

<p>Application note about usage of PTP features on ESC-RES-PTP (equipped with Broadcom BCM956440)</p> <p>SW releases referenced: GA5.03 and older</p>		
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Table of Content

- SW releases referenced: GA5.03 and older 1
- Document History 1
- Table of Content..... 2
- Introduction 3
- PTP Theory of operation 3
 - PTP device types..... 3
 - PTP message types..... 4
 - Synchronization overview 5
 - Establishing the master-slave hierarchy 5
 - Synchronization of time 5
- Summary of FASTPATH PTP support..... 6
- Configuration Examples 7
 - Telecom profile G8275.1..... 7
 - Default Profiles for boundary clock..... 8

Introduction

This document provides a quick overview about PTP and describes PTP functionality of FASTPATH currently running on the ESC-RES-PTP product including the configuration of the features using the FASTPATH CLI.

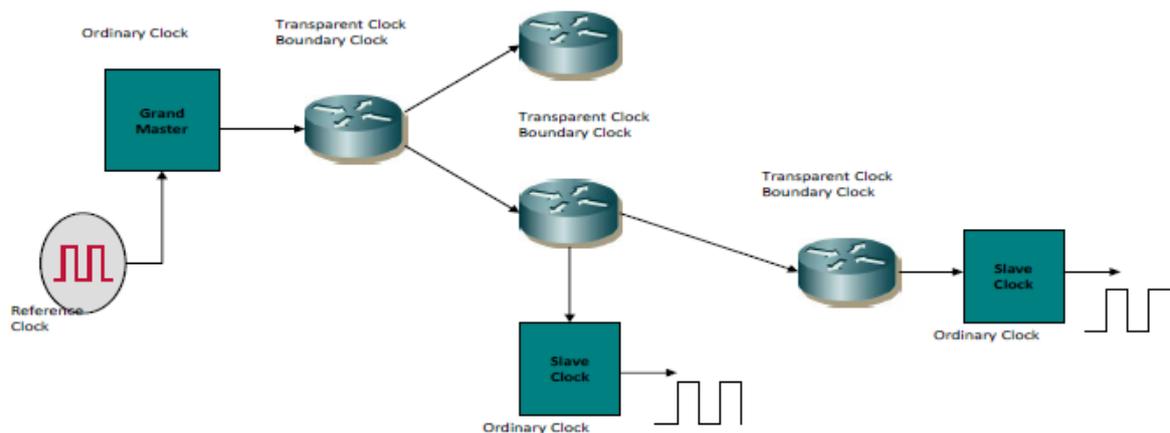
The document references FASTPATH 8.3.0 as the currently used version on the ESC-RES-PTP, it is used for GA5.02 and older.

PTP Theory of operation

IEEE 1588, also known as PTP enables precise synchronization of clocks (with a sub-microsecond accuracy) across a packet-based network. It enables systems of different precision, resolution and stability to synchronize to a grandmaster clock through an exchange of packets across the network.

Typical applications for this protocol include industrial automation, mobile cellular backhaul, financial trading, data center, power utility systems etc.

The protocol executes within a logical scope called a domain, time established within one domain is independent of the time in another domain.



PTP device types

A PTP system is a distributed, networked system comprising of PTP and non-PTP devices. Non-PTP devices are bridges, routers etc. that simply appear transparent to the PTP protocol (apart from adding some latency for the PTP packet in transit).

PTP devices get organized into a master-slave synchronization hierarchy based upon discovery and configuration.

PTP devices/nodes in the network can be classified into the following categories:

1. Ordinary clocks (OC) – These clocks are end-devices on a network and have a single PTP port. OCs can be of 2 types:
 - a. Master clock – This clock can be at the top of the master-slave hierarchy and, when selected as the best master clock in the PTP domain, determines the reference time for the entire PTP domain. In this case, the Master clock is the Grandmaster in this PTP domain. This clock is usually connected to an atomic clock or a GPS for a high-precision clock.

- b. Slave clock – This clock synchronizes itself to its master clock and can be used to drive local timing applications.
2. Boundary clocks (BC) – Boundary clocks are generally intermediate devices in the network and can have multiple PTP ports. BCs can be a source and/or destination of time. BC has slave ports on which it may synchronize to a master. Multiple master ports allow to synchronize/propagate time downstream to the slaves. The delay mechanism used with BCs is the Delay-Request/-Response mechanism, called End-to-End (“E2E”).
3. Transparent clocks (TC) – These clocks do not process PTP packets but only modify them to account for residence time correction (latency incurred while transit through this clock). The delay mechanism used with TCs is the PeerDelay-Request/-Response mechanism, called Peer-to-Peer (“P2P”).

