Ts2+ / Ts2+ + Multi-Sync Gateway

USER GUIDE

SJC-DEV7250-HR

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1 Introduction

1.1 Functional Overview

The Ts2+ and Ts2+ are small form factor, highly accurate Multi-Sync Gateways (PRS/PRC/PRTC clocks) that provide IEEE 1588-2008 PTP optical or electrical Grand Master and Boundary Clock functionality, Synchronous Ethernet (SyncE), 10 MHz, 1 PPS, ToD, sNTP, T1 and E1 with SSM timing/synchronization signals. IEEE 1588-2008 PTP is also known as PTP Version 2. The Ts2+ provides all outputs for supporting packet networks, and Ts2+ offers the same outputs plus four (4) additional outputs of port-selectable T1 or E1 with Sync Status Messaging (SSM).

Figure 1 The Ts2+

Ts2+/Ts2+ get time from the built-in GNSS receiver or 1PPS/ToD input or IEEE 1588-2008 PTP as input references. PTP algorithms are leveraged to deliver stringent timing for frequency and phase profiles. In event of input signal loss, the clocks will provide holdover depending on the chosen built-in oscillator.

Remote control and monitoring are provided over SSH, Web Interface and SNMP (v2, v3).

1.2 Interfaces

Ts2+ Interfaces are shown in Figure 2 and **Error! Reference source not found.** along with a brief description of them in the tables below them. Detailed description of the interfaces is provided in the REF section of this User Guide.

Figure 2 The Ts2+ Front Panel

Figure 3 The Ts2+ Rear Panel

Rear Panel Description
Ground connector
Primary power plug, 34 – 60 VDC / 28 – 40 VAC
Secondary power plug, 34 – 60 VDC / 28 – 40 VAC

Table 1 Ts2+ Rear Panel Interfaces

1.3 Typical Applications

Ts2+ is a small form factor IEEE-1588-2008 PTP Edge Grand Master and Boundary Clock that can be used for smart grid transmission and distribution substations. This Multi-Sync Gateway platform is designed for small cell clusters, C-RAN, and edge applications. For more information about PTP, see [1].

1.4 Oscillator Options

Standard: OCXO oscillator, 4-hour holdover for 1.5 µsec accuracy.

Superior: Super OCXO oscillator, 8-hour holdover for 1.5 µsec accuracy.

1.5 PTP Slave Capacity

The Ts2+ has variants that can support different unicast slave capacity (32, 128, 256, ..) slaves at up to 128 sync / delay packets per second when the MCE is operated as a master clock depending on the product SKU. The variants are configured at the factory and cannot be field upgraded at present. Contact information for ordering the Ts2+ with the supportable slave capacities is presented in the Contact Section of this User Guide on page 44. Section 9 of this User Guide presents all the variants available.

1.6 Components Block Diagram

The following block diagram defines the main components of the Ts2+ system along with the physical connections to each component.

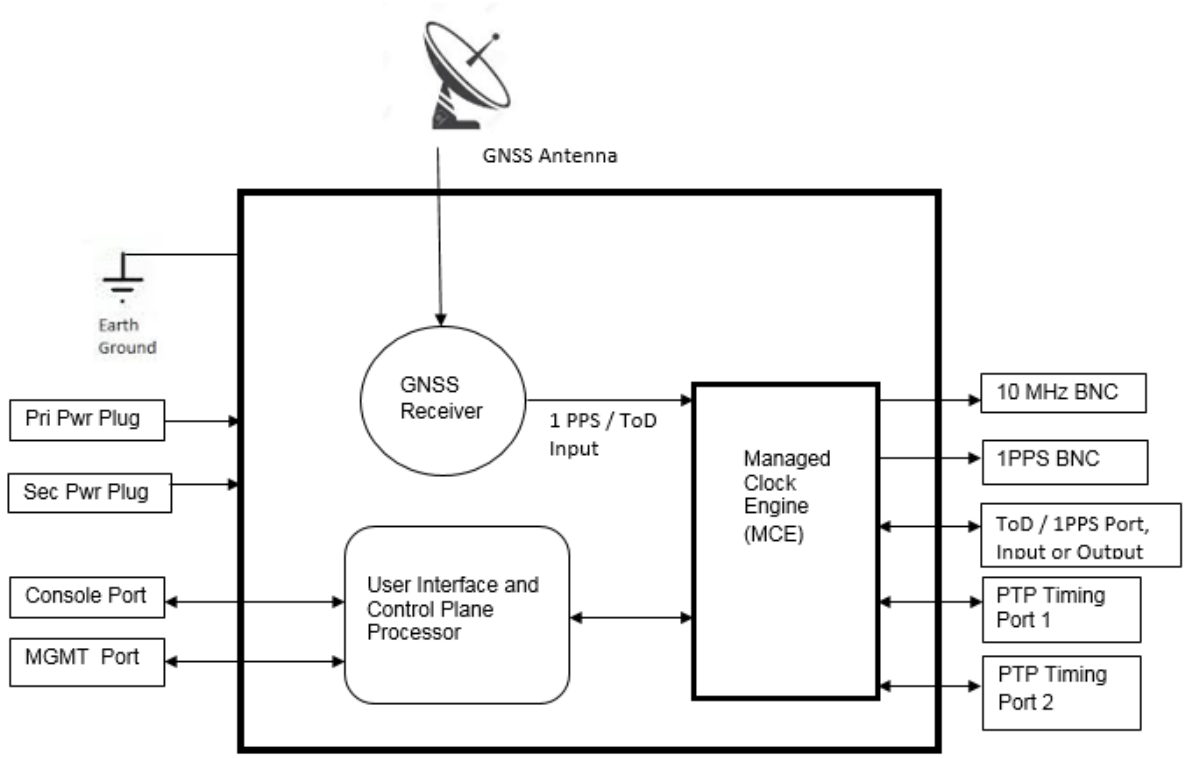


Figure 4 Ts2+ Components Block Diagram

- Managed Clock Engine (MCE) is a full packet network-based synchronization engine supporting IEEE 1588-2008 Precise Time Protocol. The MCE is where IEEE 1588-2008 PTP packet communication processing runs, and port / BNC provisioning is applied. GNSS signals and User Interface Processor (UIP) commands are sent to the MCE.
- User Interface and Control Plane Processor, which supports all the user access and connectivity to the entire system. The Processor supports DHCP, HTTP webpage/CLI access, SSH, SFTP, XML and SNMP (v2, v3).
- GNSS Receiver – GPS Receiver combined with either a Beidou or Glonass or Galileo Receiver with external antenna input. The selection of the constellation is user configurable.

2 Installation

Before the Ts2+ is installed, review the information in this section. If difficulties are encountered during the installation process, contact TesCom Customer Support, with the contact information provided in the Contact Section of this User Guide.

2.1 Security Recommendations

The Ts2+ Management port and PTP Timing ports should be installed behind the company's firewall to prevent public access. Additionally, the PTP Timing ports should be connected to a Local Area Network (LAN) or Wide Area Network (WAN) dedicated to transporting PTP timing messages.

2.2 Environmental Requirements

The Ts2+ operating temperature is 0°C to 50° C (-32°F to 122° F). Use only shielded cable for all signal wiring, including I/O, clocks and Ethernet. Use the Ground connector to appropriately ground the Ts2+ to earth ground.

2.3 Packaging List and Unpacking

The Ts2+ box contains the following:

- The Ts2+ Multi-Sync Gateway
- 48V DC power adapter

GNSS antenna, mounting bracket and console cable can optionally be supplied by the local distributor.

The Ts2+ is packaged to be protected from normal shock, vibration, and handling damage during shipment. Unpack and inspect the box contents as follows:

1. Wear a properly grounded protective wrist strap or suitable ESD protection.
2. Inspect the shipping box for signs of damage. If the box appears to be damaged, notify both the carrier and your TesCom distributor. Retain the shipping box and packaging material for the carrier to inspect.
3. Open the box, being careful to cut only the packaging tape.
4. Locate and save the printed packaging list and paperwork that is included in the box.
5. Remove the Ts2+ from the box and place the unit on an anti-static surface.
6. Locate and set aside additional parts which may be contained in the box.
7. Remove and dispose of the anti-static packaging from the Ts2+ and parts.
8. Verify that the model and serial number shown on the packaging list agrees with the model and serial number on the Ts2+. The model number can be found on a label affixed on the back of Ts2+. Contact your TesCom distributor if the model or serial number do not match.

2.4 Rack Mounting the Ts2+

The Ts2+ is half of a 19-inch rack, and occupies 1.75 in (4.5 cm, 1RU) of vertical rack space. An optional mounting bracket can be provided by the local distributor.

Warning: When rack mounting the Ts2+, use the original mounting screws provided with the mounting bracket so that the Ts2+ case will not be damaged. Do not substitute other mounting screws.

2.5 Power and Ground Connections

2.5.1 Power

The Ts2+ uses two VDC power sources, primary and backup. One or both power sources can be used. The power source can be 34 – 60 VDC. The VDC power connector uses two power feed lines, PWR A and PWR B. Ts2+ comes equipped with 2 Phoenix connectors to supply PWR A and PWR B and the user needs to connect the two terminals of it to their DC +/- supplies. The Ts2+ can also be powered by two VAC power sources, with 28 – 40 VAC supply.

IMPORTANT NOTE:

All operation, test and performance references and specifications that TesCom makes in its Ts2+ customer documents, and on its label, and to certification authorities are based on actual measurements ONLY when operated with the power supplies that TesCom provides or offers as an optional accessory. If operated with other brands and/or different specifications of power supplies, TesCom will NOT guarantee Ts2+'s proper operation, functionality or its compliance with the stated standards!

2.5.2 Ground

The Ts2+ ground is a 4 mm ground stud and is identified with the international ground marking as shown on **Error! Reference source not found.**. This ground wire should be routed to earth ground.

2.6 Input / Output Signal Connections

2.6.1 Management

Using a standard CAT5 cable, connect the cable to the port labelled MGMT of the front panel to your network. The data rate is 10/100 Base-T shielded RJ45 receptacle. The Management port supports both forms of IP address assignment, static or DHCP.

2.6.2 Console

A mini-USB connector labelled Console is available for Ts2+ to have a serial connection to a PC or laptop. The user can connect to Ts2+ console via terminal emulation applications on PC like Tera Term, PuTTy, minicom or Procomm to access the CLI over the serial port.

2.6.3 FREQ Out

BNC connector to port labelled FREQ Out to provide syntonized selectable frequencies output from Ts2+. The FREQ Out is DC Blocked.

2.6.4 Timing outputs, 1PPS

A configurable 1PPS is provided on a BNC connector, labelled 1PPS. Connect the 1PPS signal output to a frequency counter or any other measuring device.

2.6.5 Timing inputs/outputs, ToD / 1PPS

An RJ45 port is provided, labelled ToD / 1PPS. These ports are configurable to provide input or output for ToD / 1PPS. Both, the ToD format and the 1PPS signal are configurable. Refer to [2] for details of the timing ports physical/electrical characteristics.

2.6.6 PTP Port 1 and Port 2

One shielded RJ45 copper port and one SFP port is provided in parallel for Port 1. Likewise, one shielded RJ45 copper port and one SFP port is provided in parallel for Port 2. These ports provide PTP protocol messages to the timing network. See Gateway and Boundary clock Section of this User Guide for information on how the PTP Port 1 and Port 2 perform when the Clock Type Mode is configured as Gateway or Boundary clock. Selecting the Clock Type Mode is described in **Error! Reference source not found.** Section of this User Guide.

2.6.7 T1/E1 Outputs

Ts2+ provides up to four (4) outputs of port selectable T1 or E1 timing signals including Sync Status Messages (SSM), and/or 2048 kHz (2.048 MHz) square wave. The Ts2+ package includes an output cable and DIN-mount screw terminal for accessing the signals.

2.7 Connecting GNSS Antenna

Connect a suitable GNSS antenna, making sure the antenna has a clear view of the sky. When the GNSS receiver has good reception, the GNSS LED will be green. Ts2+ provides 5.0 VDC bias to power remote active antennas.

The GNSS antenna connector is a female SMA with external threads. Once the GNSS antenna is connected to Ts2+ antenna port, the GNSS operation can be configured and monitored in the **Error! Reference source not found.** Section of this User Guide.

2.8 Applying Power

Ts2+ does not have a power switch, so power should not be applied until the Ground connector is installed and connected to earth ground. To avoid accidental power up of the Ts2+, please re-check and ensure all connections are made including the Ground connector, before enabling external power to Ts2+.

3 Getting Started

This chapter describes on how the user can start using Ts2+ system after installing Ts2+ device and making the necessary connections to the various hardware interfaces.

3.1 Logging In With The Console

Log into Ts2+ using the mini-USB console. Default set-up is 115200 baud, 8 bits, no parity, and one stop bit. Login is admin and password are admin. Terminal emulation software like Tera Term, PuTTY, minicom and Procomm can be used for this purpose.

3.2 Set Up IP Address

The Management port IP address assigned to the Ts2+ can be viewed using the mini-USB console.

At the factory, the Ts2+ Management port IP is statically assigned to 192.168.2.100 with netmask of 255.255.255.0. This static IP address will be set after doing a restore to factory default configuration. To configure the Management port IP address for customer network:

1. Connect the Ts2+ mini-USB console port to a PC and run a terminal emulator application (Tera Term, PuTTY, minicom, Procomm, etc.) to login to the Ts2+. Login credentials are provided in the Ts2+ Basic Commands section. Use the “network configure” command to configure the Management port IP parameters. The Network Configure Command section provides CLI command details for setting the Management port IP address, subnet mask and Gateway IP.
2. With the Management port IP address configured successfully, the IP address can be entered into a browser URL field to access the Ts2+ Login page, with login credentials (admin/admin).

