Cambium Networks™

TECHNICAL DESCRIPTION

PTP 850C

Release 13.1

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Contents

About This Guide

This document describes the main features, components, and specifications of the PTP 850C system.

Note:

Some features described in this document may not be supported in every System Release release. For a description of feature support per release, refer to the Release Notes for the System Release version you are using.

What You Should Know

This document describes both ETSI and ANSI (FCC) standards and specifications.

Target Audience

This manual is intended for use by Cambium customers, potential customers, and business partners. The purpose of this manual is to provide basic information about the PTP 850C for use in system planning, and determining which PTP 850C configuration is best suited for a specific network.

Related Documents

- Release Notes System Release 13.1, PTP 850 Products
- User Guide for PTP 850C and PTP 850E, System Release 13.1
- MIB Reference for PTP 850 Products, System Release 13.1
- Installation Guide for PTP 850C
- Datasheet for PTP 850C

Introduction

PTP 850C is a MultiCore microwave radio suitable for all deployment scenarios. PTP 850 provides cutting-edge capabilities that enable operators to base entire networks, from small cells to massive aggregation sites, on this single product.

PTP 850C supports cutting edge capacity-boosting techniques, such as MIMO, Advanced Frequency Reuse (AFR), and a wide range of modulations from BPSK to 4096 QAM with ACM, along with a large range of channel bandwidth from 14 to 224 MHz, to offer a high capacity solution for every network topology and every site configuration.

This chapter includes:

- Product Overview
- Unique PTP 850C Feature Set
- System Configurations

Product Overview

Cambium's PTP 850C sets a new standard for microwave transmission, offering 16 Gbps switching capacity, channel spacing of up to 224 MHz, and a wide range of modulations, from BPSK to 4096 QAM with ACM. These and other advanced capabilities are combined in PTP 850C with the full range of Cambium's MultiCore technologies to produce an all-outdoor product that can be used throughout the microwave network, from small cells to massive aggregation sites.

Note:

224 MHz is only supported with certain hardware versions. For details, ask your Cambium representative.. With 224 MHz channels, PTP 850C supports up to 2 Gbps per carrier, for up to 8 Gbps in 4+0 Layer 1 Link Bonding configurations.

The ability to use PTP 850C throughout the network offers the possibility of simplifying network deployment and maintenance by reducing complexity, costs, and time-to-revenue.

PTP 850C is easily and quickly deployable compared with fiber, enabling operators to achieve faster time to new revenue streams, lower total cost of ownership, and long-term peace of mind.

PTP 850C can deliver multi-Gbps capacity on a single frequency channel, setting a new standard for efficient spectrum use. PTP 850C's unique MultiCore radio architecture is based on an advanced parallel radio processing engine, built around Cambium's in-house chipsets. The result is superior radio performance with reduced power consumption and form-factor.

Additionally, PTP 850C's MultiCore architecture enables operators to start with a single core with the option of enabling the second core remotely when network capacity requirements increase.

PTP 850C can be deployed as a stand-alone all-outdoor radio. In can also be used as an upgrade path to achieve the highest possible capacity of any existing link by utilizing Cambium's unique Layer 1 Link Bonding technique for single and dual-frequency configurations.

In a 4+0 Layer 1 Link Bonding configuration, two PTP 850C units operate together to form a multi-carrier node operating over one or two microwave channels and connected to the switch via a single cable. When utilizing XPIC and high-modulation ACM profiles, 4+0 Link Bonding can provide capacity of up to 4 Gbps over 112 MHz channels or 8 Gbps over 224 MHz channels.

Layer 1 Link Bonding can also be used to pair an PTP 850C with an PTP 820C or PTP 820C-HP. This enables operators to add an PTP 850C to existing PTP 820C or PTP 820C-HP deployments in order to add significantly to node capacity utilizing the same physical footprint, adding to rather than replacing the existing PTP 820C or PTP 820C-HP and its capacity. A node using PTP 850C and PTP 820C or PTP 820C-HP with Link Bonding can provide capacity of up to 5 Gbps when both units are utilizing their widest supported channels and highest modulations.

As an upgrade path for existing PTP 820C nodes, Link Bonding enables operators to significantly increase the link's capacity while retaining the same network configuration, antennas, mediation devices, and cabling. This can facilitate quick and efficient network growth, minimizing the cost of upgrade and lowering the total cost of ownership.

The 4x4 MIMO feature adds yet another element of scalability, enabling operators to quadruple capability with the addition of a single PTP 850C unit and antenna at each end of the link while utilizing the same exact frequency channel with no network replanning.

Along with its other configuration options, PTP 850C can be used in Multiband configurations with PTP 850E or PTP 850EX. This configuration utilizes Layer 1 Link Bonding to provide robust links that combine microwave with E-band transmissions, for capacity of up to 14 Gbps. Multiband bundles E-Band and microwave radios in a single group that is shared with an Ethernet interface. Layer 1 Link Bonding enables operators to optimize the capacity of a Multiband link by combining the capacity of the E-Band and Multiband links into a single link of up to 14 Gbps. This is achieved when the PTP 850E or PTP 850EX is used in 2000 MHz channels, providing 10 Gbps, while the PTP 850C is operating in XPIC mode over 224 MHz channels, providing 4 Gbps at high profiles.

Note:

MIMO is planned for future release.

The following are some of the highlights of PTP 850C:

- **MultiCore Radio Technology** – Parallel radio processing engine that boosts capacity, distance and availability.
- **High Capacity and Spectral Efficiency** – 4096 QAM modulation, Layer 1 Link Bonding, LoS 4x4 MIMO, Advanced Space Diversity, Advanced Frequency Reuse.
- **Simple Operation** – Software-defined radio, rapid deployment, and minimal truck rolls.
- **Environment-Friendly** – Compact, all-outdoor unit with low power consumption.

Unique PTP 850C Feature Set

The following table summarizes the basic PTP 850C feature set.

