defines a network limit for PDV in terms of FPP.
- G.8263 defines the input tolerance expected of a IEEE 1588 frequency timeReceiver in terms of FPP.

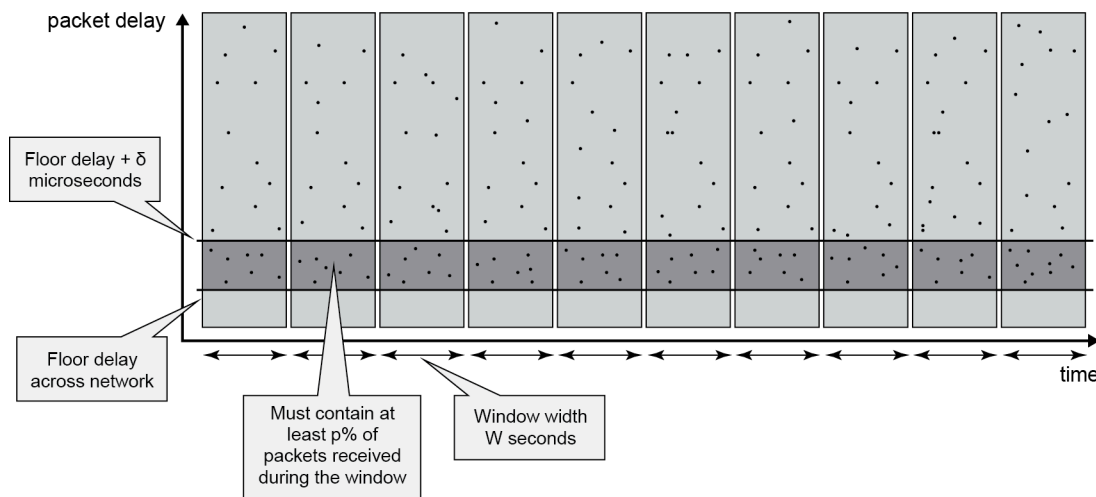
The Floor Packet Percentage (FPP) metric provides an indication of the guarantee that there are packets experiencing minimal delay across the network. The rationale behind this focus on 'fastest' packets is that many networks do provide good consistency of these packets in most operating conditions and because most timeReceiver clocks are capable of operating using only the information from these fastest packets.

There are four parameters associated with the metric:

- **W** is the width of the windows used to monitor for the presence of fastest packets.
- **Floor Delay** is a value that is as close as possible to the absolute minimum transit delay across the network. Every actual delay measurement must be equal to or larger than this value.
- **$\delta$**  is the range above the floor to be analyzed for the presence of fastest packets.
- **p** is the percentage of all the packets received in a window whose delay must be within the range floor delay to floor delay +  $\delta$ .

**Figure 6: Floor Packet Counting for FPP ( $n$ ,  $W$ ,  $\delta$ )** illustrates how these parameters and the metric work. First the delays of all individual IEEE 1588 packets are plotted over the period of observation. Next, the observation period is broken down into a series of consecutive windows of width **W** seconds. Then for each window a count is made of all the IEEE 1588 packets whose delays are within the range **floor delay** to **floor delay +  $\delta$**  and this count is compared with all the IEEE 1588 packets received during the window to turn the count into a percentage. Finally, the percentage of each window is checked against the threshold percentage **p**. For the FPP metric to be met, every window must have a percentage greater or equal to the threshold. If even one single window does not meet this threshold then the metric condition is not met.

**Figure 6: Floor Packet Counting for FPP ( $n$ ,  $W$ ,  $\delta$ )**



al\_0547



**Note:**

This metric is not perfect because it does not take into account timeReceivers that use other aspects of the packet delay distribution (such as average delay), nor does it discuss the impact of reroutes, nor do the limits discuss how to apply these limits to the forward and backward message exchanges at the same time. However, it was agreed that this metric was a good start for the definitions of the network and timeReceiver limits. Expect to see timing test

equipment vendors providing the tools to generate IEEE 1588 PDV profiles providing FPP based distributions.

## ITU-T Budget for Frequency

The network limit on PDV for frequency distribution is defined in G.8271.1 using the FPP metrics defined above.

In general most carrier grade networks with spans of up to 10 nodes and which do not exceed 80% load on their internode links should meet the requirement. However, very low (sub 50 Mbps) shaping or very long networks or last mile technologies such as xDSL or xPON may need to be studied to determine their acceptability.

A general strategy for rolling out IEEE 1588 frequency distribution is to evaluate the specific grandmaster and timeReceiver pairing in a lab environment using a network emulator to introduce controlled PDV. Once the grandmaster and timeReceiver have passed the lab tests, then field trial locations should be identified. Ideally, the sites should include locations where the PDV of the network will likely be at its worst. This would be sites with the most intervening network elements between the grandmasters and the timeReceivers and include segments of the network that have a high load. The timeReceivers' clocks should be deployed and monitored over several days to ensure that their frequency recovery engines can maintain lock with the grandmasters. During the initial field trials, it is beneficial to use external frequency test equipment at the timeReceiver locations to accurately monitor the frequency generated out of the timeReceivers and ensure it stays within limits. As more sites are evaluated and confidence in the PDV environment increases, more deployments can be rolled out. In the deployed network, PTP frequency recovery timeReceiver states can be monitored to ensure the solution continues to work.

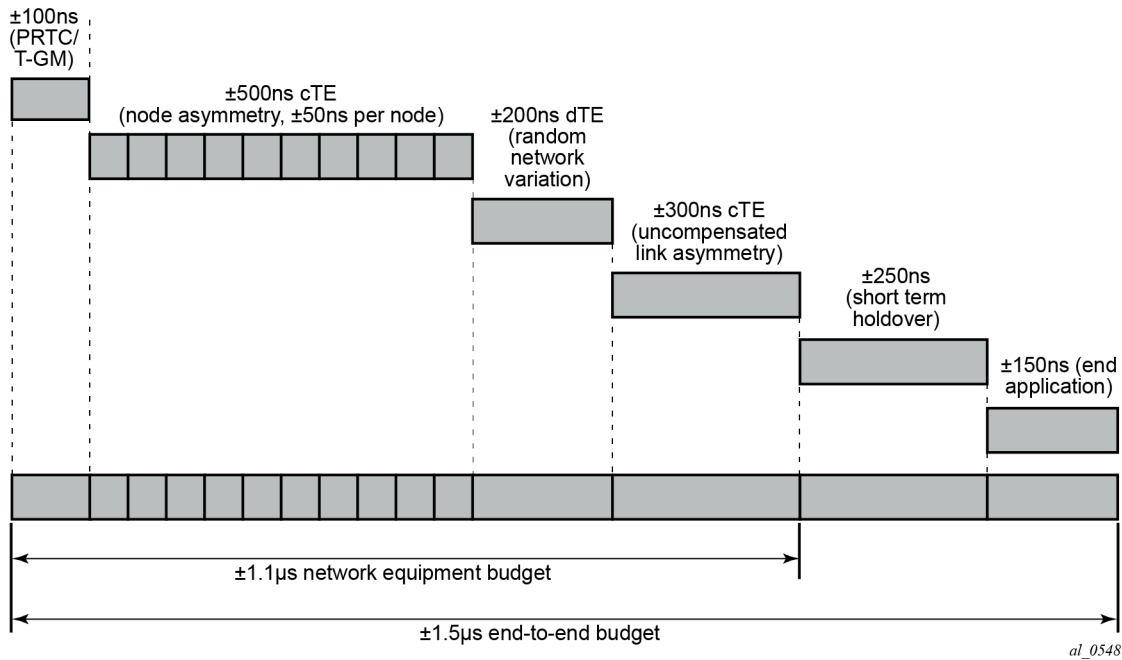
There may be some locations in the network where the PDV will be too large preventing the timeReceivers to achieve or maintain lock. If it is possible to utilize an alternate network interface to obtain a frequency such as a leased T1 or E1 interface then that could be used. A last resort would be the deployment of a GNSS receiver at the location to provide the frequency reference.

## ITU-T Budget for Time

The ITU-T has defined a topology for time distribution based on a full OPS environment. This means that every network element in the time distribution chain is an IEEE 1588 clock of some type. Currently the work has defined an environment using Boundary Clocks, but this might be modified in the future to include transparent clocks. The ITU-T tackled the time distribution problem in a more traditional way when compared with the frequency distribution. The ITU-T first defined specific network element clock performance constraints and then defined a longest chain network permitted to ensure that the solution meets the end to end budget. The breakdown of the chain and the budget is shown in [Figure 7: G.8271.1 Time Error Budget](#).



Figure 7: G.8271.1 Time Error Budget



The overall end to end budget is defined as  $\pm 1.5$  microseconds. From this the following allocations are made:

- $\pm 100$ ns Time error due to the GNSS receiver and the IEEE 1588 grandmaster.
- $\pm 500$ ns Constant Time error due to ten Telecom Boundary Clocks (50 ns limit per boundary clock).
- $\pm 200$ ns Dynamic Time error presented at the end of the boundary clock chain into the end timeReceiver.
- $\pm 300$ ns Time error due to errors in cable latency asymmetry compensation (see below).
- $\pm 150$ ns Time error due to the end timeReceiver and any internals of the base station between the recovery and the presentation on the air interface.
- $\pm 200$ ns Time error in the end application during short term holdovers such as network topology re-arrangements.