3.3 Remote Network Access to Ts2+

Ts2+ can be accessed remotely over IP network via the Management IP Interface. These are some of the methods to access Ts2+ remotely:

3.3.1 HTTP/Web Access

Ts2+ can be accessed over the web from any standard browser (IE, Chrome, Firefox, Safari, etc.). This provides a Graphical User Interface (GUI) for the user to configure or monitor Ts2+ operations.

The following web browsers / versions are supported by the Ts2+ HTTP server:

- Internet Explorer / v11.0.31
- Chrome / v63.0.3239.132
- Firefox / v56.0
- Safari / v11.0.3

3.3.2 Secure Shell (SSH) Access

SSH offers a secure shell for users to do remote login to Ts2+ using terminal emulation software. After login, the user can use Ts2+ CLI to send commands. Note that only SSH and not Telnet access is allowed for remote shell login.

3.3.3 SNMP (v2, v3)

Ts2+ can be one of many managed devices on the network with an Element Management System (EMS) or Network Management System (NMS) as the centralized server. Currently, only SNMP is supported for

PTPBASE-MIB specification from Timing Over IP Connections and Transfer of Clock (TICTOC) Working Group.

3.3.4 XML API

Applications using XML interface can access Ts2+ system via its XML API's. Support for this will be added in future release.

4 Command Reference

4.1 Ts2+ Basic Commands

The login credentials for accessing Ts2+ CLI shell is admin/admin. This is a list of the available commands related to the control and monitoring of the Ts2+. The CLI commands are case insensitive.

4.1.1 Help Command

After logging in, the user can enter “help” to get a list of commands and descriptions to be displayed on the command terminal.

```
TS2> help

Commands available:
  help                  Show available commands
  quit                  Disconnect
  history               Show a list of previously run commands
  show alarms           Show TS2 Alarms
  show status           Show TS2 Sync Status
  clear alarms          Clear TS2 Alarms
  system info           Show TS2 Version Information
  system Upgrade_Status Software Upgrade status
  system Upgrade_Start  Software Upgrade start
  network configure     Configure the MGMT Port
  network status        MGMT Port Status
  network ping          Ping Remote IP Address
  HTTPS Restore         Restore factory default certificate
  date                  Display/Set current date & time
  reboot                Reboot the TS2 System
  shutdown              Shutdown the TS2 System

TS2>
```

Figure 5 Help Command

4.1.2 History Command

To view the history of previously entered commands, enter “history”.

```
TS2> history

Command history:
  0. system info
  1. help

TS2> date
UTC time: 2021-06-23 19:43:00 (+37 sec)

TS2> history
```

Figure 6 History Command

4.1.3 Quit Command

To terminate the command session and log out, enter “quit”. Note that, pressing Control-C will have the same effect as “quit” command.

4.2 Show commands

The “show” command can be used to show alarms or clock status.

4.2.1 Show Alarms Command

This command will display any active Ts2+ alarms. If no alarms are present, the Alarm Name and State columns will be blank.

```
TS2> show alarms

        Alarm Name          |     Current Status      |     Last Failure     | Failure count
  --------------------------|-------------------------|----------------------|--------------
  System/Internal Error*    |     Not Active          |     Not Occurred     |     0
  GNSS Lock/Unlock          |     Locked              |     Not Occurred     |     0
  PTP Sync Lock             |     Locked              |     Not Occurred     |     0
  PTP Sync state            |     SYNCHRONIZING       |     Not Occurred     |     0
  PTP Port1 Link            |     Down                |     Not Occurred     |     0
  PTP Port2 Link            |     Down                |     Not Occurred     |     0

  *Internal hardware error

TS2>
```

Figure 7 Show Alarms Command

4.2.2 Show Status Command

This command shows the Managed Clock Engine’s Sync information – Ts2+ Sync Status and Ts2+ Sync State.

- Ts2+ Sync Status can be either LOCKED or UNLOCKED.
- Ts2+ Sync State can be one of the following: FREE RUNNING, SYNTONIZING, SYNCHRONIZING, or HOLDOVER.
- GNSS 1PPS Status can be either Stable or Unstable.
- GNSS ToD Status can be either Stable or Unstable.

```
TS2> show status
   PTP Sync Status      :  LOCKED
   PTP Sync State       :  SYNCHRONIZING
   GNSS 1PPS Status     :  Stable
   GNSS ToD Status      :  Stable

TS2>
```

Figure 8 Show Status Command

4.3 Inventory commands

The Inventory commands are system-level commands.

4.3.1 System Info Command

This command displays the basic system information – Ts2+ firmware version, on-board oscillator type, Managed Clock Engine Firmware version, number of PTP slaves supported and GNSS module type.

```
TS2> system info
FW Version: 2.0.0

XO: OCXO 4 hrs

Timing Engine FW Version: v2.1.2

Timing Engine FPGA Version: 2.8

PTP Slave Capacity: 32

GNSS Receiver: GPS Only


TS2>
```

Figure 9 System Info Command

4.3.2 System Upgrade Status Command

The Ts2+ System Firmware Upgrade Status will be displayed if the upgrade was initiated previously from either CLI or through Web User Interface.

```
TS2> system Upgrade_Status
FW upgrade not yet initiated

TS2>
```

Figure 10 System Upgrade Status Command

4.3.3 System Upgrade Start Command

The Ts2+ System Upgrade Start command will perform firmware upgrade when the following inputs are provided:

- File transfer protocol, 1 or 2 (for FTP or SFTP).
  Note: Option 1 (FTP) has been deprecated and is not available anymore
- Hostname, as either IP address or DNS name
- File name containing the upgrade FW

```
TS2> system Upgrade_Start
Usage:
system Upgrade_Start <protocol:(1:FTP, 2:SFTP)> <hostname> <file name>

TS2>
```

Figure 11 System Upgrade Start Command

4.4 Network Commands

The Network Command operates on the Management port. The user can set up the network parameters like enable/disable DHCP, static IPv4 address, netmask, and gateway addresses and display the current setting of it. By factory default, the Management port network parameters are set statically as follows:

- DHCP: Disabled
- IP Address: 192.168.2.100

- Netmask: 255.255.255.0
- Gateway: 0.0.0.0

4.4.1 Network Configure Command

This command lets the user configure Ts2+ Management port network parameters.

```
TS2> network config
Usage:
 network configure dhcp
 network configure ip <ip_addr> mask <netmask> gateway <gateway>

TS2>
```

Figure 12 Network Configure Command

4.4.2 Network Status Command

Get network status for the Management Port, PTP Timing Port-1, and PTP Timing Port-2.

```
TS2> network status

MGMT Port
   DHCP       : DISABLED
   IPv4 Addr  : 192.168.2.100
   NetMask    : 255.255.255.0
   Gateway    : 192.168.2.1
   MAC        : fc:af:6a:04:e9:5d
   Link       : UP

PTP Timing Port-1
   IPv4 Addr  : N/A
   NetMask    : N/A
   Gateway    : N/A
   IPv6 Addr  : fe80:0000:0000:0000:feaf:6aff:fe02:e95d
   MAC        : fc:af:6a:02:e9:5d
   Link       : Down

PTP Timing Port-2
   IPv4 Addr  : N/A
   NetMask    : N/A
   Gateway    : N/A
   IPv6 Addr  : fe80:0000:0000:0000:feaf:6aff:fe01:e95d
   MAC        : fc:af:6a:01:e9:5d
   Link       : Down

TS2>
```

Figure 13 Network Status Command

4.4.3 Network Ping Command

Send a ping message to a device on the network to test reachability. The results of the ping operation are displayed as “Ping Success” or “Ping Failed”.

The ping command takes an additional parameter “mgmt” or “ptp” to specify from which port the ping request needs to go out.

```
TS2> network ping mgmt
Usage:
 network ping mgmt <ip_addr>
 network ping ptp <ip_addr>

TS2> network ping mgmt 192.168.2.51
Ping Failed

TS2> network ping mgmt 192.168.2.52
Ping Failed

TS2> network ping mgmt 192.168.2.5
Ping Success

TS2> network ping ptp 192.168.2.5
Ping Success

TS2>
```

Figure 14 Network Ping Command

4.5 HTTPS Restore command

This command is provided in case of user uploading an incorrect file or wrongly formatted SSL certificate (PEM format) file via Ts2+ GUI. Executing this command gives the user to option to reset to factory default – removing the user uploaded SSL certificate file and restoring TesCom's self-signed certificate. This is needed if wrong user file got uploaded and user is unable to access Ts2+ from their browser.

```
TS2> HTTPS Restore
User certificate, if any, will be removed & default certificate will be restored
Do you want to continue? [Y/N] : n
Abort.

TS2>
```

Figure 15 HTTPS Restore Command

4.6 Date command

This command is provided mainly for initial customer lab bring-up or for those deployments where there is no timing reference (like GNSS) but need Ts2+ to act as a Grandmaster to propagate time and synchronization over PTP to slave units. This command enables the user to set the date and time (ToD) on Ts2+ manually. The user can enter the wall-clock time for the present date and time with this command with the "set" option. The date command without any parameters will display the current ToD.

```
Ts2> date
UTC time: 2023-03-14 09:43:34 (+37 sec)

Ts2> date set
Usage:
date
date set yyyy-mm-dd-hh-mm-ss (UTC)

Ts2> date set 2023-03-14-09-45-00
UTC time: 2023-03-14 09:45:00 (+37 sec)

Ts2>
```

Figure 16 Date Command

NOTE: If there is a proper timing reference available (like GNSS time or a remote PTP master), then the time set by this command will be overwritten by the actual ToD received from the timing reference. This command is not needed for normal operation with a good timing reference.

4.7 Reboot command

The Reboot command is to provide for user initiated manual reboot of Ts2+ system. Note that a firmware upgrade will automatically initiate reboot of the system.

5 Troubleshooting and Safety Considerations

This section provides some Ts2+ Troubleshooting and Safety Considerations. References are provided on how to get technical or sales assistance and how to obtain manual updates.

5.1 Troubleshooting

This section provides some Ts2+ Troubleshooting practices and the indicators for when a problem may be present in the Ts2+ operation. Some of the indicators of Ts2+ problems are Front Panel LED states, Interface and PTP Webpage statuses and the **Error! Reference source not found.** Webpage.

Symptom	Probable Cause	Recommended Action
Power LED is Red	User Interface and Control Plane Processor has not completed its boot up process.	Wait for a few seconds for it to turn orange and then finally green when all of software has been brought up. It takes approximately 4 minutes for the LED to turn green when system is ready for operation.
	Power supply does not meet Ts2+ requirements.	Verify that the voltage from the Ts2+ power source meets the specifications of the Power Section.
	Ts2+ Alarm condition is affecting power.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+ alarms that might affect power.

Symptom	Probable Cause	Recommended Action
GNSS LED is Off	Ts2+ has not completed its boot up process.	Wait approximately 4 minutes for software to complete booting.
	MCE running in PTP Only mode.	None. The LED is off when MCE is in PTP Only mode.

Symptom	Probable Cause	Recommended Action
GNSS LED is Red	1 PPS Input Error on Front Panel RJ45 port	Verify that the input RJ45 connector is securely inserted in the port. Verify that the 1 PPS source is outputting a 1 PPS signal.
	ToD Input Error on Front Panel RJ45 port	Verify that the input RJ45 connector is securely inserted in

		the port. Verity that the ToD source is outputting a ToD signal.
	GNSS input signal from Antenna and cable is missing or weak.	Verify that the GNSS Antenna coax is securely plugged into the SMA port. Verity that the GNSS Antenna signal is present.
	Ts2+ Alarm condition is affecting 1 PPS or ToD Input.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+ alarms that might affect 1 PPS or ToD Input.

Symptom	Probable Cause	Recommended Action
Sync Status LED is Off	MCE Processor has not completed its boot up process.	Wait approximately 4 minutes for the MCE processor to complete booting.

Symptom	Probable Cause	Recommended Action
Sync Status LED is Red	MCE is operating in GNSS Only mode and is not receiving the GNSS inputs.	Verify that the GNSS LED is Green.
	MCE is operating in PTP Only mode and is not receiving PTP Grand Master timing messages.	Verify that the PTP Port 1 or Port 2 is connected to a PTP Grand Master time source through the RJ45 or SFP connectors. Verify that the PTP Grand Master is providing PTP Timing messages.
	MCE is operating in GNSS Primary / PTP Secondary mode, or in PTP Primary / GNSS Secondary mode and is not receiving timing signals from either source.	Verify that the GNSS LED is Green. Verify that the PTP Port 1 or Port 2 is connected to a PTP Grand Master time source through the RJ45 or SFP connectors. Verify that the PTP Grand Master is providing PTP Timing messages.

	The user has selected external 1PPS / ToD inputs but has not connected the input sources.	On the Ts2+ Front Panel, connect the 1PPS / ToD RJ45 input source. On the **Error! Reference source not found.** web page, Enable 1PPS In and ToD In.
	Ts2+ Alarm condition is affecting inputs from the GNSS or the PTP Grand Master.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+ alarms that might affect timing input signals.