Table 1 *PTP 850C Feature Set*

Extended Modulation Range	**ACM BPSK – 4096 QAM**
Frequency Bands	6L to 42 GHz
Wide Range of Channels	14 to 224 MHz **Note**: 224 MHz is only supported with certain hardware versions. For details, ask your Cambium representative.
Power over Ethernet (PoE)	Proprietary
Compact Size and Weight	(H)322mm x (W)227/270mm x (D)86mm, 6kg
Antennas	Cambium proprietary RFU-C interface Direct and remote mount – standard flange
Durable All-Outdoor System	IP67-compliant

System Configurations

PTP 850C is designed to support the following site configurations**:**

- 4+0 Layer 1 Link Bonding
- Layer 1 Link Bonding with PTP 820C or PTP 820C-HP
- Multiband - PTP 850E and PTP 850C
- Multiband with Layer 1 Link Bonding – PTP 850C and PTP 850EX
- Multiband with layer 1 Link Bonding – PTP 850E and PTP 850C
- 2+0 Single/Dual Polarization
- 1+0 (Horizontal or Vertical Polarization)
- 4+0 Single/Dual Polarization

> **Note**:
>
> Planned for future release.

  - 1+1 HSB (two units)3
  - 1+1 HSB-SD (two units)3
  - 2+2 Single/Dual Polarization HSB3
  - 2+2 HSB-SD3
  - 2x2 MIMO3

- 4x4 MIMO3
- ASD 2+0 (XPIC)3
- AFR 2+03

PTP 850C Hardware Description

This chapter describes the PTP 850C and its components and interfaces.

This chapter includes:

PTP 850C Unit Description and Interfaces

PTP 850C features an all-outdoor dual-carrier architecture consisting of a single unit directly mounted on the antenna.

Figure 1: *PTP 850C Rear View (Left) and Front View (Right)*

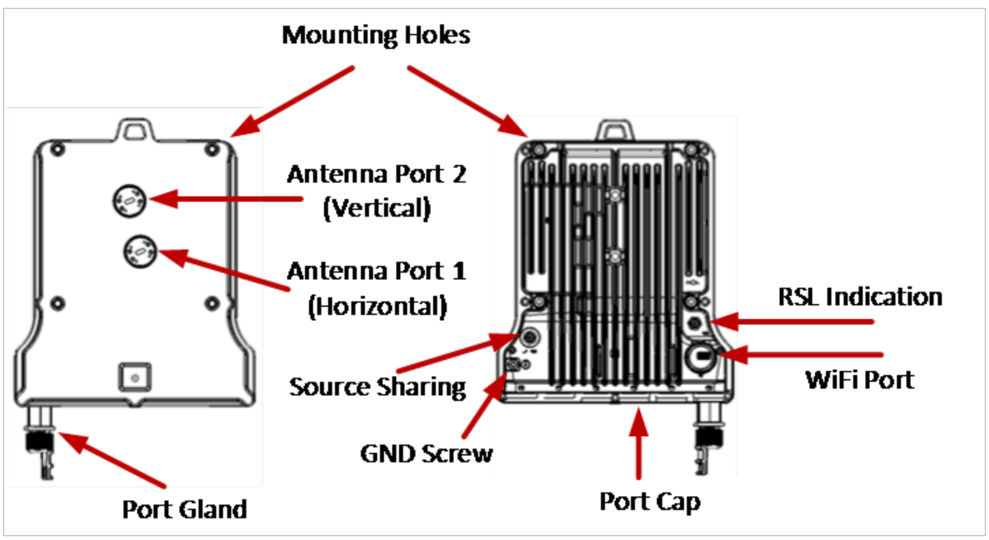
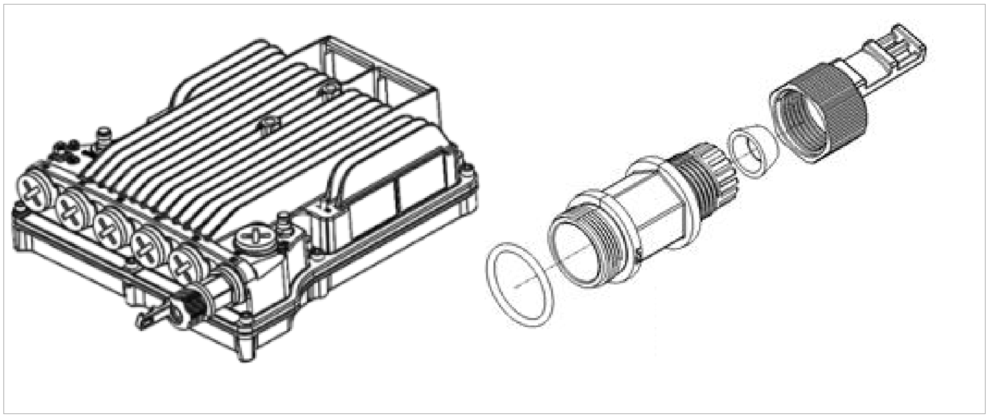
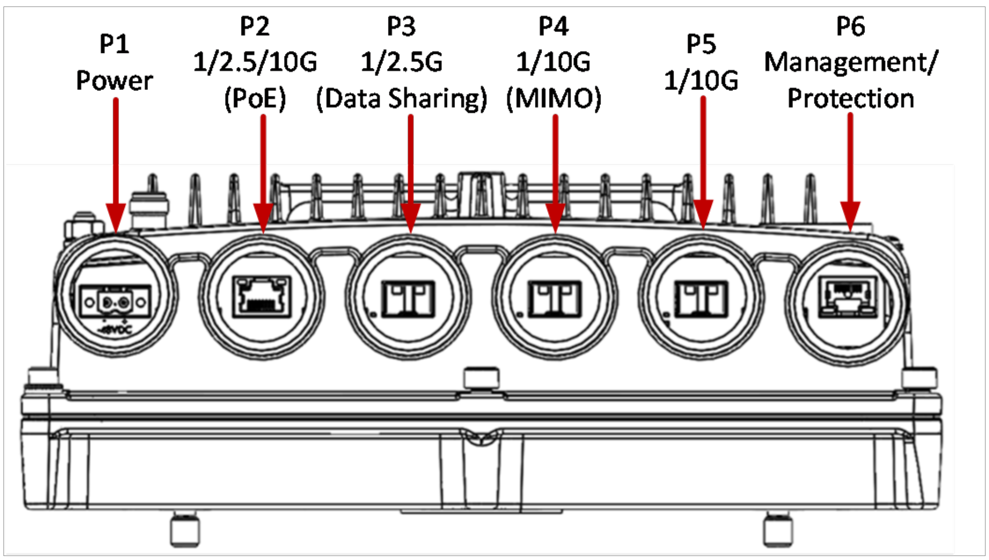


Figure 2: *Cable Gland Construction*



The following figure shows the traffic, management, and power interfaces on the PTP 850C.