**Note:**

There is discussion that some of these elements could be traded-off against each other. For example, if the link asymmetry needs a higher budget then the holdover budget would have to be less – implying a better end device or a shorter duration of holdover.

The link asymmetries are an important aspect of this budget. The network topology not only has to have the network elements that meet the clock specifications but it also needs to have links that meet certain requirements. As explained above, the time offset calculation makes the assumptions that the timeTransmitter-to-timeReceiver latency is the same from the timeReceiver-to-timeTransmitter latency. When the latency is not equal, an error is introduced. Some analysis of network intersite connections may need to be performed to determine the budget for the link asymmetries.



## Configuration

### IP Addressing for PTP Communication

The system supports communication to the PTP process on the CPM using any of the IPv4 local interface addresses or an IPv4 local loopback addresses. The system will record both the source and destination address information from the received Signaling message which establishes the unicast session. The system will then swap these addresses for use for the Sync and/or Delay\_Req messages generated toward the external clock.

The IP address becomes more significant when IEEE 1588 port based timestamping is enabled. The port level functionality will filter received PTP packets for a known IP address. This ensures that only PTP messages intended for the node are modified and not PTP messages merely transiting the node.

If the IEEE 1588 nodes are directly connected or it is ensured that the PTP messages for a peer shall always enter/exit the system through a single interface, then the IP address of that interface can be used for the PTP message communication. If the PTP messages from a peer could enter through more than one interface, then it may be easier to utilize a loopback address for the PTP message communication.

If using a loopback address and IEEE 1588 port based timestamping is also to be used, then the specific loopback address must be assigned to PTP for use using the **source-address** command. An example is provided in the "Port Based Timestamping" section below.



**Note:**

When a source address is defined for the PTP process within a given routing context, then the source address for all Signaling messages originating out of the node within that routing context shall use that address.



**Note:**

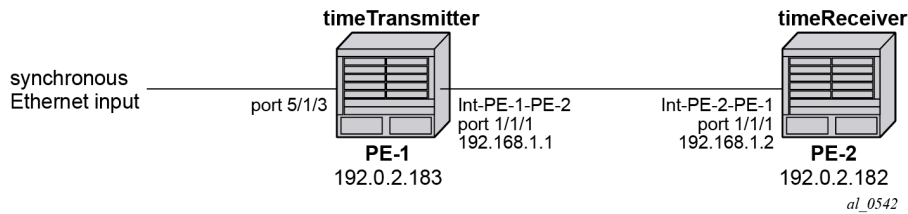
The procedures to establish IP connectivity for the specific addresses used in these examples are not included.

### TimeTransmitter and TimeReceiver Clocks for Frequency

A typical deployment scenario for a system configured as an ordinary timeTransmitter to distribute frequency to an external timeReceiver clock, often a cell site router or a base station, is shown in [Figure 8: TimeTransmitter and TimeReceiver Clocks for Frequency](#). The central clock of the system is locked via its BITS ports or a Synchronous Ethernet port to an external source that is traceable to a primary reference. The frequency of the central clock is used to generate the timestamps contained in PTP event messages. The timestamps generated do not correlate to any standard epoch and therefore indicate an arbitrary timescale. As such, it is only the rate of progression of the timestamps that has meaning.

The 7750 SR and the 7450 ESS can be configured as an IEEE 1588 timeReceiver clock for frequency recovery. In real deployments, it is more likely for the timeReceiver devices to be smaller cell site routers or base stations instead of another 7750 SR or 7450 ESS.

Figure 8: TimeTransmitter and TimeReceiver Clocks for Frequency



In the topology in [Figure 8: TimeTransmitter and TimeReceiver Clocks for Frequency](#), the systems will most likely be configured with the ITU-T G.8265.1 Profile.

For this example, a loopback address is used for PTP communication between the nodes.

## Ordinary timeTransmitter configuration

The steps to configure PE-1 as a PTP ordinary-clock timeTransmitter for frequency distribution using the G.8265.1 Telecom profile are outlined below:

Configure a /32 IPv4 system address on PE-1 and an interface to reach PE-2.

```

*A:PE-1#
  configure
    router
      interface "system"
        address 192.0.2.183/32
        no shutdown
      exit
      interface "int-PE-1-PE-2"
        address 192.168.1.1/30
        port 1/1/1
        no shutdown
      exit
    exit
  
```

Configure an input reference for the central clock on PE-1. In this example, Synchronous Ethernet port 5/1/3 is used as the source for **ref2**.

```

*A:PE-1#
  configure
    port 5/1/3
      description "Sync-E reference for node"
      ethernet
        ssm
          code-type sonet
          no shutdown
        exit
      exit
    exit
  no shutdown
exit
system
  sync-if-timing
    begin
    ql-selection
    ref2
      source-port 5/1/3
      no shutdown
    exit
  
```

```

        commit
    exit
exit

```

The default **clock-type** is set to **ordinary slave** so that must be changed to **ordinary master**. The only other relevant configuration parameter for the timeTransmitter clock running the G.8265.1 profile is the **network-type**. The coding of the SSM/ESMC Quality Level into PTP clock Class must match the environment. The system supports both SONET and SDH networks. The default **network-type** is **sdh** but for this example, the system is configured for the North American market so the **network-type** is set to **sonet**.

```

*A:PE-1#
  configure
    system
      ptp
        clock-type ordinary master
        network-type sonet
        no shutdown
      exit
    exit
  exit

```

## Ordinary timeReceiver configuration

To configure PE-2 as a PTP ordinary timeReceiver for frequency distribution using the G.8265.1 Telecom profile, firstly configure a /32 IPv4 system address on PE-2 and an interface to reach PE-1.

```

*A:PE-2#
  configure
    router
      interface "system"
        address 192.0.2.182/32
        no shutdown
      exit
      interface "int-PE-2-PE-1"
        address 192.168.1.2/30
        port 1/1/1
        no shutdown
      exit
    exit
  exit

```

As the default **clock-type** is **ordinary slave**, PE-1 is configured as a peer clock, and the PTP process is enabled. In this example, the Quality Level encoding is also changed to **sonet** in order to match the North American market

```

*A:PE-1#
  configure
    system
      ptp
        network-type sonet
        peer 192.0.2.183 create
        no shutdown
      exit
    no shutdown
  exit
exit

```

Usually, an IEEE 1588 timeReceiver has at least two peers configured in order to provide redundant sources.

Configure PTP as the reference for the central clock on PE-2.

```
*A:PE-2#
  configure
    system
      sync-if-timing
        begin
          ql-selection
          ptp
            no shutdown
        exit
      commit
    exit
  exit
```

## Verification of Session Establishment

When PTP is set to **no shutdown** on PE-2, it initiates a PTP unicast session with PE-1. Correct session establishment can be verified by checking PTP related information as follows:

```
*A:PE-1# show system ptp unicast
=====
IEEE 1588/PTP Unicast Negotiation Information
=====
Router
  IP Address      Dir Type      Rate          Duration State      Time
-----
Base
  192.0.2.182     Tx  Announce 1 pkt/2 s  300        Granted 05/30/2014 06:08:38
  192.0.2.182     Tx   Sync    64 pkt/s   300        Granted 05/30/2014 06:08:43
  192.0.2.182     Rx  DelayReq 64 pkt/s   300        Granted 05/30/2014 06:08:43
  192.0.2.182     Tx  DelayRsp 64 pkt/s   300        Granted 05/30/2014 06:08:43
-----
PTP Peers          : 1
Total Packet Rate  : 192 packets/second
=====

*A:PE-2# show system ptp unicast
=====
IEEE 1588/PTP Unicast Negotiation Information
=====
Router
  IP Address      Dir Type      Rate          Duration State      Time
-----
Base
  192.0.2.183     Rx  Announce 1 pkt/2 s  300        Granted 05/30/2014 09:08:38
  192.0.2.183     Rx   Sync    64 pkt/s   300        Granted 05/30/2014 09:08:43
  192.0.2.183     Tx  DelayReq 64 pkt/s   300        Granted 05/30/2014 09:08:43
  192.0.2.183     Rx  DelayRsp 64 pkt/s   300        Granted 05/30/2014 09:08:43
-----
PTP Peers          : 1
Total Packet Rate  : 192 packets/second
=====
```

A *Pending* state indicates the system has sent a Unicast Request toward the peer but has not received a response. If the state remains *Pending*, then the IP connectivity between the systems should be verified.

To verify the timeReceiver frequency is operating properly, first check the high level information for PTP on PE-2.