FASTPATH supports BC configuration only.

PTP message types

PTP devices in a network synchronize time by exchanging PTP messages. PTP messages are classified into two categories:

1. Event Messages – Event messages are timestamped i.e an accurate timestamp is generated on transmission or receipt of such messages. Following are the types of event messages:
 - a. Sync
 - b. Delay-Req
 - c. Pdelay-Req
 - d. Pdelay-Resp
2. General Messages – General messages are not timestamped. Following are the types of general messages:
 - a. Announce
 - b. Follow_up
 - c. Delay_Resp
 - d. Pdelay_Resp_Follow_up
 - e. Management
 - f. Signaling

The Sync, Follow-Up, Delay-Req and Delay_Resp messages are used to generate and communicate timing information required to synchronize the PTP clocks using the delay request-response mechanism.

Pdelay_Req, Pdelay_Resp and Pdelay_Resp_Follow_up are used to measure link delay between two PTP clock ports implementing the peer delay mechanism. The link delay is used to correct the timing information in Sync and Follow_Up messages.

Announce messages are used for selecting which of the available master clocks is the best, and thus for establishing the synchronization hierarchy.

Management messages are used to query and update PTP data maintained by clocks. These messages can also be used to customize a PTP system, initialization and fault management.

Signaling messages are used for communication between clocks for all other purposes.

FASTPATH does not support P2P mechanism and hence Pdelay-req, Pdelay-req and Pdelay_resp_follow_up messages are not supported.

Follow_up messages are not supported, FASTPATH only supports 1-step mode.

In addition, management and signaling messages are not supported by FASTPATH.

Synchronization overview

Time synchronization across the network involves two phases:

- Establishing master-slave hierarchy.
- Synchronizing the clocks.

Establishing the master-slave hierarchy

Each port of the PTP node maintains a PTP state machine. As a part of the best master clock algorithm, valid announce messages received on each port are converted into a dataset and compared with the datasets of all available master clocks (including its own dataset, if this port is master-capable) to determine the best clock and clock port states. Besides during initialization, hierarchy-updates and faulty situations, there are three port states determining the master-slave hierarchy:

- 1) MASTER – This port is a source of time.
- 2) SLAVE – This port synchronizes to the device on its path on the MASTER port
- 3) PASSIVE – This port is neither the master nor does it synchronize to the master.

Each PTP device on the network establishes its PTP port states hence creating a master-slave hierarchy.

Synchronization of time

Once the master-slave hierarchy tree is established, the time synchronization happens through an exchange of PTP messages.

The message exchange pattern involves the following steps (1-step and 2-step mode):

- 1) The master sends a Sync message to the slave and notes the time t_1 at which it was sent. The sync message contains the GM time.
- 2) The slave receives the sync message and notes the receipt time, t_2 .
- 3) In 2-step clocks, the master conveys the time, t_1 in a Follow_Up message to the slave. In 1-step clocks, the Sync message carries the accurate timestamp, t_1 .
- 4) The slave now sends out a delay_req message to the master and notes time, t_3 .
- 5) The master notes the time of receipt of delay_req message, t_4 and sends the time t_4 in the delay_resp message.
- 6) At the end of this exchange of messages, the slave has 4 timestamps, t_1 , t_2 , t_3 and t_4 that can be used to compute:
 - a. Time offset between slave and master.

$$\langle \text{offset} \rangle = [(t_2 - t_1) - (t_4 - t_3)] / 2.$$
 - b. Average link delay between the slave and master.

$$\langle \text{meanPathDelay} \rangle = [(t_2 - t_3) + (t_4 - t_1)] / 2.$$

The slave calculates the time offset from the above data and corrects its local clock accordingly. The above calculation assumes that there is no asymmetry (i.e transmission time from master-to-slave and reverse is same) involved in the propagation times from master-slave and slave-master. Any asymmetry introduces an error in the computed value of the offset.

The link delay calculated using the delay-request, response mechanism is E2E. Link delay can also be calculated using the P2P (Peer-to-Peer) method wherein the delay is measured on a link-by-link basis.

FASTPATH only supports 1-step mode

Only E2E delay measurement mechanism is supported on FASTPATH.

Summary of FASTPATH PTP support

The following list shows the PTP features that are supported by FASTPATH, some not supported features are explicitly mentioned.