Figure 3: *PTP 850C Interfaces*



Note:

When used with electrical SFP transceivers, the SFP interfaces support 1GE only.

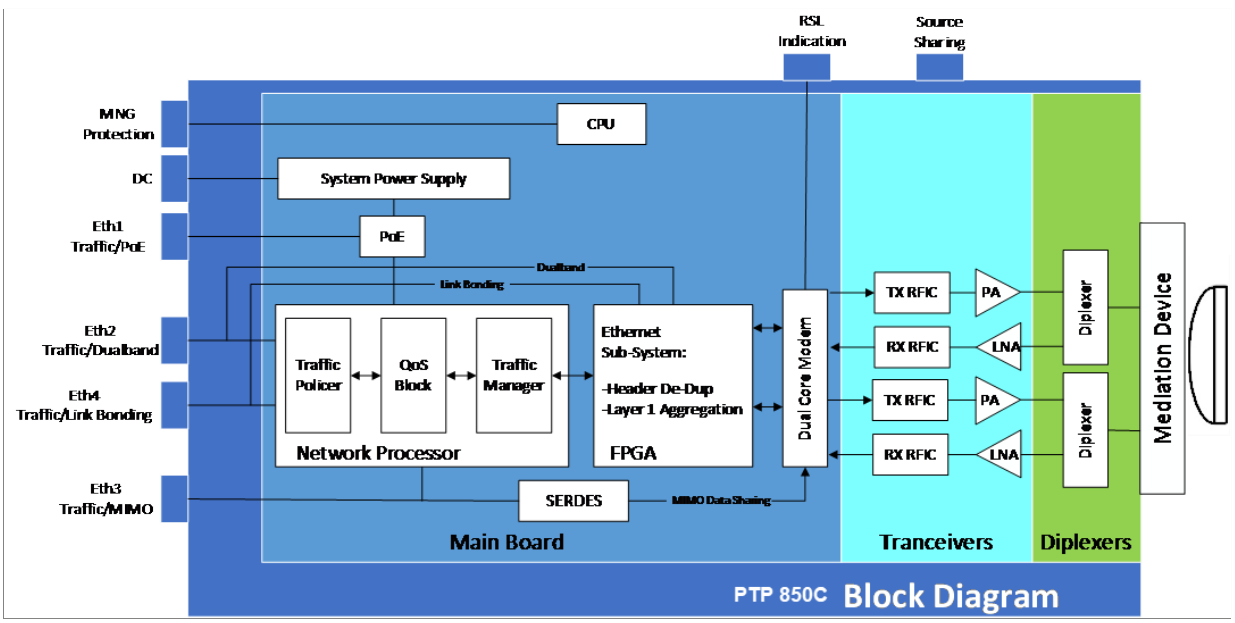
- Port 1 – Power Interface (-48V)
- Port 2 (Eth 1):
  - RJ-45: 1000BASE-T, 2.5GBASE-T, 10GBASE-T
  - PoE
- Port 3 (Eth 2):
  - SFP cage which supports SFP standard
  - Optical: 1000BASE-X, 2.5GBASE-X
  - Optical: 1/2.5GE

- Port 4 (Eth 3):
  - SFP cage which supports SFP+ standard
  - Optical: 1000BASE-X, 10GBASE-X
  - Optical: Cambium proprietary MIMO interface, if this port serves as an extension port for data sharing. By default, the port is a traffic port unless a MIMO group has been created
- Port 5 (Eth 4):
  - SFP cage which supports SFP+ standard
  - Optical: 1000BASE-X, 10GBASE-X
- Port 6:
  - RJ-45: 100BASE-T
  - Management and Protection port (no traffic)
- 2 RF Interfaces: Standard interface per frequency band
- RSL interface: BNC connector
- Source sharing: TNC connector
- Grounding screw

Hardware Architecture

The following diagram presents a detailed block diagram of the PTP 850C.

Figure 4: *PTP 850C Block Diagram*



The PTP 850C combines full system capabilities with a very compact form-fit. The all outdoor system architecture is designed around Cambium's IP core components, enabling a true MultiCore design.

For a detailed description of the system interfaces, refer to PTP 850C Unit Description and Interfaces.

Field-Replaceable Diplexer Units

Using Cambium's Easy Set technology, an PTP 850C consists of a generic radio unit and a diplexer unit. For 6 to 11 GHz, the diplexer unit is field-replaceable, which means it can be replaced without replacing the radio unit. The generic radio unit covers an entire frequency band. It is the diplexer unit, which is passive, that determines the sub-band coverage for the entire integrated PTP 850C unit. This provides operators with major benefits in terms of both deployment time and maintenance.

For maintenance, the operator can reduce the number of spare radio units in its inventory because a single generic radio unit can be used for any sub-band. This means that for a site covering four channel ranges within a single frequency band, a single spare radio unit can be kept on hand, because that unit can be used as a spare for any of the PTP 850C units in the site. The diplexer units, because they are passive, are much less likely to require replacement, so the maintenance of spare parts for the diplexer units is much less of a concern for the operator.

The use of separate generic radio units and diplexer units also enables operators to achieve a quicker system deployment time. In the planning stage, when the frequency bands have been determined but the exact sub-band layout is still under consideration, operators can already order all the radio units required for the frequency bands that have been determined, and can begin ordering diplexer units for the approximate sub-bands that are anticipated, while still determining the exact network parameters. This enables faster delivery and deployment of the network.