**Note:**

The PTP Recovery State initially shows phase-tracking and then changes to locked. The time to achieve locked state varies based on the PDV.

```
*A:PE-2# show system ptp
=====
IEEE 1588/PTP Clock Information
=====
-----
Local Clock
-----
Clock Type       : ordinary,slave   PTP Profile      : ITU-T G.8265.1
Domain          : 4                Network Type     : sonet
Admin State     : up                Oper State       : up
Announce Interval : 1 pkt/2 s      Announce Rx Timeout: 3 intervals
Peer Limit      : none (Base Router)
Clock Id        : 00233efffe808250 Clock Class       : 255 (slave-only)
Clock Accuracy  : unknown          Clock Variance    : ffff (not computed)
Clock Priority1  : 128              Clock Priority2    : 128
PTP Port State  : slave            Last Changed      : 05/30/2014 09:08:42
PTP Recovery State: phase-tracking  Last Changed      : 05/30/2014 09:08:42
Frequency Offset : -2.704 ppb
-----
Parent Clock
-----
IP Address       : 192.0.2.183      Router           : Base
Parent Clock Id  : 00233efffe69f250 Remote PTP Port  : 1
GM Clock Id      : 00233efffe69f250 GM Clock Class   : 80 (prs)
GM Clock Accuracy : unknown          GM Clock Variance : ffff (not computed)
GM Clock Priority1: 128              GM Clock Priority2 : 128
-----
Time Information
-----
Timescale       : Arbitrary
Current Time    : 2014/05/30 14:12:52.9 (ARB)
Frequency Traceable : yes
Time Traceable  : no
Time Source     : other
=====
```

In addition, PTP packet statistics can be checked to verify reception of the PTP messages and the execution of the frequency timeReceiver:

```
*A:PE-2# show system ptp statistics
=====
IEEE 1588/PTP Packet Statistics
=====
-----
Input      Output
-----
PTP Packets      5506      2742
Announce         23         0
Sync            2740         0
Follow Up         0         0
Delay Request     0      2740
Delay Response   2740         0
Signaling         3         3
  Request Unicast Transmission TLVs
    Announce       0         1
-----
```

Sync	0	1
Delay Response	0	1
Grant Unicast Transmission (Accepted) TLVs	3	0
Announce	1	0
Sync	1	0
Delay Response	1	0
Grant Unicast Transmission (Denied) TLVs	0	0
Announce	0	0
Sync	0	0
Delay Response	0	0
Cancel Unicast Transmission TLVs	0	0
Announce	0	0
Sync	0	0
Delay Response	0	0
Ack Cancel Unicast Transmission TLVs	0	0
Announce	0	0
Sync	0	0
Delay Response	0	0
Other TLVs	0	0
Other	0	0
Event Packets timestamped at port	0	0
Event Packets timestamped at cpm	2740	2740
Discards	0	0
Bad PTP domain	0	0
Alternate Master	0	0
Out Of Sequence	0	0
Peer Disabled	0	0
Other	0	0
=====		
IEEE 1588/PTP Frequency Recovery State Statistics		
=====		
State	Seconds	
-----		
Initial	0	
Acquiring	0	
Phase-Tracking	43	
Locked	0	
Hold-over	0	
=====		
IEEE 1588/PTP Event Statistics		
=====		
Event	Sync Flow	Delay Flow
-----		
Packet Loss	0	0
Excessive Packet Loss	0	0
Excessive Phase Shift Detected	0	0
Too Much Packet Delay Variation	0	0
=====		
*		

Secondly, the central clock status on the system can be checked:

```
*A:PE-2# show system sync-if-timing
=====
System Interface Timing Operational Info
=====
System Status CPM B      : Master Locked
Reference Input Mode     : Non-revertive
Quality Level Selection  : Disabled
Reference Selected       : ptp
```

```

System Quality Level      : prs
Current Frequency Offset (ppm) : +0

Reference Order           : bits ref1 ref2 ptp

Reference Mate CPM
  Qualified For Use       : No
  Not Qualified Due To    :      LOS
  Selected For Use        : No
  Not Selected Due To     :      not qualified

Reference Input 1
  Admin Status            : down
  Rx Quality Level        : unknown
  Quality Level Override  : none
  Qualified For Use       : No
  Not Qualified Due To    :      disabled
  Selected For Use        : No
  Not Selected Due To     :      disabled
  Source Port             : None

Reference Input 2
  Admin Status            : down
  Rx Quality Level        : unknown
  Quality Level Override  : none
  Qualified For Use       : No
  Not Qualified Due To    :      disabled
  Selected For Use        : No
  Not Selected Due To     :      disabled
  Source Port             : None

Reference BITS B
  Input Admin Status      : down
  Rx Quality Level        : failed
  Quality Level Override  : none
  Qualified For Use       : No
  Not Qualified Due To    :      disabled
  Selected For Use        : No
  Not Selected Due To     :      disabled
  Interface Type          : DS1
  Framing                 : ESF
  Line Coding             : B8ZS
  Line Length             : 0-110ft
  Output Admin Status     : down
  Output Source           : line reference
  Output Reference Selected : none
  Tx Quality Level        : N/A

Reference PTP
  Admin Status            : up
  Rx Quality Level        : prs
  Quality Level Override  : none
  Qualified For Use       : Yes
  Selected For Use        : Yes

```

## Optional configuration items for ordinary timeTransmitter or timeReceiver configuration

The G.8265.1 profile is the default PTP profile on the system and it uses domain number value of **4**. The domain number must match at both ends of the communication path or the PTP messages will be dropped. Some very old IEEE 1588 devices, may have the domain number set to zero, which is the value used by

the IEEE 1588 default profile. In this case, the system would need to have its domain number changed to match that of the external timeReceiver.

```
configure
  system
    ptp
      shutdown
      domain 0
      no shutdown
    exit
  exit
```



**Note:**

The domain number can only be adjusted if PTP is shutdown and only one common domain number is allowed for all IEEE 1588 messages to and from the system.

When using the system as an IEEE 1588 timeReceiver for frequency distribution, it is strongly recommended to use the default message rate of 64 pps for Sync and Delay\_Resp messages. If for some reason the parent IEEE 1588 peer cannot offer this rate, then the rate that the system requests must be adjusted. For example, if the maximum rate supported by the external IEEE 1588 grandmaster device (with an IP address of 192.0.2.166) only is 32 pps, then the system can be adjusted to request that rate as follows:

```
configure
  system
    ptp
      peer 192.0.2.166 create
      log-sync-interval -5
      no shutdown
    exit
  exit
exit
```



**Note:**

The Sync message rate can only be adjusted if the peer is shutdown.

The message rates are entered as the base 2 logarithm of the inter-message interval. So 32 pps has an inter message interval of 1/32 seconds and a log-sync-interval of -5.

The Announce message rate impacts the speed at which PTP can detect communication failures and the speed at which the PTP topology is re-arranged. The default Announce rate is one message every two seconds and this should be adequate for networks with short chains of PTP clocks, for example, G.8265.1 architectures. However, in network with longer chains of PTP clocks (for example, more than 5 boundary clocks), it may be desired to use a faster Announce message rate. In the following example, the timeReceiver is configured to request two Announce messages per second:

```
configure
  system
    ptp
      shutdown
      log-anno-interval -1
      no shutdown
    exit
  exit
```





**Note:**

The Announce rate can only be adjusted if PTP is shutdown. In addition, there is one common Announce rate for all unicast sessions; it cannot be configured on an individual peer basis.

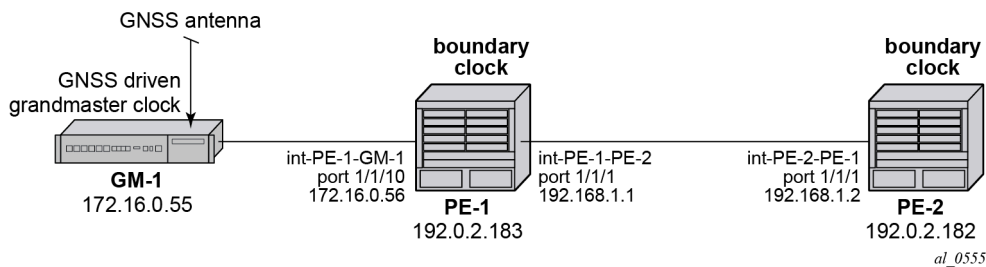
## Boundary Clock

With the increase interest in high accuracy time distribution across networks, the system most likely takes on the role of an IEEE 1588 boundary clock. In this role, the system requests time from a GNSS driven grandmaster clock or from a neighboring boundary clock. The system only supports boundary clock configuration when the ptp profile is configured as the default profile.

In this mode of operation, it is strongly recommended to have Synchronous Ethernet physical layer frequency distribution configured at the same time.

The example in [Figure 9: Boundary Clock](#) shows a boundary clock (PE-1) communicating directly with the GNSS driven grandmaster (GM-1) and a second boundary clock (PE-2) communicating with the first boundary clock.