Symptom	Probable Cause	Recommended Action
Sync Status LED is Amber	MCE is operating in GNSS Only mode and is not synchronized to the GNSS input.	Verify that the GNSS LED is Green.
	MCE is operating in PTP Only mode and is not synchronized to the PTP Grand Master.	Verify that the PTP Port 1 or Port 2 is connected to a PTP Grand Master time source through the RJ45 or SFP connectors. Verify that the PTP Grand Master is providing PTP Timing messages
	MCE synchronization loop control system has not converged to the input timing source.	Wait 2 to 15 minutes for the MCE to converge and synchronize to the input timing source.
	Ts2+ Alarm condition is affecting MCE synchronization.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+ alarms that might affect MCE synchronization.

Symptom	Probable Cause	Recommended Action
Home Webpage – GNSS 1 PPS Status Unstable/Unavailable	GNSS input signal from Antenna and cable is missing or weak.	Verify that the GNSS Antenna coax is securely plugged into the SMA port. Verify that the GNSS Antenna signal is present.
	GNSS Antenna / cable configuration does not meet requirements of the Antenna input Section.	Verify that the GNSS Antenna / cable meets requirements of the Antenna input Section.

	Ts2+ Alarm condition is affecting inputs from the GNSS.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+ alarms that might affect GNSS input signals.

Symptom	Probable Cause	Recommended Action
Home Webpage – GNSS ToD Status Unstable/Unavailable	GNSS input signal from Antenna and cable is missing or weak.	Wait approximately 2 minutes for the MCE processor to complete booting.
	GNSS Antenna / cable configuration does not meet requirements of the Antenna input Section.	Verify that the GNSS Antenna / cable meets requirements of the Antenna input Section.
	The user has selected external 1PPS / ToD inputs but has not connected the input sources.	On the Ts2+ Front Panel, connect the 1PPS / ToD RJ45 input source. On the **Error! Reference source not found.** web page, Enable 1PPS In and ToD In.
	Ts2+ Alarm condition is affecting inputs from the GNSS.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+ alarms that might affect GNSS input signals.

Symptom	Probable Cause	Recommended Action
Interface :: PTP Timing Ports Webpage – Link State not up	PTP Timing Port 1 or Port 2 IP address configuration is incorrect.	Verify that IP configuration for Port 1 and Port 2 is correct on the **Error! Reference source not found.** Webpage. Verify that the network routers/switches/hubs between the Ts2+ Port 1 and Port 2 and the timing network are properly connected.
	Port 1 and Port 2 are in the same network / subnet as the MGMT port.	Make sure that the IP addresses of Port 1, Port 2 and MGMT port are on different networks/subnets.
	Ts2+ Alarm condition is affecting Timing Ports Link State.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+

		alarms that might affect Timing Ports Link State.

Symptom	Probable Cause	Recommended Action
Interface::MGMT Port Webpage – Link State not up	MGMT Port IP address configuration is incorrect.	Verify that IP configuration for MGMT Port is correct on the **Error! Reference source not found.** Webpage. Verify that the network routers/switches/hubs between the Ts2+ MGMT Port and the management network are properly connected.
	MGMT Port is on the same network / subnet as the timing ports.	Make sure that the IP address of the MGMT port and the addresses of Port 1 and Port 2 are on different networks/subnets.
	Ts2+ Alarm condition is affecting MGMT Port Link State.	Check the **Error! Reference source not found.** Webpage for information about any Ts2+ alarms that might affect MGMT Port Link State.

5.2 Safety Considerations

The following safety consideration should be used when handling and installing the Ts2+.

- When installing or working on the Ts2+ equipment, ESD wrist straps should be worn.
- Use the specified power supply and ground for the Ts2+ equipment as stated in the Power and Ground Connections section.
- Refer to the Applying Power section when applying power to the Ts2+ equipment.
- When rack mounting the Ts2+ equipment, use the original mounting screws provided with the mounting bracket so that the Ts2+ case will not be damaged. Do not substitute other mounting screws.
- Only authorized personnel should open the Ts2+ equipment enclosure. Unauthorized access to the Ts2+ equipment could result in equipment damage and voiding the Ts2+ warranty.
- Use caution when installing the GNSS antenna near, under, or around high voltage lines. The GNSS antenna should be equipped with proper external lightning protection/grounding to avoid equipment damage should the antenna receive a lightning strike.
- If the Ts2+ is rack mounted, 1RU above the Ts2+ enclosure must be left unoccupied for heat dissipation.

6 Managed Clock Engine Overview

6.1 Ts2+ Engine Modes

The Ts2+ Managed Clock Engine can operate in four different modes. The operational mode defines the functionality supported by the engine, Ts2+ clock behavior and its properties in different operating conditions. The operational mode is specified upon startup and can only be changed by restarting the engine on the **Error! Reference source not found.**.

- PTP Only
- GNSS Only
- GNSS Primary, PTP Secondary
- PTP Primary, GNSS Secondary.

In addition to these four modes, a Slave Only mode is supported. The clock can be switched to the Slave Only mode and back at any time and from any of above operational modes. The Slave Only mode is selected on the **Error! Reference source not found.** Webpage.

6.1.1 PTP Only mode

This is an ordinary PTP master-slave mode. The GNSS interface is disabled. In this mode, the clock normally acts as a PTP slave, but may also become a PTP master if no better clock exists on the network based on the Best Master Clock Algorithm (BMCA).

The clock class is initialized to value of DEFAULT (248).

6.1.2 GNSS Only mode

In this mode, the clock is a GNSS-clock and the GNSS is the only source of synchronization. The clock can never become a slave to another clock regardless of its clock class.

In this mode, the clock class is automatically controlled by the engine. The clock is initialized with class of DEFAULT (248), and when it locks to a stable GNSS signal it raises the class to PRC_SYNC (6) or APP_SYNC (13). If only the 1PPS-input signal is available, then the class APP_SYNC (13) is selected. If the ToD-input signal is available as well, then the timescale is automatically switched to PTP and the clock class is PRC_SYNC (6).

Later, if the GNSS-signal is lost, the clock switches to the holdover mode and lowers its class to PRC_HOLDOVER (7) or APP_HOLDOVER (14). If after the holdover period, the GNSS-signal is still not available the clock downgrades its class PRC_DEGRADATION_A (52) or APP_DEGRADATION_A (58) and stays as the PTP master in the free running mode. If a better clock exists on the network based on BMCA, the clock will switch to the PTP passive state.

6.1.3 GNSS Primary, PTP Secondary mode

This mode is almost the same as Mode 1, but after the holdover interval the clock degrades its class to PRC_DEGRADATION_B (187) or APP_DEGRADATION_B (193), so clock can potentially become a PTP slave if a better clock appears on the network.

This mode means that the Ts2+ clock has the GNSS-signal as its primary source of synchronization and the PTP as a backup source, i.e. when no GNSS-signal present.

6.1.4 PTP Primary, GNSS Secondary Mode

This mode is designed for unstable GNSS-reception environments, where the node having a better signal reception becomes a PTP master and all others become PTP slaves, even if they have their own GNSS-signal.

The clock is initialized with class DEFAULT (248) and the class is not changed by the engine while operating. Instead after detecting the stable GNSS-signal the engine increases the priority2 member of the Default Dataset (lowers its value) by some small margin, which might depend on the reception quality. That clock which has a higher priority2 (better GNSS signal reception) becomes the PTP master on the network and all others synchronize with it.

6.2 GNSS Interface

The Ts2+ supports GNSS L1 input signals from a GNSS antenna. Signal frequency is 1575.42 MHz for GPS; 1561.098 MHz for Beidou; and 1602.0 MHz for Glonass. The status and configuration of GNSS interface can be accessed via the **Error! Reference source not found.** Webpage.

6.3 Ts2+ Clock Sync States

Ts2+ clock at any instance of time can be in one of four following sync states:

- FREE RUNNING
- SYNTONIZING
- SYNCHRONIZING
- HOLDOVER
- UNKNOWN/ERROR

6.3.1 FREE RUNNING State

The Ts2+ clock comes into this state upon initialization. The Ts2+ clock time is not set, the clock class is DEFAULT (248), clock accuracy is UNKNOWN (0xFE).

The timescale is PTP, the UTC offset is initially set to 37 secs, leap flags are FALSE. In Free Running state, the clock frequency comes from the on-board oscillator.

6.3.2 SYNTONIZING State

This state is only possible when the 1PPS-input signal from the GNSS interface is available, but not the ToD-input signal and the clock become a PTP master.

When the Ts2+ engine is running in GNSS Only mode or PTP Only mode, the clock class is automatically changed to either PRC_SYNC (6) or APP_SYNC (13) and the clock accuracy is set to WITHIN_100_NS. In GNSS Primary, PTP Secondary mode, the clock class remains unchanged.

Note that the frequency can be traced, but not the time in this state. Once the ToD-input signal becomes available the clock switches to SYNCHRONIZING state.

6.3.3 SYNCHRONIZING State

The Ts2+ clock enters this state when it starts to synchronize its time and frequency with either a PTP or GNSS source. If the synchronization source is the GNSS, then both time and frequency are present and traceable. The timescale is changed to PTP, the clock class is changed to PRC_SYNC (6) and the clock accuracy is set to WITHIN_100_NS.

If the ToD-input signal becomes unavailable, while the 1PPS-input is still present, the Ts2+ clock switches to SYNTONIZED state.

If the synchronization source is a PTP master, then the clock quality remains unchanged. The timescale is set according to what is distributed by the PTP master. If the timescale distributed is PTP then the UTC offset (if valid) and leap flags are also set to master's values and the time source is set to PTP.

6.3.4 HOLDOVER State

The Ts2+ clock enters this state when the synchronization source is lost. If the clock was synchronized with PTP master its clock class remains unchanged. Otherwise the clock class is modified according the engine's operational mode and the clock accuracy is changed based on the time spent in the holdover state.

There is a static parameter which defines the clock stability. Currently it is fixed to 1 ns/s for a temperature-stable environment. During the holdover state an estimated error value is calculated and the clock accuracy is set according to that value.

The maximum time the clock stays in holdover state is defined by a holdover interval. By default, this value is set to 1000 seconds which gives about 1 microsecond error at the end of holdover interval. After holdover interval expires, the clock switches to the FREE RUNNING state, and its accuracy is reset to UNKNOWN (0xFE).

6.3.5 UNKNOWN/ERROR State

The Ts2+ clock has entered a failed or error condition and the sync state is unknown.

6.4 Unicast Operations

By default, unicast operations are disabled and the Ts2+ port operates in multicast mode. After unicast is enabled no multicast communications are possible.

The PTP port can be switched to unicast operations and back at any time using the **Error! Reference source not found.** and **Error! Reference source not found.** Sections of this User Guide.

6.4.1 Unicast Master

A Ts2+ port in unicast master state can support:

- Slave nodes which dynamically request unicast message transmission services from the master using the unicast negotiation mechanism.
- Slave nodes which do not support the unicast negotiation and simply rely on the reception of unicast messages from the master.

To accept unicast negotiation requests from slave nodes the master needs to be configured as follows:

- Unicast negotiation must be enabled.
- Slave acceptance filter must be populated. Note that in the current design, the slave acceptance filter is not user configurable and it is set to accept all slaves.

To provide message transmission services to slave nodes which do not support the unicast negotiation the master needs to be manually configured with the list of static slave nodes.

6.4.2 Enabling Master Unicast Negotiation

The unicast negotiation state is controlled by the **Error! Reference source not found.** Section of this User Guide.

When unicast negotiation is enabled the master accepts unicast transmission requests from negotiation-capable nodes. If a node is allowed by the acceptance filter and if enough resources are available the master grants message transmission services to that node.

If unicast negotiation is disabled no new requests are accepted, but all existing grants remain serviced until they are either expired or cancelled.

6.4.3 Maintaining Master's Slave Acceptance Filter

Note: In the current implementation, the slave acceptance filter is not user configurable and it is set to accept all slaves. In that respect, the following documentation on slave acceptance filter is only for academic purpose.

The slave acceptance filter is a mechanism to control which slave nodes may obtain unicast services from the master. If the filter table is empty no services will be granted to any node. The **Error! Reference source not found.** Section of this User Guide is used to manipulate the slave acceptance filter.

As the result of the filter table modification, if a node becomes unacceptable or message rates of any active grants becomes beyond the newly configured limits, all affected grants will be cancelled.

6.4.4 Maintaining Master's List Of Static Slaves

Note: In the current implementation, this is not supported. To provide unicast services to slaves which do not support the unicast negotiation the master maintains a list of static slave nodes.

When a node is in this list the master can send Announce and Sync messages to that node and can reply to Delay Request messages received from that node.

Error! Reference source not found. Section of this User Guide is used to monitor and manipulate the static slave node list.

6.4.5 Unicast BOTH Mode of Operation

The PTP port on Ts2+ can be configured to automatically assume either the role of a unicast Master or an unicast Slave when the port mode is unicast BOTH. For example, if a port is in unicast Master mode and has GNSS reference and if the GNSS reference is lost, it can switch over to unicast Slave to another GM in the network.

It is important to note that it is mutually exclusive, and cannot assume both, unicast Master and unicast Slave role at the same time as the case would be in a single-armed boundary clock.

6.4.6 Unicast MIXED Mode of Operation

The MIXED mode of operation is also referred to as PTP hybrid mode. In this mode, the Announce and Sync messages are sent as a multicast, but the delay mechanism is in unicast mode. The advantage of doing so is two-fold in anetwork of single master and many slaves that are being serviced by that Master:

• The Master does not have to replicate the Announce and Sync (and Follow-up) messages for each slave in its time domain or in the network,

• Each slave does not have to receive, process and drop DelayReq and DelayResponse messages from other slaves in the network.