Figure 5: *PTP 850C Radio Unit (Left) and Diplexers Unit (Right)*

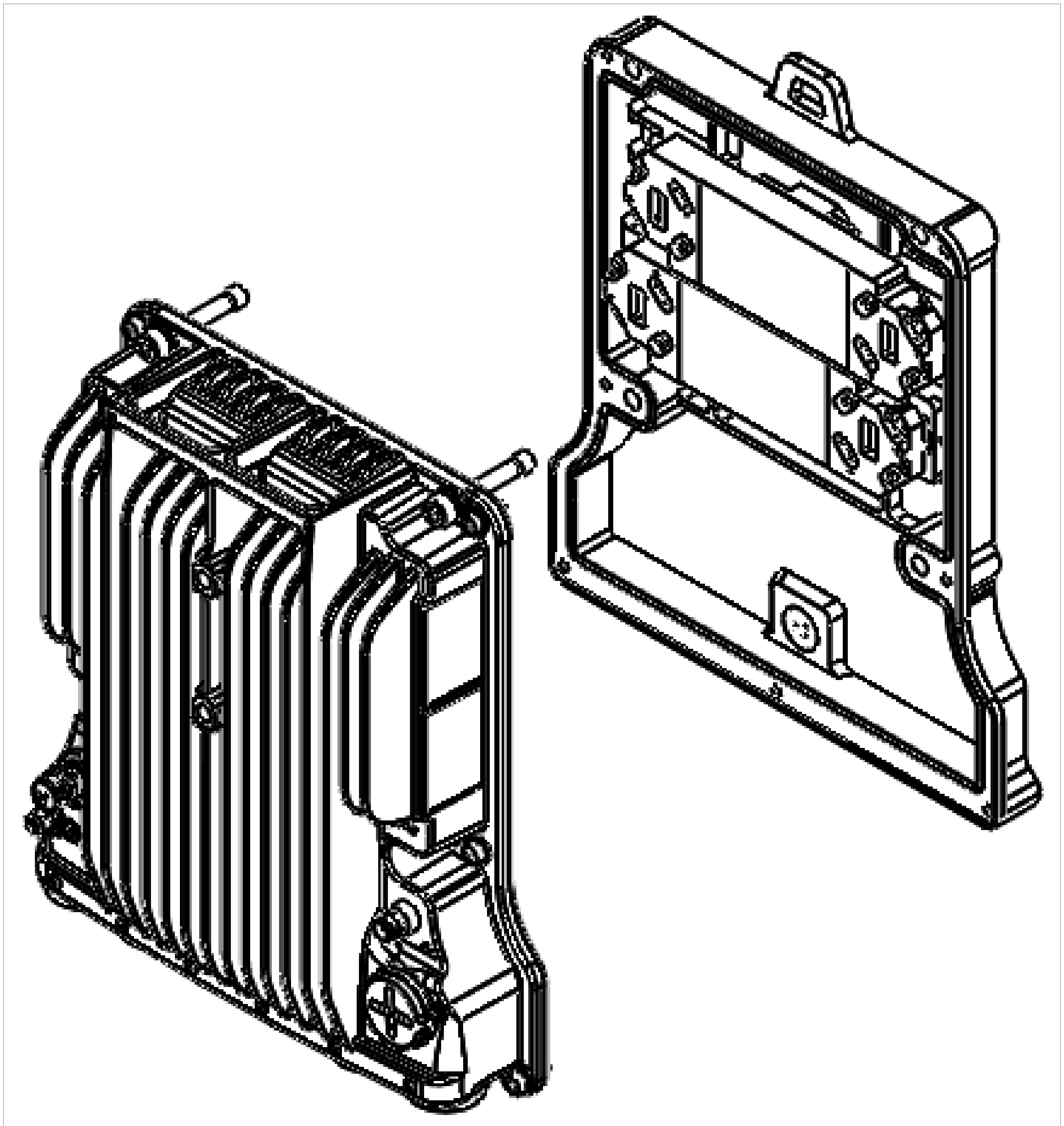
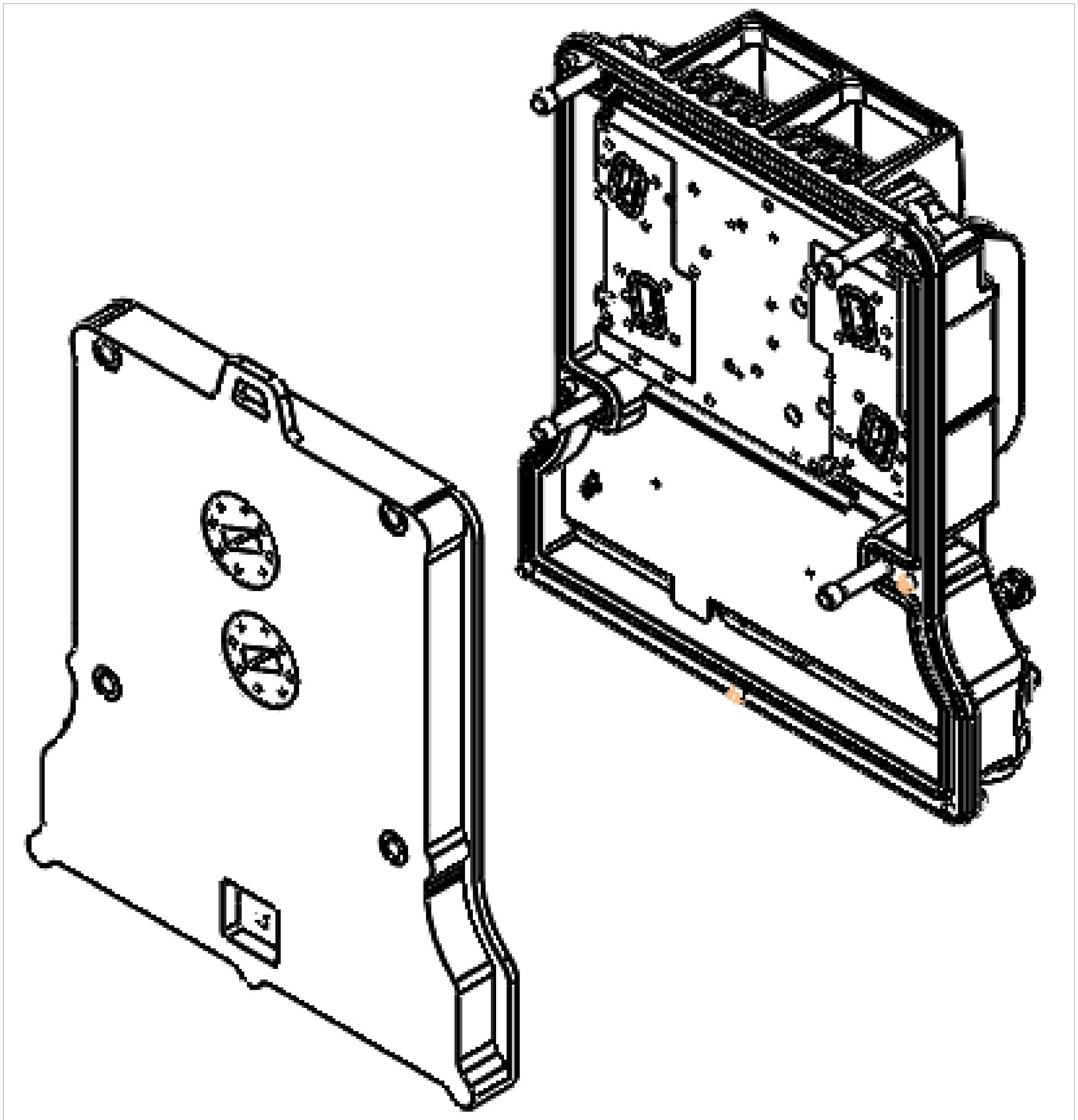