*Figure 9: Boundary Clock*



The steps to configure the systems as boundary clocks running the IEEE default profile are:

On PE-1, configure a /32 IPv4 system address, an interface to reach PE-2, and an interface to reach GM-1.

```
*A:PE-1#
configure
router
  interface "system"
    address 192.0.2.183/32
    no shutdown
  exit
  interface "int-PE-1-PE-2"
    address 192.168.1.1/30
    port 1/1/1
    no shutdown
  exit
  interface "int-PE-1-GM-1"
    address 172.16.0.56/30
    port 1/1/2
    no shutdown
  exit
exit
```

On PE-2, configure a /32 IPv4 system address and an interface to reach PE-1.

```
*A:PE-2#
```

```
configure
router
  interface "system"
    address 192.0.2.182/32
    no shutdown
  exit
  interface "int-PE-2-PE-1"
    address 192.168.1.2/30
    port 1/1/1
    no shutdown
  exit
exit
```

Configure both PE-1 and PE-2 to have physical layer frequency sources into their central clocks. PE-2 is configured to receive Synchronous Ethernet from PE-1 on the same port as is used for PTP. This commonality is not a requirement but might be common in the network topology.

On PE-1, configure the port toward PE-2 as a Synchronous Ethernet port. This will cause the port transmit timing to be sourced from the node timing. Also, configure the port to transmit ssm codes using the sonet codes.

```
*A:PE-1#
configure card 1 mda 1 sync-e
configure port 1/1/1 ethernet
  code-type sonet
  no shutdown
exit
```

On PE-2, configure the port on toward PE-1 as a Synchronous Ethernet port and to use sonet codes and to be the reference into the central clock of PE-2.

```
*A:PE-2#
configure card 1 mda 1 sync-e
configure port 1/1/1
  ethernet
    ssm
      code-type sonet
      no shutdown
    exit
  exit
exit
configure system sync-it-timing
  begin
  ql-selection
  refl
    source-port 1/1/1
    no shutdown
  exit
  commit
exit
```

Next, configure PE-1 as a boundary clock requesting service from GM-1 using the default profile. In this example, the interface address of GM-1 is used for the PTP communication.

```
*A:PE-1#
configure system ptp
  shutdown
  profile ieee1588-2008
  clock-type boundary
  peer 172.16.0.55 create
  no shutdown
```

```

        exit
        no shutdown
    exit

```

If it is desired to operate the network at the default for the G.8275.1 profile, then the Announce messages should be set to 8 pps and the Sync and Delay\_Resp messages should be set to 16 pps.

```

*A:PE-1#
    configure system ptp
        shutdown
        log-anno-interval -3
        peer 172.16.0.55
            shutdown
            log-sync-interval -4
            no shutdown
        exit
    no shutdown
exit

```

Configure PE-2 as a boundary clock using PE-1 as its parent clock and the same set of IEEE 1588 parameters. In this example, PE-2 uses a loopback address of PE-1 for communication.

```

*A:PE-2#
    configure system ptp
        shutdown
        profile ieee1588-2008
        clock-type boundary
        log-anno-interval -3
        peer 192.0.2.183 create
            shutdown
            log-sync-interval -4
            no shutdown
        exit
    no shutdown
exit

```

On PE-1, validate the status of the PTP topology by checking the unicast sessions. Also validate the PTP process has elected GM-1 as both the parentClock and the grandmaster clock.

```

*A:PE-1# show system ptp unicast
=====
IEEE 1588/PTP Unicast Negotiation Information
=====
Router
  IP Address      Dir Type      Rate      Duration State      Time
-----
Base
  192.0.2.182     Tx  Announce  8 pkt/s    300      Granted  05/30/2014 07:02:36
  192.0.2.182     Tx   Sync     16 pkt/s    300      Granted  05/30/2014 07:02:37
  192.0.2.182     Rx DelayReq  16 pkt/s    300      Granted  05/30/2014 07:02:37
  192.0.2.182     Tx DelayRsp  16 pkt/s    300      Granted  05/30/2014 07:02:37
  172.16.0.55     Rx  Announce  8 pkt/s    300      Granted  05/30/2014 07:02:42
  172.16.0.55     Rx   Sync     16 pkt/s    300      Granted  05/30/2014 07:02:43
  172.16.0.55     Tx DelayReq  16 pkt/s    300      Granted  05/30/2014 07:02:43
  172.16.0.55     Rx DelayRsp  16 pkt/s    300      Granted  05/30/2014 07:02:43
-----
PTP Peers          : 2
Total Packet Rate   : 112 packets/second
=====
*A:PE-1# show system ptp

```

```

=====
IEEE 1588/PTP Clock Information
=====
-----
Local Clock
-----
Clock Type      : boundary      PTP Profile      : IEEE 1588-2008
Domain         : 0              Network Type     : sdh
Admin State    : up             Oper State       : up
Announce Interval : 8 pkt/s      Announce Rx Timeout: 3 intervals
Peer Limit     : none (Base Router)
Clock Id       : 00233efffe69f250
Clock Accuracy : unknown        Clock Class      : 248 (default)
Clock Priority1 : 128           Clock Variance   : ffff (not computed)
Clock Priority2 : 128           Clock Priority2  : 128
PTP Recovery State: locked      Last Changed     : 05/30/2014 07:05:17
Frequency Offset : +50.305 ppb
-----
Parent Clock
-----
IP Address      : 172.16.0.55      Router           : Base
Parent Clock Id : 8887868584838281 Remote PTP Port  : 1
GM Clock Id     : 8887868584838281 GM Clock Class   : 7
GM Clock Accuracy : within 250 ns  GM Clock Variance : 0x6400 (3.7E-09)
GM Clock Priority1: 128           GM Clock Priority2 : 128
-----
Time Information
-----
Timescale       : PTP
Current Time    : 2014/05/30 15:07:01.1 (UTC)
Frequency Traceable : yes
Time Traceable  : yes
Time Source     : GPS

```

On PE-2, validate the PTP process has elected PE-1 as its parentClock and that the grandmaster clock is GM-1.

```

*A:PE-2# show system ptp
=====
IEEE 1588/PTP Clock Information
=====
-----
Local Clock
-----
Clock Type      : boundary      PTP Profile      : IEEE 1588-2008
Domain         : 0              Network Type     : sdh
Admin State    : up             Oper State       : up
Announce Interval : 8 pkt/s      Announce Rx Timeout: 3 intervals
Peer Limit     : none (Base Router)
Clock Id       : 00233efffe808250
Clock Accuracy : unknown        Clock Class      : 248 (default)
Clock Priority1 : 128           Clock Variance   : ffff (not computed)
Clock Priority2 : 128           Clock Priority2  : 128
PTP Recovery State: locked      Last Changed     : 05/30/2014 10:02:36
Frequency Offset : -9.345 ppb
-----
Parent Clock
-----
IP Address      : 192.0.2.183      Router           : Base
Parent Clock Id : 00233efffe69f250 Remote PTP Port  : 1
GM Clock Id     : 8887868584838281 GM Clock Class   : 7
GM Clock Accuracy : within 250 ns  GM Clock Variance : 0x6400 (3.7E-09)
GM Clock Priority1: 128           GM Clock Priority2 : 128
-----
Time Information

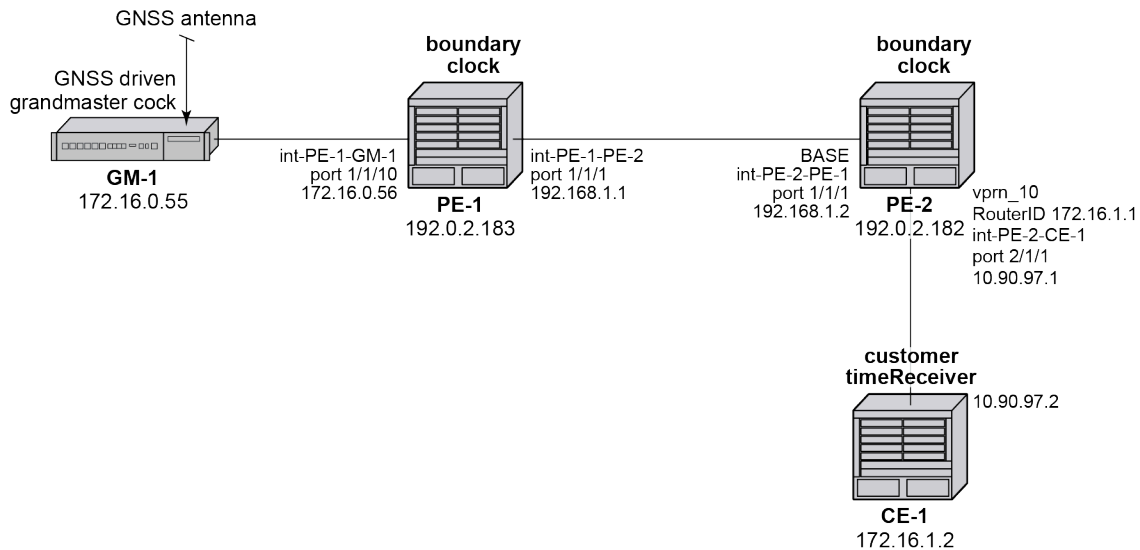
```

```
-----
Timescale      : PTP
Current Time   : 2014/05/30 15:09:26.5 (UTC)
Frequency Traceable : yes
Time Traceable  : yes
Time Source     : GPS
=====
```

## Boundary Clock with VPRN Access

The system supports access to the IEEE 1588 process through **Base routing**, **ies**, and **vprn** contexts. This permits the system IEEE 1588 topology to be created and managed in one context with access for edge distribution through other contexts. For example, building on top of the base routing distribution shown in the previous example, access can be given to the IEEE 1588 process on PE-2 via a VPRN existing on that node. This allows the VPRN customer to have access to the high accuracy time available within the system in the customer edge equipment connecting into that node.