- Boundary clock configuration with max 32 ports
- Single PTP domain
- L2 multicast configuration
- ITU-T G.8275.1 telecom phase profile configuration
 - ITU-T G.8265.1 profile is not supported by FASTPATH
- MAC timestamping – 32 or 48 bit based on hardware support
 - PHY timestamping is not supported with the current design (Current Carrier and FASTPATH)
- Broadcom Servo support for all all-1588 BC network
- E2E delay measurement mechanism
 - P2P delay measurement is not supported by FASTPATH
- PTP message types supported
 - sync
 - delay-request
 - delay-response
 - announce
- Support for 1-step mode
 - 2-step mode not supported by FASTPATH
- 2 VLAN tags for one PTP clock port are not supported
- Hybrid mode (with SyncE) is not supported

Configuration Examples

The examples below show valid configurations being tested in the test lab.

Please note, all nodes within the same PTP domain must use the same PTP profile and shall use the same configuration values mentioned below.

For CLI command usage, please refer to the CLI reference manual of the ESC-RES-PTP.

Telecom profile G8275.1

The profile primarily specifies the following PTP parameters:

1. Domain number range – (24-43)
2. PTP messages Sync, Announce, Delay_req
3. Clock type supported is BC
4. Ethernet multicast messaging for PTP messages
5. PTP message rates
 - a. Sync, delay_req - 16 pkts/sec.
 - b. Announce – 8 pkts/sec.
6. Alternate BMCA
7. Priority1 – Default value of 128 is used.
8. Priority2 range is 0-255, default setting - 128

The following configuration example shows a combination which has been tested successfully

```
vlan database
vlan 100,200
exit

line console
exit
line telnet
exit
line ssh
exit

# Interface settings as required, depending on physical setup
# e.g.

interface 0/1
vlan pvid 100
vlan participation exclude 1
vlan participation include 100
exit

interface 0/24
vlan pvid 200
vlan participation exclude 1
vlan participation include 200
exit

interface 0/25
vlan pvid 100
vlan participation exclude 1
vlan participation include 100
exit

interface 0/28
vlan pvid 200
vlan participation exclude 1
vlan participation include 200
exit

router rip
exit
```

ESC-RES-PTP_AN-0002-PTP-v1.00

```
router ospf
exit
ipv6 router ospf
exit

# ptp settings
#-----

ptp enable

# domain number needs to be compliant with G.8275.1
# range between 24-43, default: 24

ptp clock boundary domain 24
profile telecom g.8275.1

# The ports on the switch connected to Master and Slave shall be in different VLANs

clock-port slave slave
transport ethernet multicast vlan 100
exit
clock-port master master
transport ethernet multicast vlan 200
exit

exit
exit
```

Default Profiles for boundary clock

Beside other predefined settings, the BC default profiles allow to use the set delay-req, announce, announce receive timeout and sync intervals within dedicated ranges:

- Announce messages intervals of 1, 2, 4, 8 or 16 seconds, with a default value of 2 seconds
- Announce receipt timeout intervals of 2-10 times the Announce interval, with a default value of 3
- Sync message intervals or 0.5, 1, or 2 seconds, with a default value of 1 second
- Delay request messages intervals of 1, 2, 4, 8, 16 or 32 seconds, with a default value of 2 seconds.

Please note, FASTPATH defines the default interval settings as follows:

- Default Announce interval: 1 1 packet every 2 seconds
- Announce timeout: 3
- Default sync interval: setting: -5: 32 packets per second
- Default Delay-req interval: -5: 32 packets per second

To setup BC default profiles, the values need to be changed, accordingly

The following configuration example shows a combination which has been tested successfully, with:

- sync interval -1: 2⁻¹ 2 p/s
- announce interval 0: 2⁰ 1 p/s
- delay-req interval -1 2⁻¹ 2 p/s

```
vlan database
vlan 100,200
exit

line console
exit
line telnet
```

ESC-RES-PTP_AN-0002-PTP-v1.00

```
exit
line ssh
exit

# Interface settings as required, depending on physical setup
# e.g.

interface 0/1
vlan pvid 100
vlan participation exclude 1
vlan participation include 100
exit

interface 0/24
vlan pvid 200
vlan participation exclude 1
vlan participation include 200
exit

interface 0/25
sfp auto-configure
vlan pvid 100
vlan participation exclude 1
vlan participation include 100
exit

interface 0/28
sfp auto-configure
vlan pvid 200
vlan participation exclude 1
vlan participation include 200
exit

router rip
exit
router ospf
exit
ipv6 router ospf
exit

# ptp settings
#-----

ptp enable

# default domain for non-G8275.1 profiles set to 0
ptp clock boundary domain 0

clock-port slave slave
transport ethernet multicast vlan 100
exit

clock-port master master
transport ethernet multicast vlan 200

# sync interval set to 2 p/s (2^-1)
sync interval -1

# announce interval set to 1 p/s (2^0)
announce interval 0

# delay-req interval set to 2 p/s (2^-1)
delay-req interval -1
exit

exit

exit
```