Figure 6: *PTP 850C Radio Unit (Right) and Diplexers Unit (Left)*



Management Connection for 4x4 MIMO and 1+1/2+2 HSB Configurations

In 4x4 MIMO and all HSB protection configurations, two Y-splitter cables and a special signaling cable must be used to connect the management ports (MGT/PROT) of the two PTP 850C units and provide management access to each unit.

- MIMO and HSB protection are planned for future release.

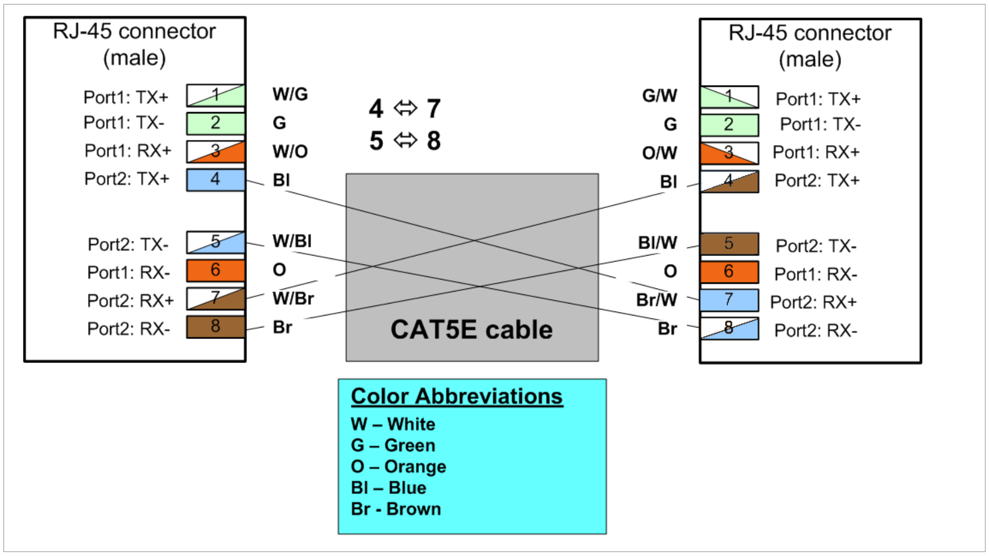
The MIMO/Protection signaling cables are available pre-assembled from Cambium in various lengths, but users can also prepare them in the field.

The following sections explain how to prepare and connect these cables.

Preparing a MIMO/Protection Signaling Cable

The MIMO/Protection signaling cables require the following pinouts.

Figure 7: *MIMO/Protection Signaling Cable Pinouts*



Note:

Other than the pinout connection described above, the cable should be prepared according to the cable preparation procedure described the PTP 850C Installation Guide.

Connecting the MIMO/Protection Splitters and Protection Signaling Cable

Each splitter has three ports:

- System plug (“Sys”) – The system plug should be connected to the PTP 850C’s management port.
- Management port (“Mng”) – A standard CAT5E cable should be connected to the splitter’s management port in order to utilize out-of-band (external) management.

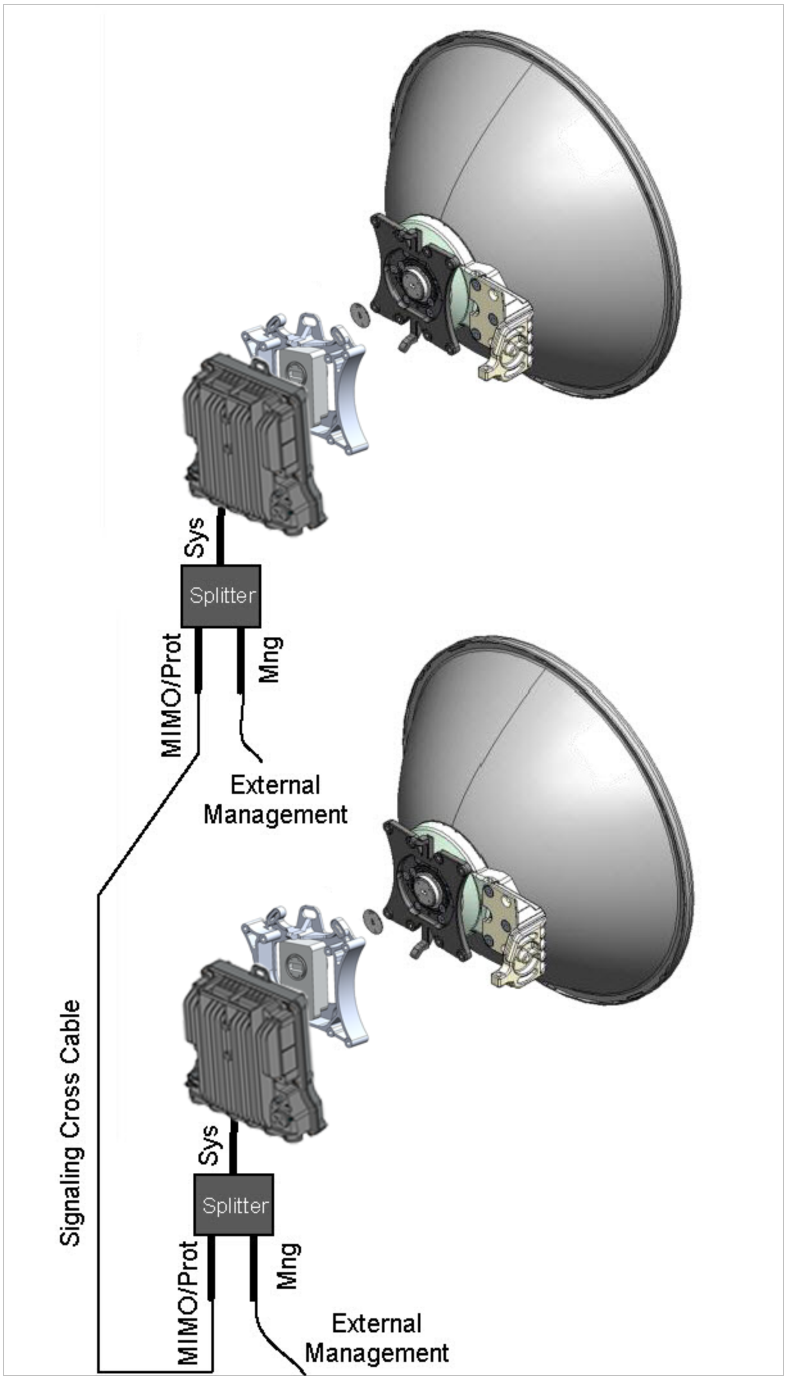
Note:

Even for systems that use in-band management, initial configuration of a 4x4 MIMO and any HSB protection configuration must be performed manually using out-of-band management.

- MIMO/Protection signaling port (“MIMO/Prot”) – A MIMO/Protection signaling cross cable, as described above, should be connected between this port and the other “MIMO/Prot” port of the second splitter on the mate PTP 850C unit.

The following figure demonstrates a 4x4 MIMO configuration in which both PTP 850C units are connected to an external management station and to each other, using two splitters.

Figure 8: *4x4 MIMO or HSB Protection Configuration with External Management*



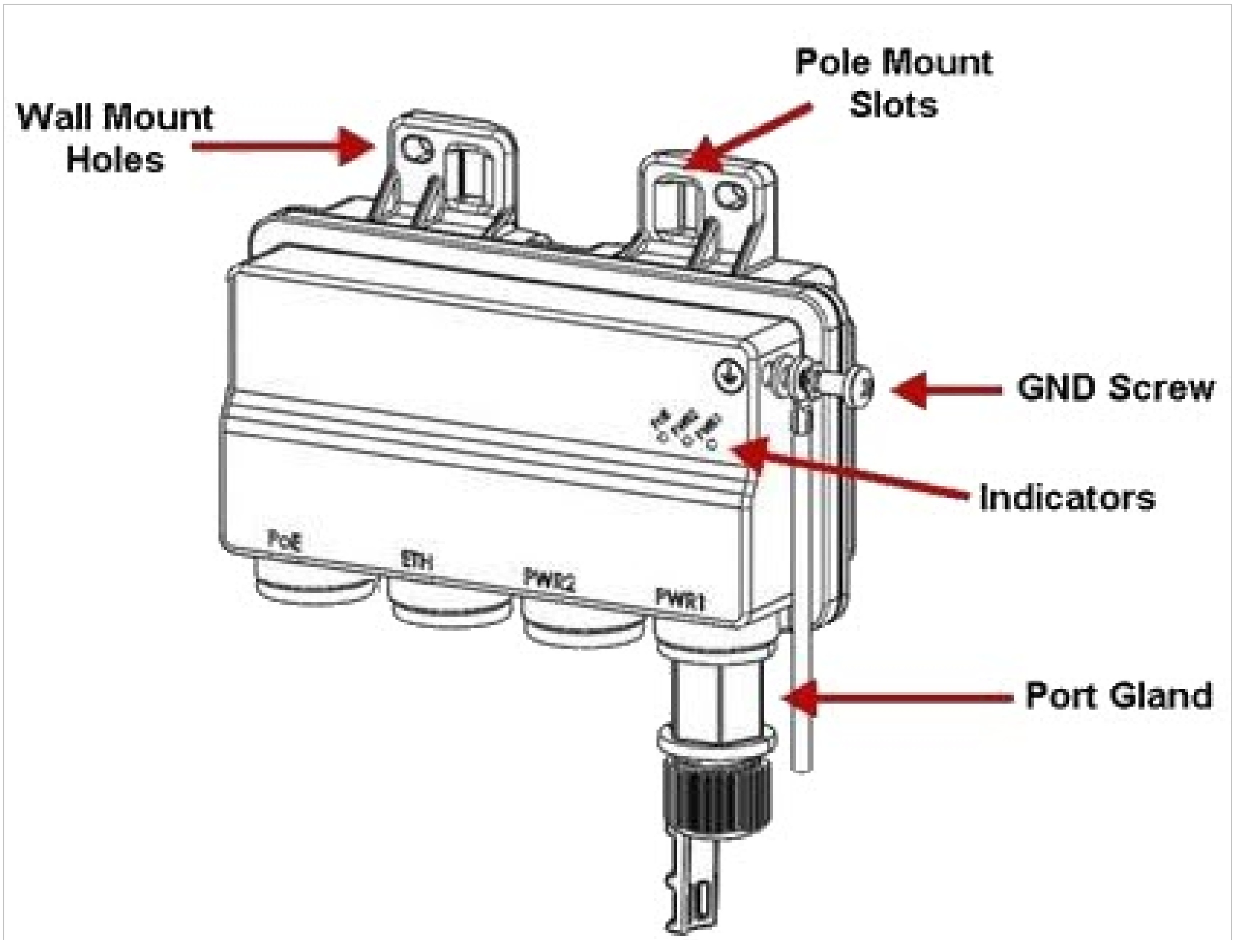
PoE Injector

The PoE injector box is designed to offer a single cable solution for connecting both data and the DC power supply to the PTP 850C system.

To do so, the PoE injector combines 48VDC input and GbE signals via a standard CAT5E cable using a proprietary Cambium design.

The PoE injector can be ordered with a DC feed protection, as well as EMC surge protection for both indoor and outdoor installation options. It can be mounted on poles, walls, or inside racks.

Figure 9: *PoE Injector*



Two models of the PoE Injector are available:

- **PoE_Inj_AO_2DC_24V_48V** – Includes two DC power ports with power input ranges of -(18-60)V each.
- **PoE_Inj_AO** – Includes one DC power port (DC Power Port #1), with a power input range of -(40-60)V.