Figure 10: Boundary Clocks with Edge VPRN Access



al\_0556

For the example shown in [Figure 10: Boundary Clocks with Edge VPRN Access](#), it is assumed that a VPRN service is already configured and operational on PE-2 providing connectivity between PE-2 and CE-1:

```
*A:PE-2#
configure service vprn 10 customer 1 create
  router-id 176.16.1.1
  autonomous-system 64496
  route-distinguisher 64496:10
  interface "int-PE-2-CE-1" create
    address 10.90.97.1/30
    sap 2/1/1 create
  exit
exit
no shutdown
exit
```

To enable access to the PTP process via VPRN 10 in PE-2, PTP must be enabled within the **vprn** context. To ensure that no more than 10 external clocks access the system PTP through this VPRN at any one time, a peer-limit may be defined.

```
*A:PE-2#
  configure service vprn 10
    peer-limit 10
    ptp no shutdown
  exit
```

To confirm PTP access with the VPRN, the PTP information with the **vprn** context can be queried. Either of the following two commands can be used:

```
*A:PE-2# show system ptp unicast router 10
```

or

```
*A:PE-2# show service id 10 ptp unicast
```

These two commands provide the same information as shown below.

```
*A:PE-2# show system ptp unicast router 10
=====
IEEE 1588/PTP Unicast Negotiation Information
=====
Router
  IP Address      Dir Type      Rate      Duration State      Time
-----
10
  172.16.1.2      Tx  Announce  1 pkt/2 s  300      Granted  05/30/2014 12:40:53
  172.16.1.2      Tx  Sync      64 pkt/s   300      Granted  05/30/2014 12:40:59
  172.16.1.2      Rx  DelayReq  64 pkt/s   300      Granted  05/30/2014 12:40:59
  172.16.1.2      Tx  DelayRsp  64 pkt/s   300      Granted  05/30/2014 12:40:59
-----
PTP Peers          : 1
Total Packet Rate  : 192 packets/second
=====
```

## Port Based Timestamping

As described above, optimal performance is achieved when the IEEE 1588 port based timestamping (PBT) feature is used. This feature is not available on all hardware and the interfaces for PTP should be planned in advance if this feature is to be used.

Because IEEE 1588 messages ingress and egress the node through router interfaces, the configuration of the IEEE 1588 PBT feature is enabled within the **router interface** context. In the previous examples, if IEEE 1588 PBT is to be enabled on all the PTP interfaces the following commands are required.

On PE-1, enable IEEE 1588 PBT on the interface toward GM-1 and PE-2.

```
*A:PE-1#
  configure
    router
      interface "int-PE-1-PE-2"
        ptp-hw-assist
      exit
    interface "int-PE-1-GM-1"
```

```

        ptp-hw-assist
    exit
exit

```

On PE-2, enable IEEE 1588 PBT on the interface toward PE-1 and CE-1.

```

*A:PE-2#
  configure
    router
      interface "int-PE-2-PE-1"
        ptp-hw-assist
      exit
    exit
  exit
  configure service vprn 10 customer 1
    interface "int-PE-2-CE-1"
      ptp-hw-assist
    exit
  exit
exit

```

To verify IEEE 1588 PBT is active on the IEEE 1588 messages to the peers, check the timestamp point for the specific peer. It now indicates *port* rather than *cpm*.

On PE-1 for the CE-1 communication:

```

*A:PE-1# show system ptp peer 172.16.0.55
=====
IEEE 1588/PTP Peer Information
=====
Router      : Base
IP Address  : 172.16.0.55      Announce Direction : rx
Admin State : up              G.8265.1 Priority   : n/a
Sync Interval : 16 pkt/s
Local PTP Port : 2            PTP Port State      : slave
Clock Id    : 8887868584838281 Remote PTP Port     : 1
GM Clock Id  : 8887868584838281 GM Clock Class       : 7
GM Clock Accuracy : within 250 ns GM Clock Variance    : 0x6400 (3.7E-09)
GM Clock Priority1: 128          GM Clock Priority2    : 128
Steps Removed : 0              Parent Clock          : yes
Tx Timestamp Point: port        Rx Timestamp Point    : port
Last Tx Port   : 5/1/1         Last Rx Port          : 5/1/1
=====

```

On PE-1 the communication with the PE-2 will still be CPM timestamping because the port has not been configured to watch for the **system** loopback address.

```

*A:PE-1# show system ptp peer 192.0.2.182
=====
IEEE 1588/PTP Peer Information
=====
Router      : Base
IP Address  : 192.0.2.182     Announce Direction : tx
Admin State : n/a            G.8265.1 Priority   : n/a
Sync Interval : n/a
Local PTP Port : 3            PTP Port State      : master
Clock Id    : 00233efffe808250 Remote PTP Port     : 4
Tx Timestamp Point: cpm        Rx Timestamp Point    : cpm
Last Tx Port   : 5/1/2         Last Rx Port          : 5/1/2
=====

```

In order to configure the **system** loopback address for PTP, enter the following on PE-1:

```
*A:PE-1#
configure
system security
source-address application ptp "system"
exit
exit
```

Now the timestamp point on PE-1 will be the port.

```
*A:PE-1# show system ptp peer 192.0.2.182
=====
IEEE 1588/PTP Peer Information
=====
Router          : Base
IP Address       : 192.0.2.182      Announce Direction : tx
Admin State      : n/a             G.8265.1 Priority   : n/a
Sync Interval    : n/a
Local PTP Port    : 3              PTP Port State      : master
Clock Id         : 00233efffe808250 Remote PTP Port     : 4
Tx Timestamp Point: port           Rx Timestamp Point  : port
Last Tx Port     : 5/1/2           Last Rx Port        : 5/1/2
=====
```

Repeat this configuration of system address for the base routing context on PE-2

```
*A:PE-2#
configure
system security
source-address application ptp "system"
exit
exit
```

Now the timestamp point on PE-2 will be the port.

```
*A:PE-2# show system ptp peer 192.0.2.183
=====
IEEE 1588/PTP Peer Information
=====
Router          : Base
IP Address       : 192.0.2.183      Announce Direction : rx
Admin State      : up              G.8265.1 Priority   : n/a
Sync Interval    : 16 pkt/s
Local PTP Port    : 4              PTP Port State      : slave
Clock Id         : 00233efffe69f250 Remote PTP Port     : 3
GM Clock Id      : 8887868584838281 GM Clock Class      : 6
GM Clock Accuracy : within 100 ns   GM Clock Variance   : 0x6400 (3.7E-09)
GM Clock Priority1: 128             GM Clock Priority2   : 128
Steps Removed    : 1              Parent Clock         : yes
Tx Timestamp Point: port           Rx Timestamp Point  : port
Last Tx Port     : 1/1/2           Last Rx Port        : 1/1/2
=====
```

On PE-2, a loopback address must assigned for PTP communication as follows:

```
*A:PE-2#
configure service vprn 10
interface "ptp_loopback"
address 172.16.1.1/32
```



```

    loopback
  exit
  source-address
    application ptp "ptp_loopback"
  exit
exit

```

## IEEE 1588 as NTP Local Clock (server)

If the system is configured as a boundary clock or timeReceiver clock, then the time recovered from the IEEE 1588 timeReceiver port can be used as the source of system time on the node. This allows for higher accuracy and better stability in the timebase when compared to NTP. To enable this, PTP must be made the preferred server in the **ntp** context in the node.



### Note:

If the system is acting as an NTP server or peer to other NTP clocks, then turning on this feature will impact the existing NTP topology. The system shall advertise itself as an NTP Stratum 1 server to external clients and peers. Given the much higher accuracies achievable with PTP time distribution, this change in topology does not degrade the time in the clients and peers.

```

*A:PE-1#
  configure system time ntp
    server ptp prefer
  exit

```

To validate PTP is now being used for NTP time and system time, use the following command:

```

*A:PE-1# show system ntp all
=====
NTP Status
=====
Configured      : Yes          Stratum         : 1
Admin Status    : up           Oper Status     : up
Server Enabled  : No           Server Authenticate : No
Clock Source    : ptp
Auth Check      : Yes
Current Date & Time: 2014/05/30 17:53:11 UTC
=====
NTP Active Associations
=====
State           Reference ID   St Type  A  Poll Reach  Offset(ms)
-----
Remote
-----
chosen          PTP           0  srvr  -  64  .....YY  0.000
  ptp
=====
NTP Clients
=====
vRouter                                     Time Last Request Rx
Address
-----
=====

```

## Conclusion

The systems provide support for IEEE 1588 frequency and time distribution for the synchronization applications of the mobile networks. They can be configured as frequency distribution grandmasters and timeReceiver clocks or time distribution boundary and timeReceiver clocks.