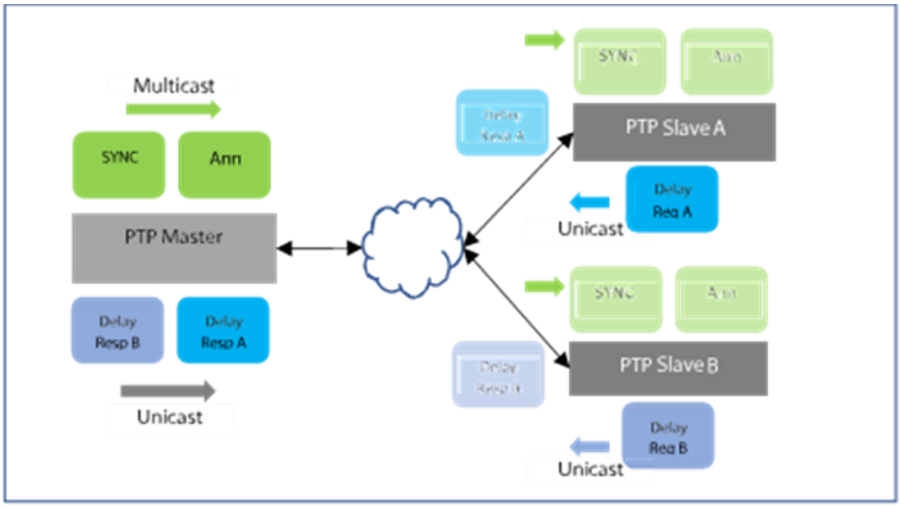


Figure 17 MIXED Mode of Operation

The delay mechanism can be end-to-end (E2E) as show in the figure or can be peer-to-peer(P2P). In P2P, typically the peer delay mechanism (i.e., sending a Peer Delay Request and getting a Peer Delay Mechanism) is typically over multicast. But, in the case of MIXED mode and with P2P delay mechanism enabled, then the peer unicast addresses may be used and need to be statically configured.

The MIXED mode of operation is used in the broadcast industry with SMPTE profile.

6.4.7 Monitoring Unicast Operations

Monitoring the status of master unicast operations can be done on the **Error! Reference source not found.** and **Error! Reference source not found.** Sections of this User Guide.

6.5 PTP Clocks

IEEE 1588 v2 standard specifies different types of clocks that are used to propagate timing and synchronization. The grandmaster, master and slave (or subordinate) clocks are generally grouped as ordinary clocks. Intermediate switches and routers in the network can either be a Transparent Clock (TC) or Boundary Clock (BC). BCs are preferable to TCs as they provide more accuracy and can easily scale in large networks. Using a hierarchical architecture and using divide and conquer principle, a single grandmaster does not have to serve large number of slaves.

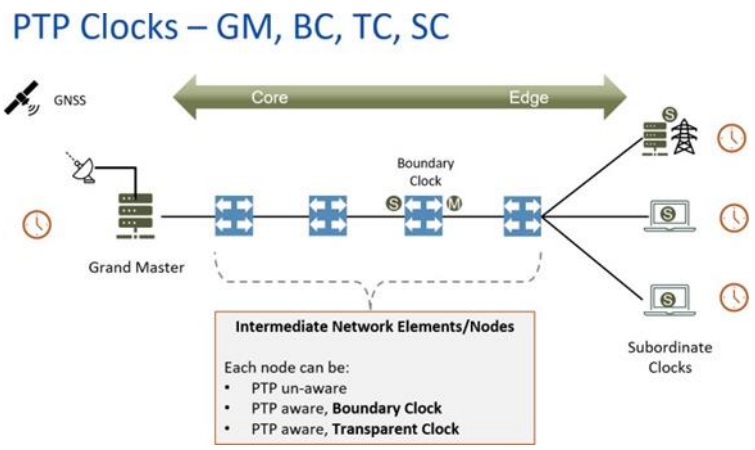


Figure 18 PTP Clocks

6.6 Gateway and Boundary clock

The Ts2+ Multi-Sync Gateway has the capability of using both of its Ethernet ports (Port 1 and Port 2) as PTP ports. This opens the possibility of using the Ts2+ as a two-port gateway or boundary clock. For more information about Gateway and Boundary Clocks, see [1].

6.6.1 The Gateway Clock

The Gateway Clock (GC) can be considered as an Ordinary Clock (OC) with two ports, with one port configured as a master and the other port configured as a slave.

Another capability of the Ts2+ is for both ports to be configured as master ports. In that configuration, each port would have its own IP address and be associated with different subnets. However, both ports would have the same PTP Clock Identity. With each port connected to different subnets, the ports can serve as GM for the slaves on the two different subnets. The slaves on the two separate subnets would then use the BMCA to select the best GM from which to recover the PTP time messages.

6.6.2 The Boundary Clock

The Boundary Clock (BC) has one port defined as a master port and the second port as a slave port receiving PTP messages from an external Grand Master (GM) Clock. The PTP Clock Webpage is used to set the Ts2+ clock as a boundary clock, described in **Error! Reference source not found.** Section of this User Guide.

The following figure illustrates the difference between a Gateway Clock and a Boundary Clock. The slaves connected to a Gateway Clock will only recognize the Gateway Clock as a Grand Master and not any other upstream masters. In the following figure, the slaves connected to the Gateway Clock will not recognize the Clock 1(GM). The slaves that are connected to the Boundary Clock will recognize Clock 1(GM) as the Grand Master.

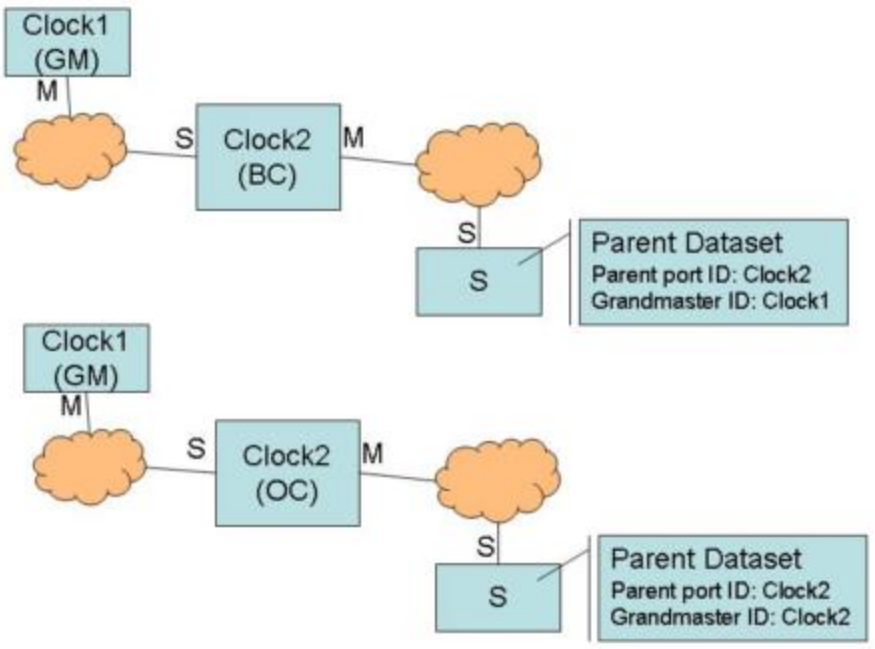


Figure 19 Gateway Clock (GC) vs. Boundary Clock (BC)

6.7 PTP Servo Configuration Parameters

6.7.1 Main Time Constant

The main time constant used by the PTP Servo algorithm, in seconds. A longer time constant makes the oscillator frequency change more slowly and less responsive to changes in a network environment, such as the temperature or the network delays. For networks with low packet delay variation a short time constant (e.g. 30 sec) can be used. For networks with unknown or high traffic load, a longer time constant (e.g. 300 sec) would be a better setting. A longer time constant requires a more stable oscillator to be effective. For example, a time constant above 500 sec requires the Ts2+ super OCXO. The default value is 100 sec.

6.7.2 Startup Time Constant

The time constant used during the period of obtaining a preliminary synchronization (startup phase), in seconds. If this field is set to 0 the main time constant will be used. This parameter can help to shorten the synchronization time when a long main time constant is required. But values that are too short may lead to unwanted oscillations which increase the total time required to synchronize and eliminate any positive effects of shorter startup time constant. The default value is 0.

6.7.3 Quality Threshold

Defines the maximum allowed time variation in nanoseconds before the slave goes into holdover. The time variation is based on a statistical measurement of time error between the source input time and the slave's formulated time, where the source input time is the GNSS or ToD + 1PPS input. The default value is 1500 nsec.

6.7.4 Network Type

The Network Type selection is used to adjust the loop control algorithm behavior according to the underlying network characteristics. There are two types of networks currently supported: Unmanaged and Managed.

“Unmanaged” selection is used for a network with unknown or unspecified packet delay and delay variation or with packet delay distribution that may dramatically change its characteristics over time.

“Managed” selection is used for a network where the packet delay and delay variation distribution are specified and that always has a distinct “floor”. That “floor” may vary over the time, but the distribution limitations provided by the “floor” should still be present.

6.7.5 Frequency Out

The syntonized frequency that will be output on the FREQ Out port on the Ts2+ Front Panel.

6.8 SNTP

Besides PTP timing protocol, Ts2+ supports SNTP (Simple Network Time Protocol) for those applications where very high precision (i.e., sub-microsecond accuracy) synchronization is not a requirement. Manyclient devices and their operating systems synchronize to a NTP server. Ts2+ can operate as a Stratum-1 NTP server to provide of this time. In this regard, Stratum-1 NTP server is the same as SNTP server.

Ts2+ can operate as a PTP grandmaster or as a NTP Stratum-1 server, by getting time reference from GNSS and distributing that over the network to PTP slaves or NTP clients. If SNTP is enabled, then Ts2+ can service both, PTP slaves as well as NTP clients.

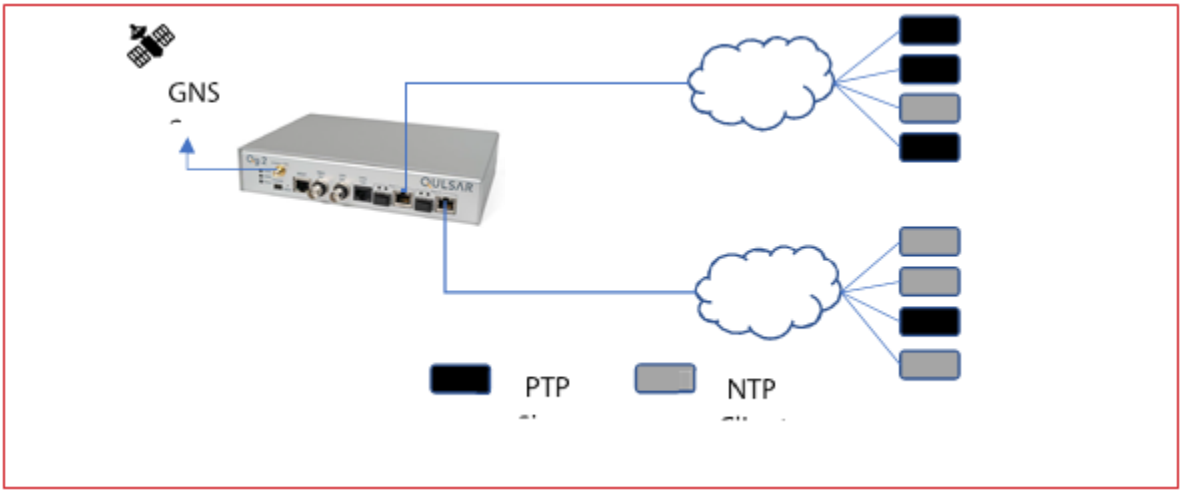


Figure 20 Support of PTP slaves and NTP Clients

SNTP server implementation of Ts2+ as per the specification in RFC 4330 - Simple Network Time Protocol (SNTP) Version 4 for IPv4, IPv6 and OSI.

7 Network Architecture and Deployment Considerations

7.1 Network Operator's or Carrier's Perspective

The diagram below shows the carrier's perspective of the network with a view of the synchronization requirements. The left side of the drawing is more on the customer/applications side which require synchronization while the core of the network is on the right. Traditionally, from TDM world to packet world, the synchronization flow is hierarchical, starting from the core and propagating down to the end-points.