Note:

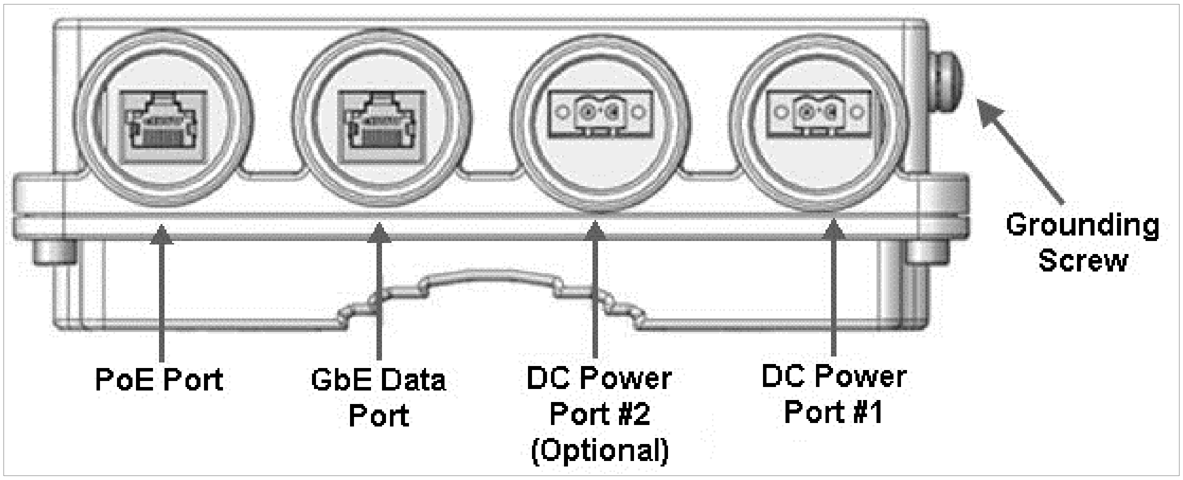
These PoE injectors cannot be used if the PoE port (P2, Eth1) is set to 10 Gbps mode.

PoE_Inj_AO can only be used for frequencies of 13 GHz to 42 GHz.

PoE Injector Interfaces – Standard PoE

- DC Power Port 1 -(18-60)V or -(40-60)V
- DC Power Port 2 -(18-60)V
- GbE Data Port supporting 10/100/1000Base-T
- Power-Over-Ethernet (PoE) Port
- Grounding screw

Figure 10: *PoE Injector Ports*



Voltage Alarm Thresholds and PMs

The allowed power input range for the PTP 850C is -40.5V to -60V. An undervoltage alarm is triggered if the power goes below a defined threshold, and an overvoltage alarm is triggered if the power goes above a defined threshold. The default thresholds are:

- Undervoltage Raise Threshold: 36V
- Undervoltage Clear Threshold: 38V
- Overvoltage Raise Threshold: 60V
- Overvoltage Clear Threshold: 58V

These thresholds are configurable.

PTP 850C also provides PMs that indicate, per 15-minute and 24-hour periods:

- The number of seconds the unit was in an undervoltage state during the measured period.
- The number of seconds the unit was in an overvoltage state during the measured period.
- The lowest voltage during the measured period.
- The highest voltage during the measured period.

Activation Keys

This chapter describes PTP 850C's activation key model. PTP 850C offers a pay as-you-grow concept in which future capacity growth and additional functionality can be enabled with activation keys. For purposes of the activation keys, each PTP 850C unit is considered a distinct device. Each device contains a single activation key.

Note:

Alternatively, a Smart Activation Key is available for simplified and centralized activation key management, using a Smart Activation Key server to manage licensing for multiple devices. For further information about Smart Activation Key management, refer to the *Smart Activation Key User Guide*.

This chapter includes:

Working with Activation Keys

Cambium provides a web-based system for managing activation keys. This system enables authorized users to generate activation keys, which are generated per device serial number.

In order to upgrade an activation key, the activation key must be entered into the PTP 850C. The system checks and implements the new activation key, enabling access to new capacities and/or features.

In the event that the activated-key-enabled capacity and feature set is exceeded, an Activation Key Violation alarm occurs and the Web EMS displays a yellow background and an activation key violation warning. After a 48-hour grace period, all other alarms are hidden until the capacity and features in use are brought within the activation key's capacity and feature set.

Demo Mode

The system can be used in demo mode, which enables all features for 60 days. Demo mode expires 60 days from the time it was activated, at which time the most recent valid activation key cipher goes into effect. The 60-day period is only counted when the system is powered up. 10 days before demo mode expires, an alarm is raised indicating to the user that demo mode is about to expire.

Note:

Demo mode does not include AES radio encryption functionality unless a valid AES activation key has been applied for at least one carrier when demo mode is activated.

Activation Key Reclaim

If a customer needs to deactivate an PTP 850C device, whether to return it for repairs or for any other reason, the customer can reclaim the device's activation key and obtain a credit that can be applied to activation keys for other devices.

Where the customer has purchased upgrade activation keys, credit is given for the full feature or capacity, not for each individual upgrade. For example, if the customer purchased five capacity activation keys for 300M and later purchased three upgrade activation keys to 350M, credit is given as if the customer had purchased three activation keys for 350M and two activation keys for 300M.

Activation Key-Enabled Features

The default (base) activation key provides each carrier with a capacity of 10 Mbps. In addition, the default activation key provides:

- A single management service.
- A point-to-point (L1) service per each GbE port covered by the activation key.
- 1 x GbE port for traffic.
- Full QoS with basic queue buffer management (fixed queues with 1 Mbit buffer size limit, tail-drop only).
- LAG
- No synchronization

Note:

As described in more detail below, a CET Node activation key allows all CET service/EVC types including Point-to-Point, Multipoint, and MSTP for all services, as well as an additional GbE traffic port for a total of 2 x GbE traffic ports.

As your network expands and additional functionality is desired, activation keys can be purchased for the features described in the following table.