# Synchronous Ethernet

This chapter provides information about Synchronous Ethernet (SyncE).

Topics in this chapter include:

- [Applicability](#)
- [Overview](#)
- [Configuration](#)
- [Conclusion](#)

## Applicability

This chapter was initially written for SR OS Release 8.0.R7. The CLI in the current edition is based on SR OS Release 14.0.R6. There are no software prerequisites for this configuration, however, the hardware requires the use of Synchronous Ethernet capable MDA-XPs/CMA-XPs or the IMMs.

In addition, Synchronous Ethernet is only supported on optical interfaces. It is not supported on 10/100/1000 base copper interfaces.

## Overview

### Synchronous Ethernet

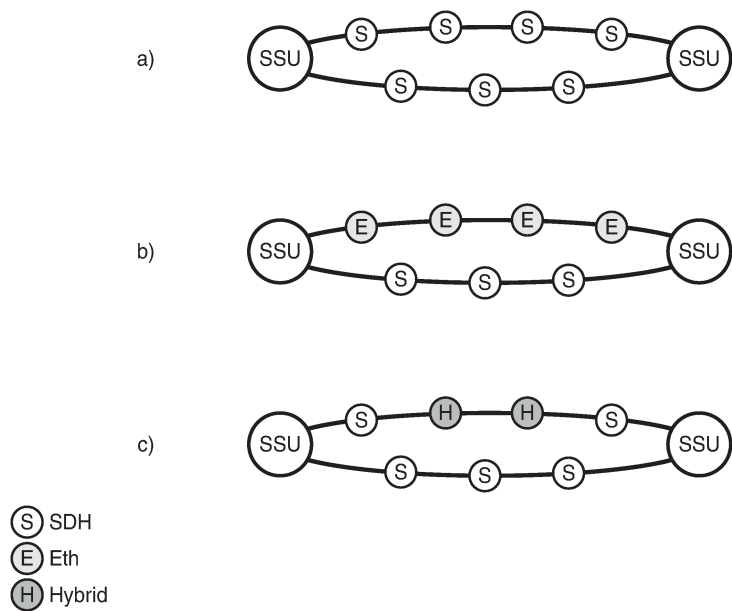
Synchronous Ethernet (SyncE) is the ability to provide PHY-level frequency distribution through an Ethernet port. It is one of the building blocks of Next Generation Networks (NGNs).

Traditionally, Ethernet based networks employ the physical layer transmitter clock to be derived from an inexpensive +/-100ppm crystal oscillator and the receiver locks onto it. There is no need for long term frequency stability because the data is packetized and can be buffered. For the same reason, there is no need for consistency between the frequencies of different links. However, one could choose to derive the physical layer transmitter clock from a high quality frequency reference by replacing the crystal with a frequency source traceable to a primary reference clock. This would not affect the operation of any of the Ethernet layers, for which this change would be transparent. The receiver at the far end of the link would lock onto the physical layer clock of the received signal, and thus itself gain access to a highly accurate and stable frequency reference. Then, in a manner analogous to conventional hierarchical master-slave network synchronization, this receiver could lock the transmission clock of its other ports to this frequency reference and a fully time synchronous network could be established.

The advantage of using SyncE, as compared to methods relying on sending timing information in packets over an unlocked physical layer, is that SyncE is not influenced by impairments introduced by the higher levels of the networking technology (packet loss, packet delay variation). Therefore, the frequency accuracy and stability may be expected to exceed those of networks with unsynchronized physical layers. In addition, SyncE was designed to integrate into any existing SONET/SDH synchronization distribution

architecture to allow for the easy migration from the traditional to the new synchronous interfaces. SyncE includes the concept of a hybrid switch which supports the interworking of synchronization distribution through SONET/SDH and the SyncE interfaces at the same time.

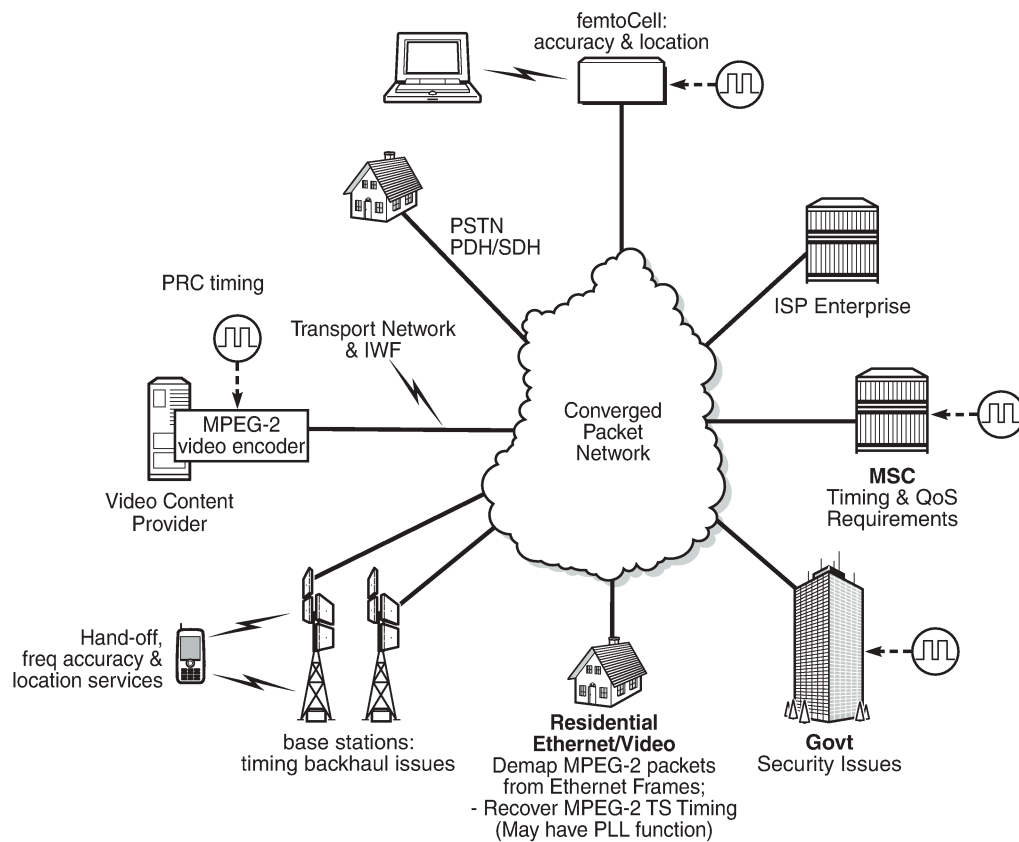
Figure 11: SyncE Hypothetical Reference Network Architecture



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Many Tier 1 carriers are looking to migrate their synchronization infrastructure to a familiar and manageable model. In order to enable rapid migration of these networks, SyncE may be the easiest to deploy in order to ensure robust frequency synchronization.

Figure 12: Packet Based Network Timing Infrastructure



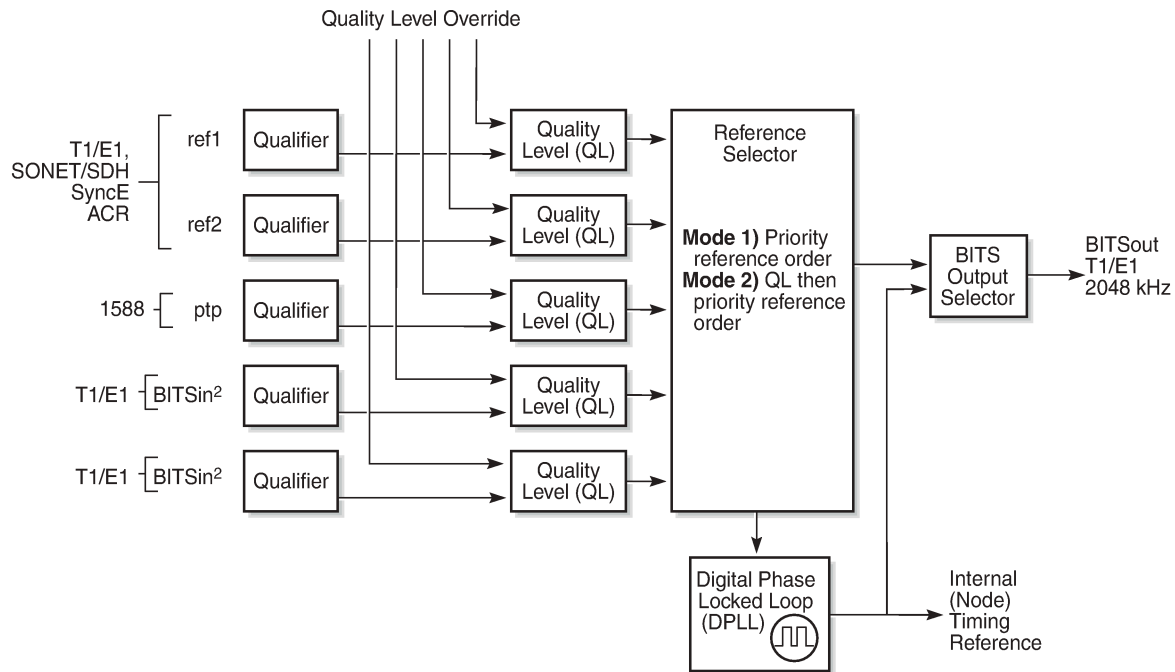
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## Central Synchronization Sub-System

The timing subsystem for the SR OS platforms has a central clock located on the Control Processor Module (CPM). The timing subsystem performs many of the duties of the network element clock as defined by Telcordia GR-1244 and ITU-T G.781.