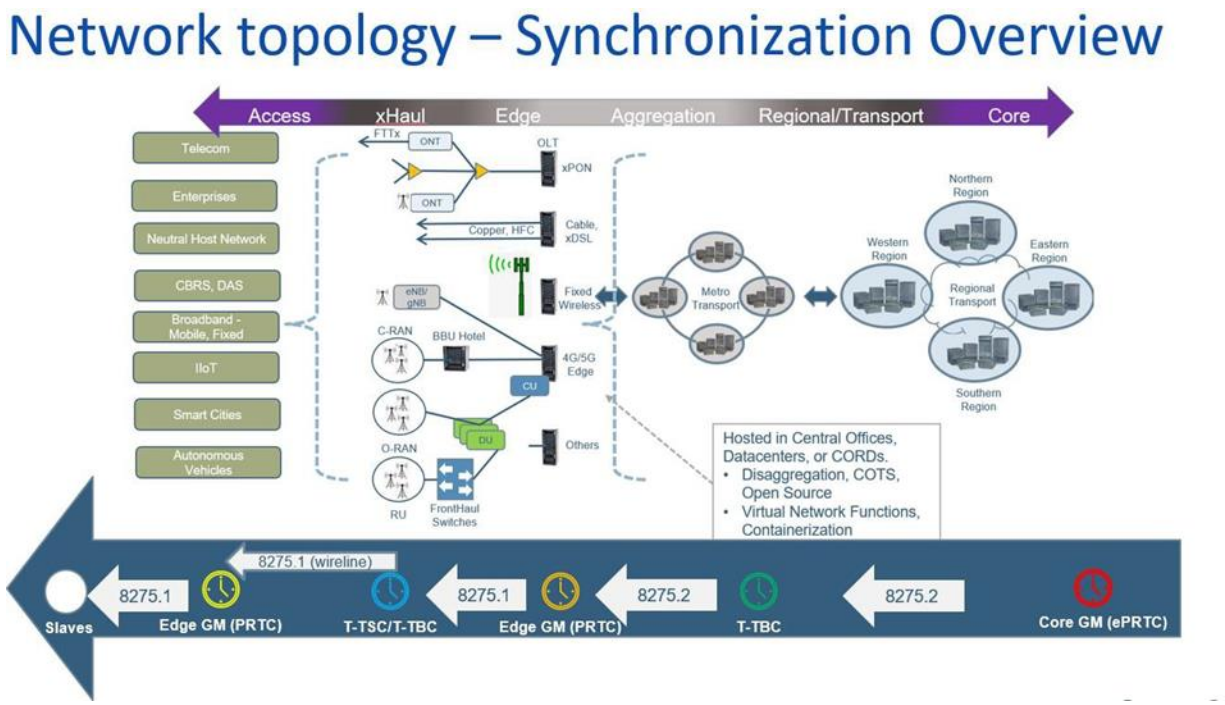
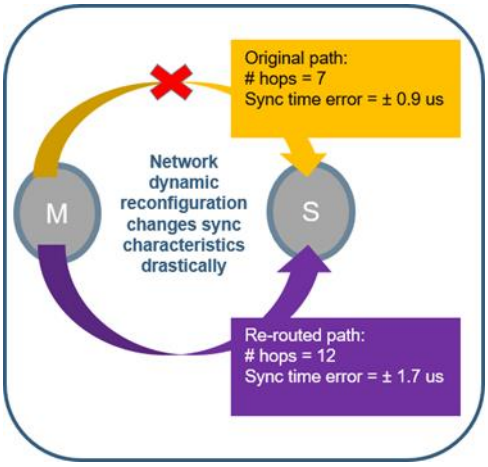


Figure 21 Network Topology Synchronization Overview



For tighter precision, this method of propagation is changing with more Grandmasters put in the network path and the Grandmasters are moving to the edge. Timing and synchronization over large segments of network has its challenges, especially when higher layer protocols and traffic engineering (TE) methods can dynamically re-route traffic based on network conditions.

With less hops, a good accuracy and precision can be maintained. Conceptually, this is similar to how low-latency applications require caching or mirroring of data locally on-site or at the edge. The figure shows how network dynamic reconfiguration could impact the sync characteristics at the end-point (PTP slave).

7.2 PTP Profiles

Ts2+ provides the flexibility and ease for customers to select one of the many PTP profiles provided to set the Ts2+ timing engine mode of operation. In the current release, both ports will be set to the same profile and not independently.

There are many different PTP profiles that have been specified based on specific industries like Telecom, Power, Broadcasting, Enterprise, etc. while a few others are being created. These profiles will put some restrictions on some of the configuration parameters that are part of the IEEE 1588 to make it simpler and targeted towards specific industry and deployment. Typically, the profile dictates the PTP domain value range, PTP over L2 (Ethernet) or IP/UDP, multicast or unicast or mixed mode, message rates, announce timeout, delay mechanism, datasets, etc. are customized per profile. This covers most of it but for some of the profiles some additional parameters also need to be specified.

With Ts2+, the user can select one of these PTP profiles for the timing engine to operate in. To make it user friendly, once the profile is selected, internally Ts2+ software will set up the most of the PTP profile specific parameters to default values for that profile and it is up to the customer if they want to customize it further (like a power user).

Below is the list of PTP profiles that Ts2+ currently supports. More profiles will be added in future releases and this documentation will be updated accordingly.

7.2.1 1EEE 1588 Default Profile

This is the profile that is specified by IEEE 1588 Standard itself. It uses domain 0, PTP over IPv4/UDP and multicast mode of operation.

7.2.2 G.8275.1 Telecom Profile

This is one of the Telecom profiles specified by ITU-T and is recommended for new deployment or green-field networks comprising switches. It is expected that every node or element in the network is PTP-aware, or in other words, the network has full on-path support. This is used in conjunction with Synchronous Ethernet (SyncE) which provides the physical layer frequency synchronization. G.8275.1 uses L2 (Ethernet) multicast as PTP transport layer. This is a better option as using the physical layer assist for frequency and phase/time from PTP over packet network as it gives the best of both worlds.

With G.8275.1 profile and SyncE, a slave or the network is congruent if the PTP source and SyncE source is traced back to the same Grandmaster. If they are not, then it is said to be non-congruent. In either case, the SyncE frequency reference that is used by the slave should be traceable as specified in the Quality Level(QL) value in the ESMC messages.

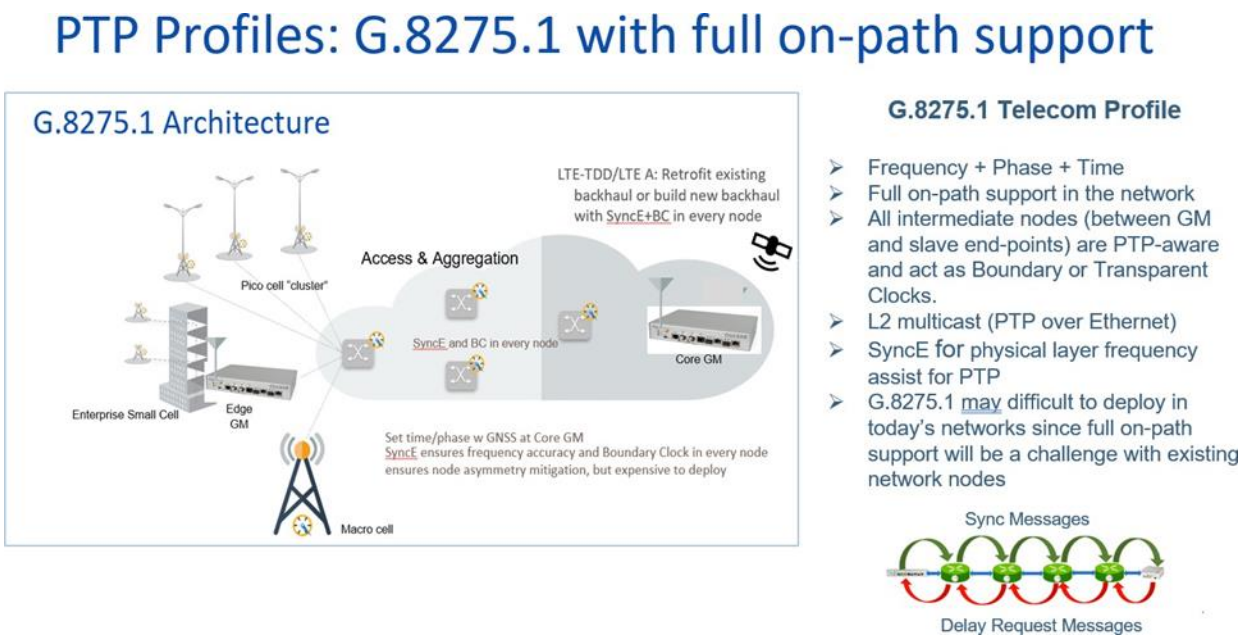
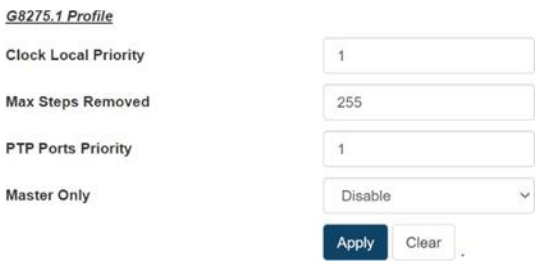


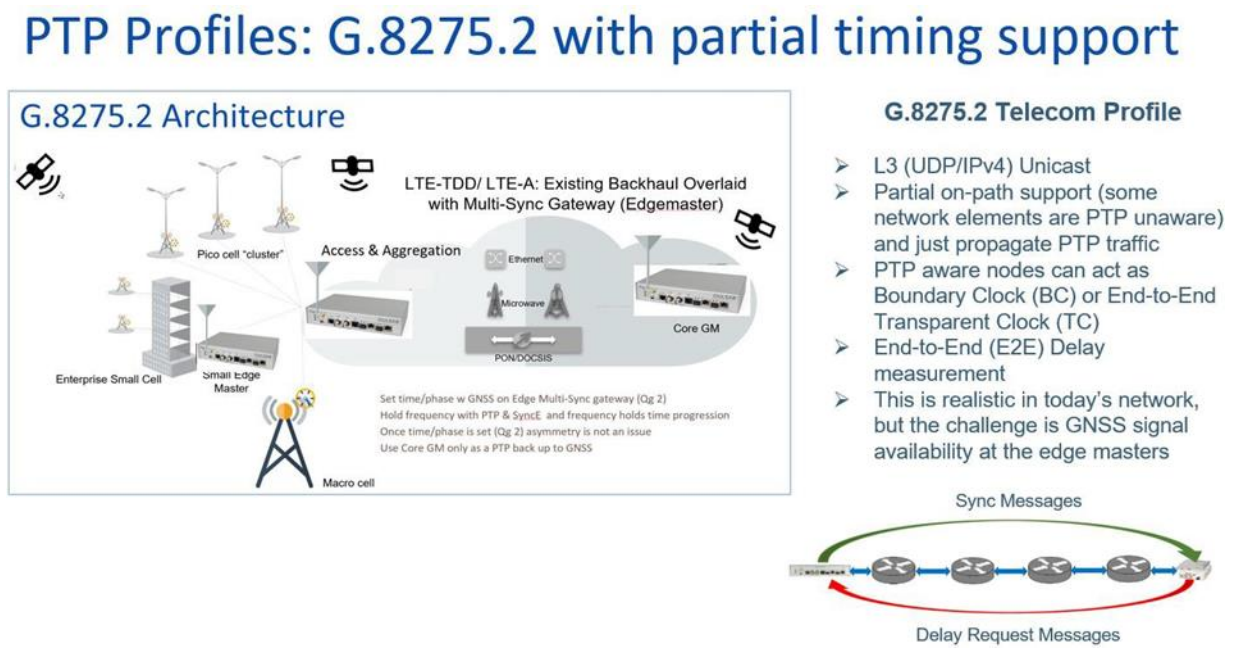
Figure 22 G.8275.1 PTP Profile

In PTP::Clock page, additional configuration parameters are provided that are specific to G.8275.1 profile as shown below.



7.2.3 G.8275.2 Telecom Profile

This is another Telecom profile specified for legacy (brownfield) networks that work in conjunction with the older networks which can comprise switches and routers. This profile is used where there are network elements which are not PTP-aware and do not participate in PTP protocol processing. They act as pass-through elements but introduce additional delays which the end-points or slaves need to compensate for, to maintain timing precision. Since the sync path traverses over routers, this profile specifies PTP over UDP/IPv4 or UDP/IPv6 and unicast mode of operation.



In PTP::Clock page, additional configuration parameters are provided that are specific to G.8275.2 profile as shown below.

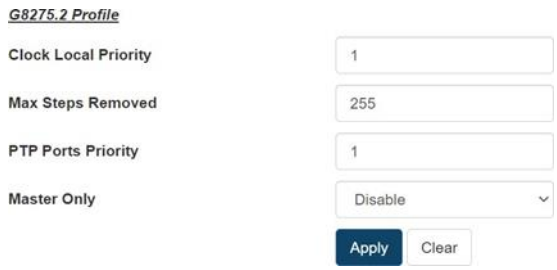


Figure 23 G.8275.2 Profile - Additional Configuration Parameters

7.2.4 G.8265.1 Telecom Profile

This is yet another Telecom profile from ITU-T for providing frequency-only synchronization (or syntonization) over packet network. This was specified to support legacy TDM networks like (SONET/SDH, etc.). It does not provide time/ phase synchronization.

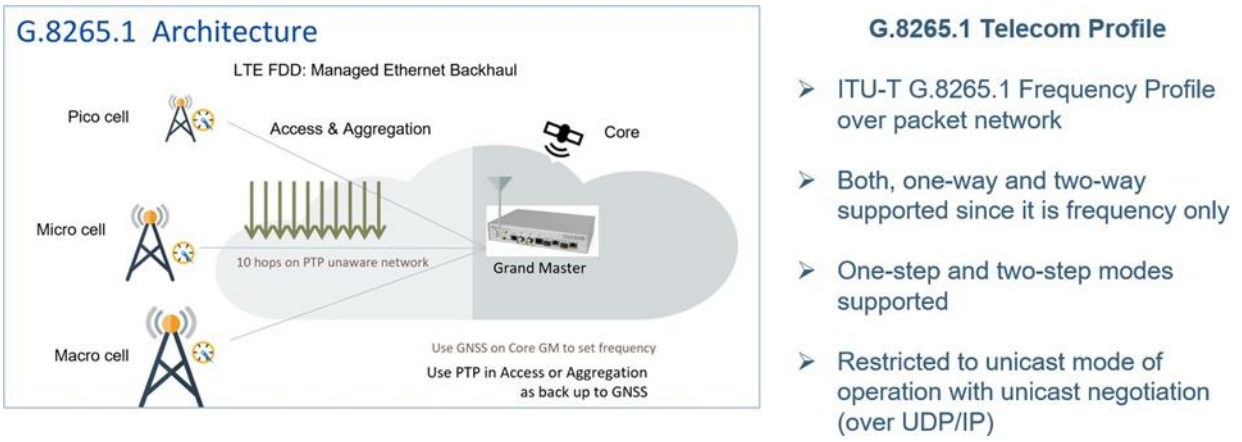


Figure 24 G.8265.1 PTP Profile

7.2.5 Power Version-1 Profile

This profile is specified for the power industry mainly in power system protection, control, automation, and data communication applications. This specific Power V1 is according to the IEEE C37.238-2011 standard. It uses PTP over L2 multicast, P2P delay mechanism and one of the salient features of this profile is that it uses priority tagging for VLAN (i.e., VLAN-id = 0, priority = 4).