The system can select from up to three (7950 XRS) or four (7450 ESS and 7750 SR) timing inputs to train the local oscillator. The priority order of these references must be specified. This is a simple ordered list of inputs: {BITS [Building Integrated Timing Source], ref1, ref2, PTP [Precision Time Protocol]}. The CPM clock output has the ability to drive the clocking for all line cards in the system. The SR OS platforms support selection of the node reference using Quality Level (QL) indications.

Figure 13: CPM Clock Synchronization Reference Selection



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The recovered clock is able to derive its timing from any of the following:

- OC3/STM1, OC12/STM4, OC48/STM16, OC192/STM64 ports (7450 ESS and 7750 SR only)
- T1/E1 CES channel (adaptive clocking) (7750 SR only)
- SyncE ports
- T1/E1 ports (7750 SR only)
- BITS port on a channelized OC3/STM1 CES CMA (7750 SR-c12 only)
- BITS port on the CPM, CFM, or CCM module
- 10GE ports in WAN PHY mode
- IEEE 1588v2 slave port (PTP) (7450 ESS and 7750 SR only)

On 7750 SR-12 and 7750 SR-7 systems with redundant CPMs, the system has two BITS input ports (one per CPM). On the 7750 SRc-4 systems, there are two BITS input ports on the chassis front plate. These BITS input ports provide redundant synchronization inputs from an external BITS/SSU. However, the 7750 SR-c12 does not support BITS input port redundancy or BITS out.

All settings of the signal characteristics for the BITS input apply to both ports. When the active CPM considers the BITS input as a possible reference, it will consider first the BITS input port on the active CPM followed the BITS input port on the standby CPM in that relative priority order. This relative priority order is in addition to the user definable **ref-order**. For example, a ref-order of 'bits-ref1-ref2-ptp' would actually be BITS in (active CPM) followed by BITS in (standby CPM) followed by ref1 followed by ref2 followed by PTP. When **ql-selection** is enabled, then the QL of each BITS input port is viewed independently. The higher QL source is chosen.

On the 7750 SR-c4 platform CFM, there are two BITS input ports and two BITS output ports on this one module. These two ports are provided for BITS redundancy for the chassis. All settings of the signal characteristics for the BITS input apply to both ports. This includes the **ql-override** setting. When the CFM considers the BITS input as a possible reference, it will consider first the BITS input port "bits1" followed the BITS input port "bits2" in that relative priority order. This relative priority order is in addition to the user definable **ref-order**. For example, a ref-order of 'bits-ref1-ref2' would actually be "bits1" followed by "bits2" followed by ref1 followed by ref2. When **ql-selection** is enabled, then the QL of each BITS input port is viewed independently. The higher QL source is chosen.

The BITS output ports deliver a unfiltered recovered line clock from a SR/ESS port directly to a dedicated timing device in the facility (BITS or Standalone Synchronization Equipment (SASE) device). The signal selected will be one of ref1 or ref2. It cannot be the BITS input port signal nor can it be the output of the central clock.

When QL selection mode is disabled, then the reversion setting controls when the central clock can re-select a previously failed reference.

[Table 1: Revertive, Non-Revertive Timing Reference Switching Operation](#) shows the selection followed for two references in both revertive and non-revertive modes.

*Table 1: Revertive, Non-Revertive Timing Reference Switching Operation*

Status of Reference A	Status of Reference B	Active Reference Non-revertive Case	Active Reference Revertive Case
OK	OK	A	A
Failed	OK	B	B
OK	OK	B	A
OK	Failed	A	A
OK	OK	A	A
Failed	Failed	holdover	holdover
OK	Failed	A	A
Failed	Failed	holdover	holdover
Failed	OK	B	B
Failed	Failed	holdover	holdover
OK	OK	A or B	A

## Synchronization Status Messages (SSM)

SSM provides a mechanism to allow the synchronization distribution network to both determine the quality level of the clock sourcing a given synchronization trail and to allow a network element to select the best of multiple input synchronization trails. Synchronization Status messages have been defined for various transport protocols including SONET/SDH, T1/E1, and SyncE, for interaction with office clocks, such as BITS or SSUs (synchronization supply unit) and embedded network element clocks.

SSM allows equipment to autonomously provision and reconfigure (by reference switching) their synchronization references, while helping to avoid the creation of timing loops. These messages are particularly useful to allow synchronization reconfigurations when timing is distributed in both directions around a ring.

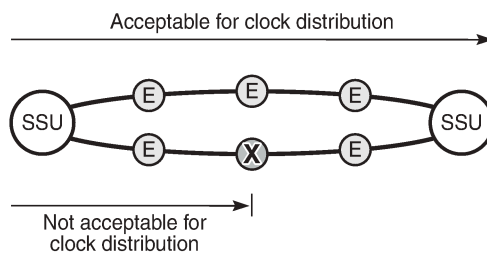
In SyncE, the SSM is provided through the Ethernet Synchronization Messaging Channel (ESMC). This mechanism uses Ethernet OAM PDU to exchange the Quality Level values over the SyncE link.

## SyncE Chains

Transmission of a reference clock through a chain of Ethernet equipment requires that all of the equipment support SyncE.

A single piece of equipment not capable of SyncE breaks the chain as shown in [Figure 14: Network Considerations for Ethernet Timing Distribution](#). Ethernet frames will still get through but downstream devices will recognize that the signal is out of pull-in range so they can not use it for reference.

Figure 14: Network Considerations for Ethernet Timing Distribution



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## Configuration

### Configuration 1 - QL-Selection Mode Disabled

The following example shows the configuration options for SyncE when ql-selection mode is disabled. Generally, North American SONET networks do not use the automatic reference selection mechanisms. If SyncE is being added into such a network, it would likely have ql-selection set to disabled.

```
*A:PE-1# configure card 1 mda 1
- mda <mda-slot>
- no mda <mda-slot>

<mda-slot>          : [1..2]

  access             + Configure access MDA parameters
  atm                 + Configure ATM MDA parameters
  clock-mode          - Configure clock mode and timestamp frequency
  egress              + Configure egress MDA parameters
  egress-xpl          + Configure egress MDA XPL interface error parameters
[no] fail-on-error    - Configure the behavior of the MDA state when an error is
                      detected
[no] hi-bw-mcast-src  - Enable/disable allocation of resources for high bandwidth
```



	multicast streams
ingress	+ Configure ingress MDA parameters
ingress-xpl	+ Configure ingress MDA XPL interface error parameters
[no] mda-type	- Provisions/de-provisions an MDA to/from the device configuration for the slot
named-pool-mode	+ Enable/Disable named pool mode
network	+ Configure network MDA parameters
[no] shutdown	- Administratively shut down an mda
[no] sync-e	- <b>Enable/Disable Synchronous Ethernet</b>

SyncE is enabled on MDA 1 of card 1 as follows:

```
*A:PE-1# configure card 1 mda 1 sync-e
```

After syncE is enabled, the configuration of MDA 1 is as follows

```
*A:PE-1# configure card 1 mda 1
*A:PE-1>config>card>mda#          info detail
-----
mda-type m4-10gb-xp-xfp
sync-e
named-pool-mode
  ingress
    no named-pool-policy
  exit
  egress
    no named-pool-policy
  exit
exit
ingress
exit
ingress-xpl
  threshold 1000
  window 60
exit
egress
  no hsmda-pool-policy
  hsmda-aggregate-burst
    no low-burst-multiplier
    no high-burst-increase
  exit
exit
egress-xpl
  threshold 1000
  window 60
exit
no fail-on-error
network
  ingress
    pool default
    no amber-alarm-threshold
    no red-alarm-threshold
    resv-cbs default
    slope-policy "default"
  exit
  queue-policy "default"
exit
egress
  pool default
  no amber-alarm-threshold
  no red-alarm-threshold
  resv-cbs default
  slope-policy "default"
```

```

        exit
    exit
    exit
    access
    ingress
    pool default
---snip---
```

The synchronous interface timing can be configured with the following parameters:

```

*A:PE-1# configure system sync-if-timing
- sync-if-timing

    abort          - Discard the changes that have been made to sync interface
                    timing during a session
    begin          - Switch to edit mode for sync interface timing - use commit to
                    save or abort to discard the changes made in a session
    bits           + Configure parameters for the Building Integrated Timing
                    Supply (BITS)
    commit         - Save the changes made to sync interface timing during a session
    ptp            + Configure parameters for Precision Timing Protocol (PTP)
                    timing reference
[no] ql-minimum   - Configure the minimum quality level of the input
[no] ql-selection - Enable/disable reference selection based on quality-level
[no] ref-order    - Priority order of timing references
    ref1          + Configure parameters for the first timing reference
    ref2          + Configure parameters for the second timing reference
[no] revert       - Revert/do not revert to a higher priority re-validated
                    reference source
[no] wait-to-restore - Configure the wait-to-restore timer
```

The synchronous interface timing configuration parameters for the first timing reference ref1 are the following:

```

*A:PE-1# configure system sync-if-timing ref1
- ref1

[no] ql-override  - Override the quality level of a timing reference
[no] shutdown     - Administratively shutdown the timing reference
[no] source-port  - Configure the source port for the first timing reference
```

The synchronous interface timing for ref1 with source port 1/1/2 is configured as follows:

```

configure
  system
    sync-if-timing
      begin
        ref-order bits ref1          # default setting
        ref1
          source-port 1/1/2
          no shutdown
        exit
      bits
        interface-type ds1 esf      # default setting
        input
          no shutdown
        exit
      exit
    revert
  commit
```

The detailed settings for the synchronous interface timing are as follows:

```
*A:PE-1>config>system>sync-if-timing# info detail
-----
no ql-minimum
no ql-selection
ref-order bits ref1 ref2 ptp
ref1
    source-port 1/1/2
    no shutdown
    no ql-override
exit
ref2
    shutdown
    no source-port
    no ql-override
exit
bits
    interface-type ds1 esf
    no ql-override
    input
        no shutdown
    exit
    output
        shutdown
        line-length 110
        no ql-minimum
        source line-ref
        no squelch
    exit
exit
ptp
    shutdown
    no ql-override
exit
revert
no wait-to-restore
-----
*A:PE-1>config>system>sync-if-timing#
```

The following output displays the associated show information.

```
*A:PE-1# show system sync-if-timing

=====
System Interface Timing Operational Info
=====
System Status CPM A           : Master Locked
Reference Input Mode           : Revertive
Quality Level Selection        : Disabled
Reference Selected              : ref1
System Quality Level           : unknown
Current Frequency Offset (ppm) : +0
Input Minimum Quality Level     : none
Wait to Restore Timer          : Disabled

Reference Order                 : bits ref1 ref2 ptp

Reference Mate CPM
Qualified For Use                : No
Not Qualified Due To             : LOS
Selected For Use                 : No
Not Selected Due To              : not qualified
```

```

Reference Input 1
  Admin Status           : up
  Rx Quality Level       : unknown
  Quality Level Override : none
  Qualified For Use      : Yes
  Selected For Use       : Yes
  Source Port            : 1/1/2

Reference Input 2
  Admin Status           : down
  Rx Quality Level       : unknown
  Quality Level Override : none
  Qualified For Use      : No
    Not Qualified Due To : disabled
  Selected For Use       : No
    Not Selected Due To  : disabled
  Source Port            : None

Reference BITS A
  Input Admin Status     : up
  Rx Quality Level       : failed
  Quality Level Override : none
  Qualified For Use      : No
    Not Qualified Due To : LOS
  Selected For Use       : No
    Not Selected Due To  : not qualified
  Interface Type         : DS1
  Framing                : ESF
  Line Coding             : B8ZS
  Line Length            : 0-110ft
  Output Admin Status    : down
  Output Minimum Quality Level : none
  Output Source          : line reference
  Output Reference Selected : none
  Output Squelch         : Disabled
  Tx Quality Level       : N/A

Reference PTP
  Admin Status           : down
  Rx Quality Level       : failed
  Quality Level Override : none
  Qualified For Use      : No
    Not Qualified Due To : disabled
  Selected For Use       : No
    Not Selected Due To  : disabled

```

```
=====
*A:PE-1#
```

## Configuration 2 - QL Selection Mode Enabled

The following example shows the configuration options for SyncE when ql-selection mode is enabled.

This is the normal case for European SDH networks.

SyncE is enabled as follows:

```
*A:PE-1# configure card 1 mda 1 sync-e
```

On port 1/1/2, the Synchronization Status Message (SSM) channel is configured to SDH, as follows:

```
*A:PE-1# configure port 1/1/2 ethernet ssm
- ssm

[no] code-type      - Set the SSM channel to either use sonet or sdh
[no] shutdown       - Enable/Disable SSM
[no] tx-dus         - Enable/disable always transmit 0xF (dus/dnu) in SSM
                    messaging channel

configure port 1/1/2 ethernet ssm code-type sdh
configure port 1/1/2 ethernet ssm no shutdown
```

The synchronization interface timing is configured as follows with timing reference ref1:

```
configure
  system
    sync-if-timing
      begin
        ql-selection
        ref-order bits ref1          # default setting
        ref1
          source-port 1/1/2
          no shutdown
        exit
        bits
          interface-type e1 pcm31crc # for Europe
          ql-override prc           # for Europe
          input
            no shutdown
          exit
        exit
      revert
    commit
```

The European QL-codes are the following: prc, ssu-a, ssu-b, sec, eec1. For North America, the QL-codes are: prs, stu, st2, tnc, st3e, st3, eec2. In this configuration example, Primary Reference Clock (PRC) is chosen.

```
*A:PE-1>config>system>sync-if-timing# info detail
-----
no ql-minimum
ql-selection
ref-order bits ref1 ref2 ptp
ref1
  source-port 1/1/2
  no shutdown
  no ql-override
exit
ref2
  shutdown
  no source-port
  no ql-override
exit
bits
  interface-type e1 pcm31crc
  ssm-bit 8
  ql-override prc
  input
    no shutdown
  exit
  output
```

```

        shutdown
        no ql-minimum
        source line-ref
        no squelch
    exit
exit
ptp
    shutdown
    no ql-override
exit
revert
no wait-to-restore
-----

```

The following output displays the associated show information.

```
*A:PE-1# show system sync-if-timing
```

```

=====
System Interface Timing Operational Info
=====

```

```

System Status CPM A           : Master Holdover
  Reference Input Mode         : Revertive
  Quality Level Selection      : Enabled
  Reference Selected           : none
  System Quality Level         : st3
  Current Frequency Offset (ppm) : +0
  Input Minimum Quality Level   : none
  Wait to Restore Timer        : Disabled

Reference Order                : bits ref1 ref2 ptp

Reference Mate CPM
  Qualified For Use             : No
  Not Qualified Due To          : LOS
  Selected For Use              : No
  Not Selected Due To           : not qualified

Reference Input 1
  Admin Status                  : up
  Rx Quality Level              : failed
  Quality Level Override        : none
  Qualified For Use              : Yes
  Selected For Use              : No
  Not Selected Due To           : ssm quality
  Source Port                   : 1/1/2

Reference Input 2
  Admin Status                  : down
  Rx Quality Level              : unknown
  Quality Level Override        : none
  Qualified For Use              : No
  Not Qualified Due To          : disabled
  Selected For Use              : No
  Not Selected Due To           : disabled
  Source Port                   : None

Reference BITS A
  Input Admin Status            : up
  Rx Quality Level              : failed
  Quality Level Override        : prc
  Qualified For Use              : No
  Not Qualified Due To          : LOS

```

```
Selected For Use           : No
  Not Selected Due To      :      not qualified
Interface Type             : E1
Framing                    : PCM31 CRC
Line Coding                : HDB3
Line Length               : 8
Output Admin Status        : down
Output Minimum Quality Level : none
Output Source              : line reference
Output Reference Selected  : none
Output Squelch             : Disabled
Tx Quality Level           : N/A

Reference PTP
  Admin Status             : down
  Rx Quality Level         : failed
  Quality Level Override   : none
  Qualified For Use        : No
    Not Qualified Due To   :      disabled
  Selected For Use         : No
    Not Selected Due To   :      disabled
=====
*A:PE-1#
```

Conclusion

With the world rapidly transitioning to IP/MPLS-based NGNs with Ethernet as the transport medium of choice, there is an increasing need to enhance services and capabilities while still leveraging existing infrastructure, thereby easing the transition while continuing to increase revenue and reduce the Total Cost of Ownership (TCO). In areas such as mobile backhaul, TDM CES etc., these requirements create a need for SONET/SDH-like frequency synchronization capability in the inherently asynchronous Ethernet network.

SyncE, natively supported on the Nokia SR OS routers, is an ITU-T standardized PHY-level way of transmitting frequency synchronization across Ethernet packet networks that fulfills that need in a reliable, secure, scalable, efficient, and cost-effective manner. It allows service providers to keep existing revenue streams alive and create new ones while simplifying the network design and reducing TCO.

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