In PTP::Clock page, additional configuration parameters are provided that are specific to Power Profile v1 as shown below.

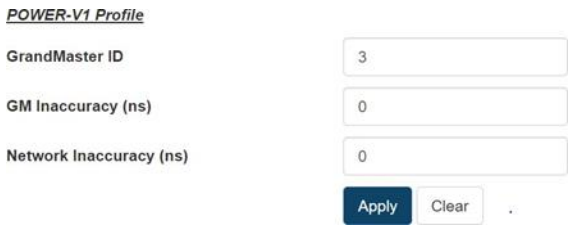


Figure 25 Power Profile v1 - Additional Configuration Parameters

7.2.6 Power Version-2 Profile

This is version 2, 2017 edition of the power industry standards, IEEE C37.238-2017). One of the main differences from the 2011 edition is that there is no restriction on VLAN priority tagging on the PTP ports.

In PTP::Clock page, additional configuration parameters are provided that are specific to Power Profile v2 as shown below.

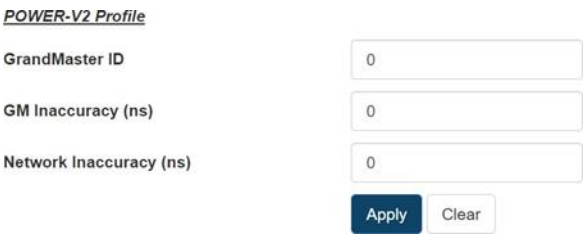


Figure 26 Power Profile v2 - Additional Configuration Parameters

7.2.7 Power Utility Profile

This profile is specified as in Power Utility (IEC/IEEE 61850-9-3:2016) standard: Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation. In many aspects, this is very similar to Power v2 profile mentioned earlier.

In PTP::Clock page, additional configuration parameters are provided that are specific to Power Utility profile as shown below.

Power Utility:

Figure 27 Power Utility Profile - Additional Configuration Parameters

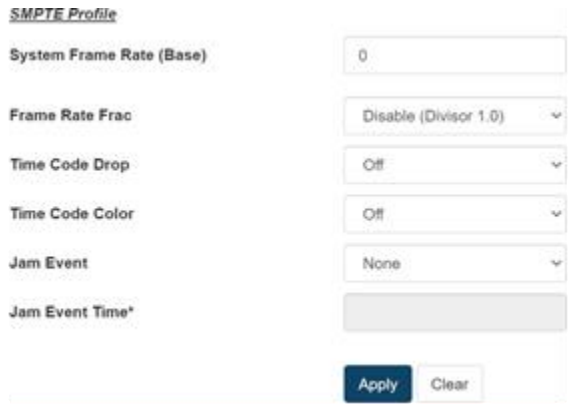
7.2.8 SMPTE Profile

SMPTE 2059 is a standard from the Society of Motion Picture and Television Engineers (SMPTE) that describes how to synchronize video equipment over an IP network. The standard is based on IEEE 1588-2008. SMPTE 2059 is published in two parts on 9 April 2015:

- SMPTE 2059-1 – Defines signal generation based on time information delivered by the IEEE 1588 protocol.
- SMPTE 2059-2 – Defines an operating profile for the IEEE protocol optimized to the needs of media synchronization.

The new television standard as specified by ATSC 3.0 uses SMPTE and for synchronization via IEEE 1588 v2. ATSC 3.0, also known by the moniker NextGen TV, is a major version of the ATSC standards for television broadcasting created by the Advanced Television Systems Committee (ATSC).

In PTP::Clock page, additional configuration parameters are provided that are specific to Power Utility profile as shown below.



7.3 Synchronous Ethernet (SyncE)

7.3.1 What is Synchronous Ethernet?

Synchronous Ethernet feature is to help in providing frequency syntonization over packet based networks using Ethernet. It provides a mechanism to distribute frequency from Ethernet packet network to Time Division Multiplexed (TDM) circuits and nodes. For this, the (natively asynchronous) Ethernet physical layer is utilized in a fashion similar to (natively synchronous) SONET/SDH networks, with clock recovery and the assist of a new IEEE 802.3 slow-protocol packet called Ethernet Synchronization Channel Message (ESMC). This ESMC message is to convey the reference clock quality and traceability information in the form of Quality Level (QL). The SyncE feature is considered a physical layer characteristic unlike PTP which is in higher-layer software.

In today's and next generation networks, there is need for time and not just frequency synchronization. That is, a combination of frequency, phase and time-of-day synchronization is required and expected to be delivered in a reliable and resilient fashion. Synchronous Ethernet can provide a stable frequency and can also be used as a local short-term holdover clock for maintaining time.

The Synchronous Ethernet standard is specified in ITU-T G.8262 and ESMC message in ITU-T G.8264.

7.3.2 SyncE feature in Ts2+

Synchronous Ethernet feature is a configurable option on Ts2+ that can be enabled or disabled from the Home webpage, depending on the customer use-case and deployment. There are 4 main modes of operation in which SyncE feature can be deployed as described below. The PHY's used in Ts2+ support SyncE in terms of supporting clock recovery on Ethernet Rx and being able to provide 125MHz clock externally for Ethernet Tx. This is supported with native RJ45 (1000BASE-T) PTP port interfaces and with optical 1GE SFP modules. SyncE is currently not supported on Copper SFPs.

7.3.3 SyncE in OFF mode

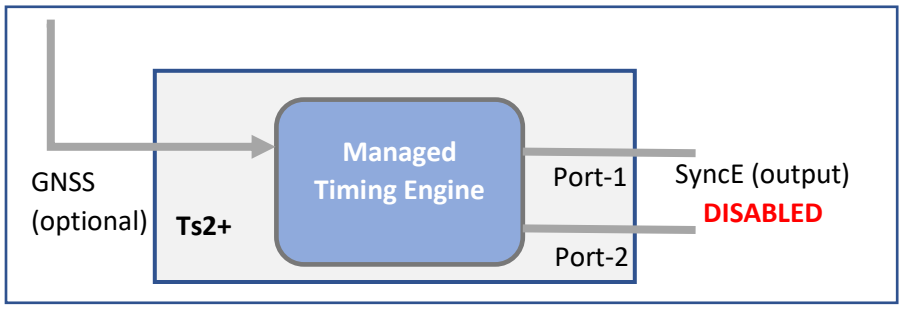


Figure 28 SyncE OFF

In this mode of operation, Synchronous Ethernet feature is turned off completely. Any incoming ESMC packets will be ignored and not processed, and no generation of outgoing ESMC packets. No clock recovery is done on Ethernet Rx. Frequency, along with phase and time are extracted from GNSS or PTP. This applies to both PTP ports.

7.3.4 SyncE in Master mode

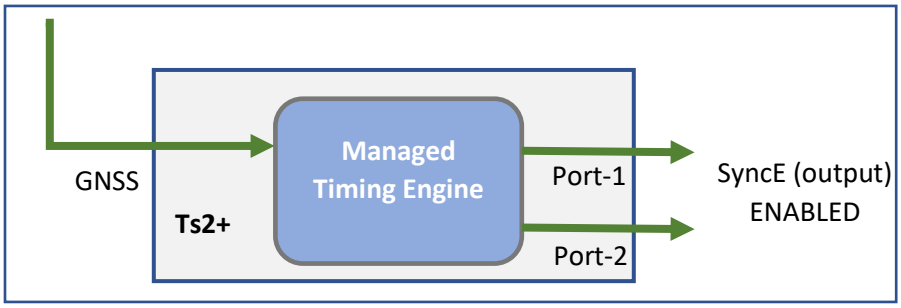


Figure 29 SyncE in Master Mode

In this mode of operation, Ts2+ is in GNSS-only operating mode where it gets 1pps and ToD signals from a GNSS receiver (internal or external to Ts2+), which was originally extracted from GNSS L1 signal . In this mode, the frequency, phase and time references are extracted from GNSS signal, and SyncE is output on both ports for frequency with ESMC/QL message distribution to next downstream L2 network node. The outgoing QL enumeration is PRC (for EEC Option-1) or PRS (for EEC Option-2) when locked to GNSS.

7.3.5 SyncE in Boundary Clock Mode

In Boundary Clock mode, SyncE feature can be enabled when engine is operating in PTP-only mode. In this mode, one of the PTP ports operates as a PTP-slave synchronizing to a PTP master upstream, while the other PTP port operates as a PTP-master distributing time and sync downstream to other PTP slaves.

There are some differences that should be noted when using L2 (Ethernet multicast) based PTP profile like G8275.1 and L3 based PTP profile like G8275.2. More details to follow in the sections below.

7.3.5.1 SyncE in Boundary Clock Mode for G8275.1 Telecom Profile

G8275.1 profile is specified for PTP clock distribution in a Layer-2 Ethernet multicast network. This network is expected to have full on-path support, ie. every node is PTP-aware and participates in the PTP protocol. When Ts2+ is put in Boundary Clock mode in this network, the input SyncE from upstream is used as frequency reference and used directly for SyncE distribution on downstream port.

On Ts2+ Home webpage, the SyncE selection provides the flexibility of specifying upstream port (PTP slave + SyncE reference input) and downstream port (PTP slave +SyncE output) and as shown in the figures below.

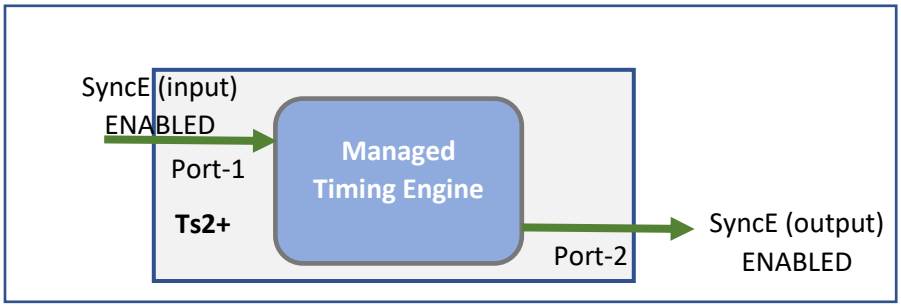


Figure 30 SyncE in BC mode for G8275.1, ref input on Port-1

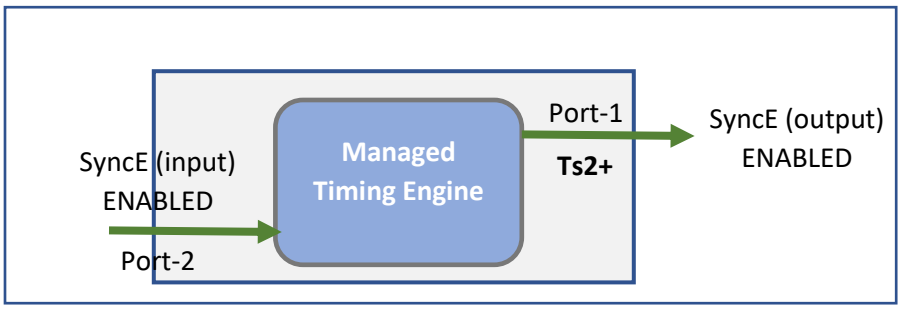


Figure 31 SyncE in BC mode for G8275.1, ref input on Port-2

7.3.5.2 SyncE in Boundary Clock Mode for G8275.2 Telecom Profile

G8275.2 profile is specified for L3 unicast network and is based on partial timing support from the network. This means that not all network nodes may participate in PTP protocol. In this mode, SyncE input frequency reference can be used as a frequency-assist for PTP. The physical layer (ie. frequency) output is controlled by both, the input (from SyncE) and PTP engine. Unlike in G8275.1, here the physical layer output is NOT directly from input reference and hence not traceable and cannot be used for SyncE output distribution. SyncE output is disabled in this case.

The figures below show the flexibility of specifying the ports for operation in this mode.

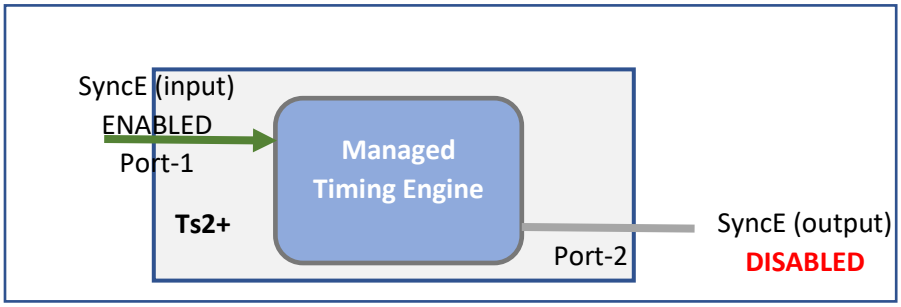


Figure 32 SyncE in BC mode for G8275.2, ref input on Port-1

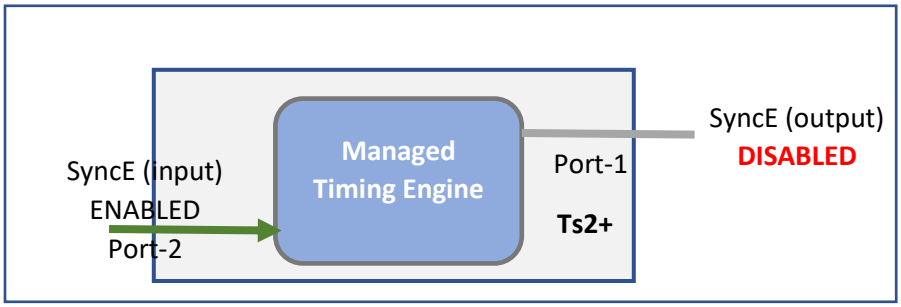


Figure 33 SyncE in BC mode for G8275.2, ref input on Port-2

7.3.6 SyncE Status

The SyncE status is displayed at the bottom of PTP::Port webpage.

7.3.6.1 SyncE Status in GM Mode

	Port 1	Port 2
Synchronous Ethernet		
SSM channel (ESMC)	Enabled	Enabled
Link Mode	master	none
Input QL	AUTO (QL-DNU)	AUTO (QL-FAILED)
Output QL	QL-PRC (QL-PRC)	QL-PRC (QL-DNU)
Active Reference	NO	NO

Figure 34 GM SyncE status output on PTP::Port Webpage

The above figure is a sample status when Ts2+ is operating as a GM and Port1 is connected to a SyncE slave and Port2 is not connected to a link partner (link down condition). The following describes the different fields in this use case:

- SSM channel (ESMC) – it is enabled for both ports.
- Link Mode – This is applicable only for Copper/RJ45. This is as per 802.3 standard which specifies the physical media and the working characteristics of Ethernet. To work in conjunction with SyncE, link mode on Ts2+ ports will be (forced) set to master clock and 1000 Mbps full-duplex and auto-negotiation turned off. In the example above, there is a link on port-1 and its Link Mode set to “master”, while for port-2 there is no link, it shows as “none”.
- Input QL – This is the Quality level in the ESMC message received on that port (from its link partner).
    - For Port1, it indicates AUTO (QL-DNU), and
    - For Port2, it indicates AUTO (QL-FAILED)

In GM mode, the input QL processing in Ts2+ is set to AUTO to take the input from the port and feed it into the PLL as one of the inputs. What is shown in the parentheses is the actual value received.

- Port1, receives QL-DNU (DNU = do not use) from its link partner.
- Port2, since the link is down, it shows QL-FAILED.

- Output QL – In this use case, the frequency reference is coming from GNSS (or 1pps) and not from either of the two Ethernet ports. The quality level for that is PRC (or PRS). This QL is what should be propagated downstream as the Ts2+ is a Grand Master.
    - For Port1, the link is up and so the actual QL that is put in the outgoing ESMC message is QL-PRC as shown in the parentheses.
    - For Port2, not that it matters since the link is down, the value that will be put in the ESMC message will be QL-DNU.
- Active Reference – this will indicate YES or NO to indicate the recovery of frequency on that Ethernet port. The YES would mean that the frequency is recovered from this port. In a BC clock mode of operation with SyncE enabled, it will YES on the (slave)port where we get the frequency reference and NO on the other (master) port. In our sample use case of GM, it will show NO on both pots as the active reference is from GNSS (1pps) and not from the Ethernet ports.

7.3.6.2 SyncE Status in BC Mode

	Port 1	Port 2
Synchronous Ethernet		
SSM channel (ESMC)	Enabled	Enabled
Link Mode	slave	master-slave
Input QL	AUTO (QL-PRC)	QL-DNU (QL-DNU)
Output QL	QL-DNU (QL-DNU)	AUTO (QL-PRC)
Active Reference	YES	NO

Figure 35 BC SyncE status output on PTP::Port webpage

The above figure is a sample status of SyncE when Ts2+ is operating as a BC, getting the SyncE reference from Port1 and propagating it on Port2. Here, on port-2 a SFP optical module is used instead of the native RJ45 Copper port. The following explains the different fields for this use case:

- SSM channel (ESMC) – it is enabled for both ports. On Port1 it is recovered and on Port2 it is transmitted.
- Link Mode – this is as per 802.3 standard as mentioned in the previous GM use case.
    - Port1: The link mode is in alignment with SyncE as this is a SyncE slave port and getting the frequency reference from its link partner.
    - Port2: The link mode does not matter as it is not copper but is SFP optical. It is displayed as “master-slave”. If it had been Copper/RJ45, then it would have displayed as “master”.
- Input QL – This is the Quality level received on that port (from its link partner).
    - For Port1, it indicates AUTO (QL-PRC) indicating that incoming SyncE ESMC has QL-PRC. This is used as SyncE reference.
    - For Port2, it indicates AUTO (QL-DNU) indicating that incoming SyncE ESMC has QL-DNU.
- Output QL – This is the Quality level transmitted out on the port.
    - For Port1, QL-DNU is sent out. This is required on the port that is being used as SyncE reference to avoid any clock loops
    - For Port2, the AUTO indicates that we are transmitting QL that was received as reference. The actual value is QL-PRC, the frequency propagated from Port1 input.
- Active Reference - This will indicate YES or NO and pertains to recovery of frequency on a specific Ethernet port
    - For Pot1, it is YES since the reference frequency is recovered here

- For Port2, it is NO since the recovered frequency is not used as reference

7.3.7 SyncE – additional notes

Some additional notes regarding SyncE feature in Ts2+:

1. Synchronous Ethernet is supported only for 1GE interface speed. If user had configured previously on Interfaces::PTP webpage for a different Auto-Negotiation and speed parameters, they will be reset to 1000Mbps Full-duplex.
2. Support for enhanced EEC (eEEC) bandwidth options will be supported in future release
3. For other profiles besides G8275.1 and G8275.2, the SyncE operation will depend on whether the profile is specified for L2-multicast or L3-unicast. If L2-multicast, then it will follow G8275.1 operation, and if L3-multicast, it will follow G8275.2 operation.
4. SyncE operation is valid only in association with Operating Modes, GNSS-only and PTP-only. Synchronous Ethernet field should be set to off for other operating modes.

7.4 5G and Synchronization

As the reader may be aware, in 5G the base stations is decomposed into remote radio unit (RRU), distribution unit (DU), and the control unit (CU). For the proper functioning and getting optimal performance from RU, DU and CU in 5G RAN, precise timing and synchronization plays a crucial role. Not only just from RAN perspective, but also from an end-to-end network perspective for new applications and services like network slicing that run on 5G network.

For 5G RAN, the typical sync and time error budget is +/-1.5us from the core to RAN over the air (OTA) interface.

For specific deployments and network operation use case scenarios, a higher precision or sync accuracy may be required. For Time Alignment Error (TAE) within a cluster of RUs, , all of which synchronizing from the same DU, it is +/-130ns. It should be noted that this budget is specified for synchronization and not latency.

7.4.1 Open RAN, ORAN Deployment Scenarios

Ts2+ is a simple yet powerful and flexible stand-alone timing and synchronization solution for todays and next generation networks. Specifically with the advent of commercial off the shelf hardware (COTS), open source software and disaggregation concepts and technologies into Radio Access Network(RAN).

Below shows the RAN Architecture evolution. Prior to 5G, the RAN architecture was such that the base stations are co-located with the Radio tower and all the layer-1 (or PHY or Radio) including analog/digital conversions at or near the radio. In 5G, with massive MIMO, millimeter wave with shorter range radios, and more end applications, there will be more radios (small cells, and towers). This is needed to provide the necessary coverage. The radios need to be small, economical and efficient and located remotely for 5G. Centralized RAN, virtualized RAN and Open RAN are some of the new architectures that are gaining traction in this regard.

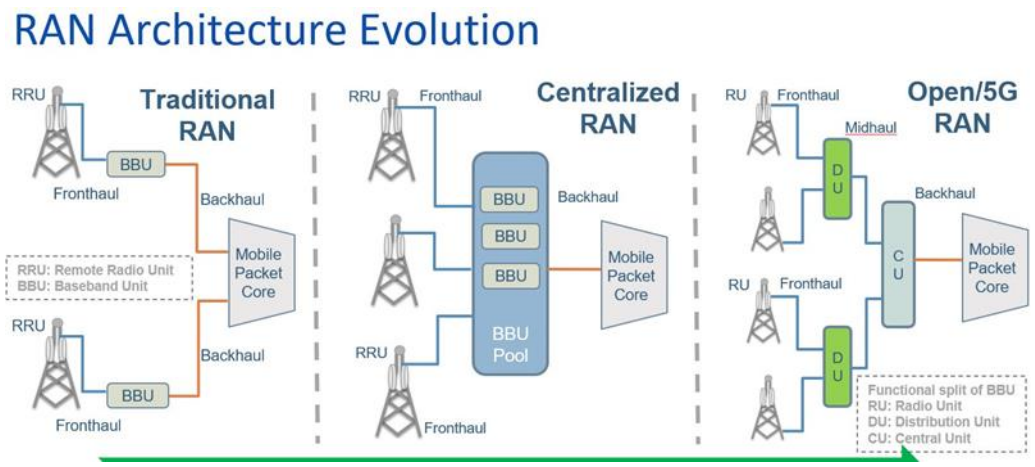


Figure 36 5G RAN Architecture Evolution

7.5 Ts2+ for 5G Deployment

There is a lot of activity currently going on in 5G as the ecosystem evolves. There are legacy vendors (Ericsson, Huawei, Nokia, etc.) working with the carriers in building and deploying a single-vendor solution. Besides these legacy vendors and providers, a new host of companies have entered the 5G ecosystem. The basic driving factor for new players is that 5G is seen as a new technology that requires products from multi-vendors to be interoperable and there is no single vendor "lock-in". Most of the hardware is off-the-shelf and the software is open-source which empowers smaller players to enter into this market. Regardless of whether the network operator deploys a disaggregated multi-vendor or the legacy single-vendor infrastructure, precise timing and synchronization is critical.

Shown below is how Ts2+ can be deployed for the different configurations as specified in Synchronization plane (or S-plane) of ORAN Workgroup-4. The configurations are specified as LLS-C1 through LLS-C4, where LLS = low-level split. The recommendation by ORAN is to use G.8275.1 profile along with SyncE.

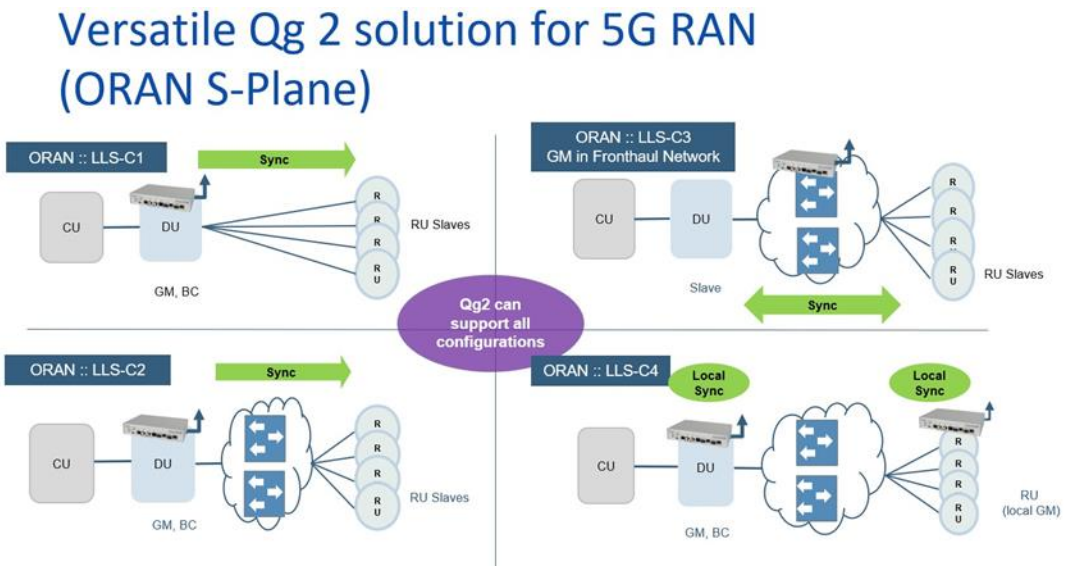
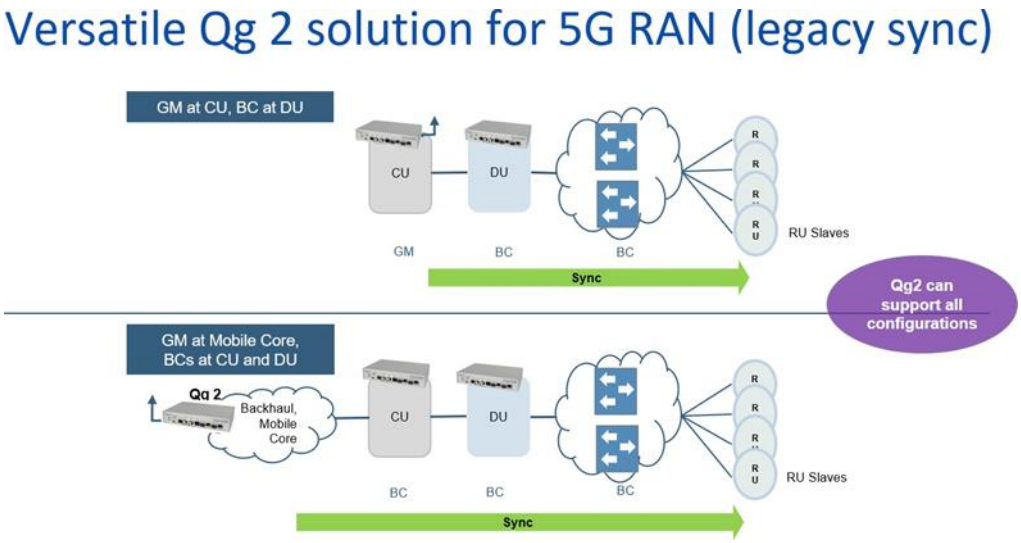


Figure 37 Ts2+ solution for ORAN S-plane

The figure below shows other deployment scenarios – for 5G using legacy network architecture for synchronization.



7.5.1 Integrated Sync Solutions from TesCom (Qg-iNT)

Ts2+ as a stand-alone is a flexible solution for different deployments. In addition, TesCom can provide customized solution that can be integrated into DU/CU white box server(Qg-i), or into the switch (Qg-iS) or into the radio unit(Qg-iR). These solutions use the hardened, performance proven Ts2+ architecture and design as the reference model and can be easily customized for a PoC trial.

The obvious advantage of this is to have a small footprint, less devices to manage and be part of vendor offering of complete solution. Precise timing and synchronization, especially to meet the requirements of 5G is complex requires expertise for an optimal solution.

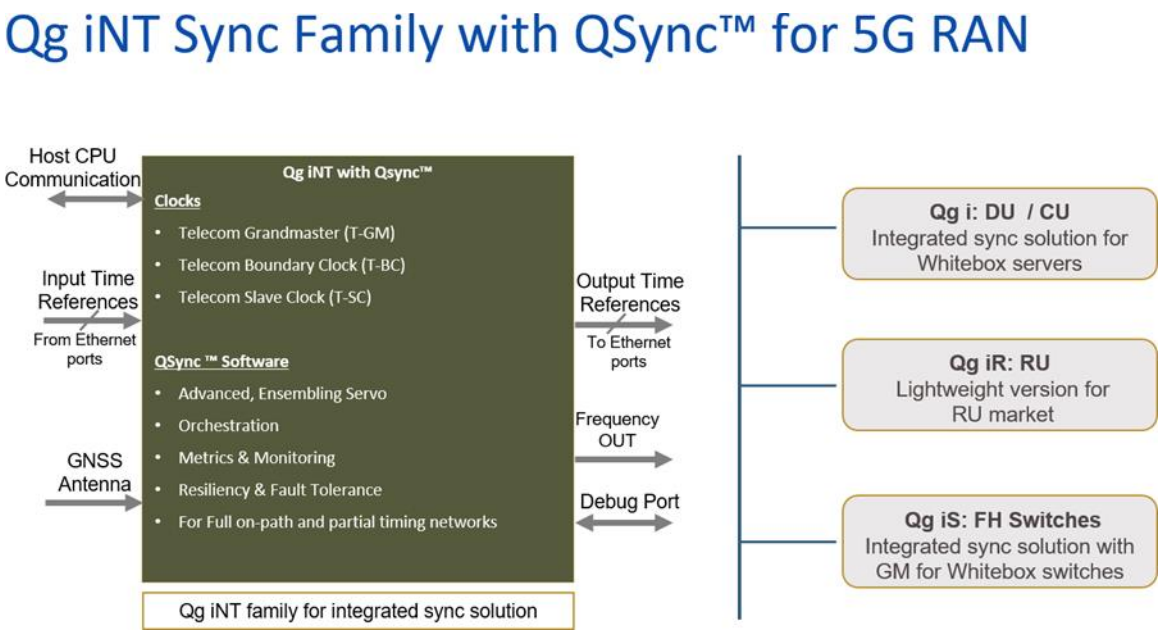


Figure 38 Qg iNT Solution

If interested, please contact TesCom for more details on Qg-iNT.

8 Physical Interfaces

8.1 Antenna input

SMA 50 ohm. Protected for shorted antenna. The Ts2+ provides 5.0 VDC bias to power remote active antennas that provide 40 dB gain. The antenna system supports cable length up to 50 meters with RG59/RG58 and 50 to 100 meters with LMR500/LMR600.

8.2 Console

The console port uses mini-USB serial terminal protocol. The connector is on the front panel and the default settings are as follows:

- Baud = 115.2K
- Data Bits = 8 bits
- Parity = None
- Stop Bits = 1
- Flow Control = None

8.3 Hard Reset Button

The Hard Reset Button provides 2 different functionalities depending on how it is used or pushed. These are described below.

Note: It should be noted that using the Hard Reset Button should be a last resort consideration as it is abrupt and not a graceful way.

8.3.1 Hard Reset Button – Quick Push for Reboot

When Hard Reset Button is pushed and held for a short duration (approx. 1 or 2 seconds), it will reboot the unit. The current configuration of Ts2+ is preserved.

8.3.2 Hard Reset Button – Long Push for Factory Reset

When Hard Reset Button is pushed and held for a longer duration (approx. 10 seconds), it will do a factory reset of the unit followed by a reboot. The current configuration of Ts2+ will NOT be preserved and the user should save and restore their configuration as needed.

8.4 Management Interface

Management port is 10/100BaseT RJ45. The Management port supports DHCP, HTTP Webpages, XML, SNMP (v2,v3), and SSH remote login.

8.5 Frequency Out Port

BNC 50 ohm. 3.3V TTL DC blocked. Frequency Out selectable on the **Error! Reference source not found.** Webpage.

8.6 1PPS Timing Output

BNC 50 ohm. 3.3V TTL output.

8.7 Time-of-Day / 1PPS Input/Output

ToD / 1PPS port is RJ45, input/output. The pin-outs for this RJ45 connector are defined in ITU-T G.703 Transmission Systems and Media, Digital Systems and Networks, Section 19. For more information about ITU-T G.703, see [6].

The Time-of-Day Input format is selectable on the **Error! Reference source not found.** Webpage and the Time-of-Day Output format is selectable on the **Error! Reference source not found.** Webpage. The selections for both input and output are NMEA, ASCII text and China Mobile.

8.8 PTP Interface, Port 1 and Port 2

Two Electrical RJ45 ports and two SFP ports. Each RJ45 port can support triple-speed (10/100/1000 Mbps) and each SFP port can support 1GE.

For Port 1, the same PTP messages/packets will be present in both the RJ45 and SFP connections, but the data rates may be different depending on the speed of the network to which they are connected.

For Port 2, the same PTP messages/packets will be present in both the RJ45 and SFP connections, but the data rates may be different depending on the speed of the network to which they are connected.

8.8.1 SFP (and SFP+) Optical Modules for PTP Port 1 and 2

SFP optical modules can be plugged into the PTP ports for Ethernet connectivity instead of the electrical RJ45 ports. These ports have been designed for standard SFP 1GE modules and dual-rate SFP+ modules operating at 1GE speed.

TesCom has verified the operation with modules from leading vendors as shown below:

Finisar: FTRJ8519P1BNL, FCLF-8521-3
Intel: AFBR709DMZ-IN3
Avago: AFBR-709SMZ
Ubiquity: UF-MM-1G

FiberStore (FS): H3C SFP-10GSR-85 (SFP+ dual-rate configured for 1GE)

NOTE: SFP Copper modules are also available and will work with Ts2+. The user should be aware that in that case, the PHY is inside the SFP Copper and in most cases will not fully support Synchronous Ethernet feature. In that case, we recommend to use the native electrical RJ45 ports on Ts2+.

8.9 LED Description

The Ts2+ has 3 LED's on the front panel which communicates the status of the Power, GNSS Signal and Sync Status.

8.9.1 Power

Power LED state	Description
Red	Any of the internal voltages are in alarm state
Amber/Orange	Initial boot and OS load completed successfully. Loading Applications.
Green	HW and SW Applications loaded and ready for normal operation
Green - blinking	Ts2+ software upgrade in progress – do NOT reboot or turn power off!
Red - blinking	Previous attempt to upgrade software on Ts2+ failed

8.9.2 GNSS

GNSS LED state	Description
Off	MCE not running or MCE running in PTP only mode or software upgrade in progress
Red	1PPS Input Error or ToD Input Error
Green	Signal acquired, 1PPS Input or ToD Input Available

8.9.3 Sync Status

Sync Status LED state	Description
Off	MCE not running or software upgrade in progress
Red	MCE running, Not Synchronized and engine state is FREE RUNNING
Amber	MCE running, Not Synchronized and engine state is SYNCHRONIZING, SYNTONIZING or HOLDOVER
Green	MCE running, Locked / Synchronized

8.10 Power

The options are -48 VDC, (-34 to -60 VDC supply) or 28 – 40 VAC. 17-25W power consumption, depending on oscillator option.

Estimated Power Consumption based on Oscillator Option	
Oscillator Option	Power Consumption
OCXO	17 watts
Super OCXO	25 watts
Green	MCE running Locked / Synchronized

8.11 Physical dimensions

Size: 218 (W) x 160 (D) x 43 (H) mm excluding connectors
Weight: 1.01 kg

9 End User License Agreement (2020 - 2021)

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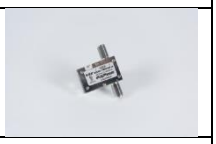
TesCom
3317 El Salido PKWY
Cedar Park, TX 78613
U. S. A.

10 Part Numbers

Ts2+ P/N (GP ID)	Description	Photo
Ts2+ (Ts2+)	Ts2+ w/4-hour holdover	
Ts2+e (Ts2+e)	Ts2+ w/8-hour holdover	
Ts2+RKM19 (Ts2+RKM19)	Kit, Rackmount, 19"	
007-02319-000 (007-02319-000)	Kit, Standard Antenna e/w L1 band, 5VDC, 30dB antenna, 50ft RG58 cable, antenna retaining collar/pole mount, L mount bracket, hardware	
007-02534-000 (007-02534-000)	Kit, Lightning Arrester e/w PolyPhaser arrester, arrester mount bracket, 50ft RG58 cable, non-conductive electrical box, sealant, hardware	
?	Supply, Power, Commercial, 48VDC	
Ts2+ OPT-Pxx	OPTION- XXX PTP Clients	
Ts2+ OPT-Pxy	OPTION- XXy PTP Clients	
TS2+-GNSS	Antenna, patch	
VIC-100 (8060)	Antenna, L1 Band, 5VDC, 30dB Gain, TNC	
8063 (8063)	Collar, antenna retaining/pole mount	
039-01525-002 (8061)	Arrester, Lightning, PolyPhaser	
8071 (8071)	Bracket, PolyPhaser mount	
8065 (8065)	AC adaptor	

Please visit https://tescomusa.com/collections/gps-clock-accessories

11 Glossary

Acronyms and Abbreviations	
1PPS	Pulse Per Second
1RU	1 Rack Unit, 1.75 inches or 44.45 millimeters
API	Application Program Interface
ASCII	American Standard Code for Information Interchange
BaseT	Megabits / second Transferred over CAT5 cable
BC	Boundary Clock
BMCA	Best Master Clock Algorithm
BNC	Bayonet Neill-Concelman connector
CAT5	Category 5 cable
CLI	Command Line Interface
C-RAN	Cloud-Radio Access Network
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server
DST	Daylight Savings Time
E2E	End to End delay measurement mechanism
ESD	Electrostatic Discharge
ETH	Layer 2 network communication for PTP messages
FTP	File Transfer Protocol
FW	Firmware
GC	Gateway Clock
GM	Grand Master
GNSS	Global Navigation Satellite System
GPS	Global Position System
HMI	Human Machine Interface
HTTP	HyperText Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
LAN	Local Area Network
LED	Light-emitting Diode
MAC	Media Access Control address
Mbps	Megabits per second
MGMT Port	Management Port
MHz	Megahertz Frequency
Mini-USB	Mini Universal Serial Bus
MCE	Managed Clock Engine
NMEA	National Marine Electronics Association
NV	Nonvolatile Memory
OC	Ordinary Clock
OCXO	Oven Controlled Crystal Oscillator
P2P	Peer to Peer delay measurement mechanism

PLL	Phase Locked Loop
PoE	Power over Ethernet
PTP	Precise Time Protocol
PWR	Power
RF	Radio Frequency
RU	Rack Unit
RMC	Recommended Minimum data for GPS, Sentence C from NMEA
SFP	Small Form-Factor Pluggable transceiver
SFTP	SSH File Transfer Protocol or Secure File Transfer Protocol
SMA	SubMiniature version A connector
SNMP	Simple Network Management Protocol
SSH	Secure Shell cryptographic network protocol
ToD	Time of Day
TTL	Transistor-transistor Logic
TZ	Time Zone
UDP	User Datagram Protocol, IPv4. Layer 3 network communication
UDP6	User Datagram Protocol, IPv6. Layer 3 network communication
UIP	User Interface Processor
UTC	Coordinated Universal Time
VAC	Voltage Alternating Current
VDC	Voltage Direct Current
WAN	Wide Area Network
XML	eXtensible Markup Language
ZDA	Data and Time from GPS, NMEA standard

12 References

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[4] ITU-T G.8261 Timing and synchronization aspects in packet networks
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