Table 2 *Activation Key Types*

Name	Marketing Model	Description	Addition Information
2nd Core Activation	N000082L027A	Enables the second carrier of an PTP 850C. A separate activation key is required per radio.	Unique MultiCore Architecture
ACM	N000082L029A	Adaptive Coding Modulation. A separate activation key is required per radio.	Adaptive Coding Modulation (ACM)
Advanced Security	SL-ADV-SEC	Enables Syslog Encryption and NTP Authentication. One activation key is required per device.	• NTP Support • Syslog Support

Name	Marketing Model	Description	Addition Information
AES Encryption	N000082K027B	Enables the use of AES-256 encryption for full radio payload encryption. A separate activation key is required per carrier. Note that: • If no AES activation key is configured for the unit and the user attempts to enable AES on a radio carrier, in addition to an Activation Key Violation alarm the feature will remain inactive and no encryption will be performed. • After entering an AES activation key, the user must reset the unit before AES can be activated. Unit reset is only necessary for the first AES activation key. If AES activation keys are acquired later for additional radio carriers, unit reset is not necessary.	AES-256 Payload Encryption
AFR	SL-Freq-Reuse	Enables the use of Advanced Frequency Reuse (AFR). For an AFR 1+0- configuration, two activation keys are required for the hub site (one per radio member) and one activation key is required for each tail site. **Note**: AFR is planned for future release.	Advanced Frequency Reuse (AFR)
ASD	SL-ASD	Enables the use of Advanced Space Diversity (ASD). A separate activation key is required per radio member **Note**: ASD is planned for future release.	Advanced Space Diversity (ASD)
ASP and LLF	N000082K165A	Enables the use of Link Loss Forwarding (LLF) with Automatic State Propagation (ASP). Without the activation key, only one LLF ID can be configured. This means that only one ASP pair can be configured per radio interface or radio group. One activation key is required per device.	Automatic State Propagation and Link Loss Forwarding
Carrier Ethernet Transport (CET)	Refer to Table 4.	Enables Carrier Ethernet Transport (CET) and a number of Ethernet services (EVCs), depending on the type of CET Node activation key: • Edge CET Node – Up to 8 EVCs.	• Ethernet Service Model • Quality of Service (QoS)

Name	Marketing Model	Description	Addition Information
		• Aggregation Level 1 CET Node – Up to 64 EVCs. • Aggregation Level 2 CET Node – Up to 1024 EVCs. A CET Node activation key also enables the following: • A GbE traffic port in addition to the port provided by the default activation key, for a total of 2 GbE traffic ports. • Network resiliency (MSTP/RSTP) for all services. • Full QoS for all services including basic queue buffer management (fixed queues buffer size limit, tail-drop only) and eight queues per port, no H-QoS.	• Network Resiliency
Eth. OAM - Fault Management	N000082L039A	Enables Connectivity Fault Management (FM) per Y.1731 (CET mode only). One activation key is required per device.	Connectivity Fault Management (FM)
Eth. OAM - Perf. Monitoring	SL-Eth-OAM-PM	Enables performance monitoring pursuant to Y.1731 (CET mode only). One activation key is required per device. **Note**: Performance monitoring pursuant to Y.1731 is planned for future release.	
Ethernet traffic ports - 10GbE	N000082K167A	Enables the use of 10GbE ports. A separate activation key is required per port.	PTP 850C Unit Description and Interfaces
Ethernet traffic ports - 1GbE/2.5GbE	N000082L042A	Enables the use of 1GbE/2.5GbE ports. One GbE port is enabled by default without requiring any activation key. A separate activation key is required per port.	PTP 850C Unit Description and Interfaces
Frame Cut-Through	N000082L041A	Enables Frame Cut-Through. One activation key is required per device. **Note**: Frame Cut-Through is planned for future release.	Frame Cut-Through
H-QoS	SL-H-QoS	Enables H-QoS. This activation key is required to add service-bundles with	Quality of Service (QoS)

Name	Marketing Model	Description	Addition Information
		dedicated queues to interfaces. Without this activation key, only the default eight queues per port are supported. One activation key is required per device.	
IEEE 1588v2 Boundary Clock BRCM	SL-IEEE-1588-BC-BRCM	Enables IEEE-1588 Boundary Clock. One activation key is required per device.	IEEE-1588v2 PTP Optimized Transport
IEEE 1588v2 Transparent Clock BRCM	C800085K004A	Enables IEEE-1588 Transparent Clock. One activation key is required per device.	IEEE-1588v2 PTP Optimized Transport
L1 Link Bonding	SL-L1-Link-Bonding	L1 Link Bonding. One activation key is required per device.	Layer 1 Link Bonding and Layer 1 Link Bonding with Multiband
LACP	N000082K166A	Enables Link Aggregation Control Protocol (LACP). One activation key is required per device.	Link Aggregation Groups (LAG) and LACP
MIMO	N000082L049A	Multiple Inputs Multiple Outputs. A separate activation key is required per radio member. **Note**: MIMO is planned for future release.	Line of Sight (LoS) MIMO
Multi Carrier ABC	N000082L048A	Multi-Carrier ABC. A separate activation key is required per radio member.	Enhanced Multi-Carrier ABC
Netconf/YANG	SL-NETCONF/YANG	Enables management protocol Netconf on the device. One activation key is required per device.	SDN Support
Network Resiliency	N000082L050A	Enables the following protocol for improving network resiliency: • G.8032 One activation key is required per device.	Network Resiliency
Radio Capacity	Refer to Table 4.	Enables you to increase your system's radio capacity in gradual steps by upgrading your capacity activation key. Without a capacity activation key, each core has a capacity of 10 Mbps. A separate activation key is required per radio.	Capacity Summary
SD	SL-SD	Space Diversity. A separate activation key is	Space Diversity

Name	Marketing Model	Description	Addition Information
		required per radio member. **Note**: Space Diversity is planned for future release.	
Secured Management	N000082L051A	Enables secure management protocols (SSH, HTTPS, SFTP, SNMPv3, TACACS+, and RADIUS).	Secure Communication Channels
Single Sign-On (SSO)	SL-SSO	Enables single sign-on (SSO).	SSO Web Login with Microsoft Entra ID
Synchronous Ethernet	N000082L052A	Enables the ITU-T G.8262 SyncE and ITU-T G.8264 ESMC synchronization unit. This activation key is required in order to provide end-to-end synchronization distribution on the physical layer. This activation key is also required to use Synchronous Ethernet (SyncE). One activation key is required per device.	Synchronization
XPIC	N000082L056A	Enables the use of Cross Polarization Interference Canceller (XPIC). A separate activation key is required per radio member.	Cross Polarization Interference Canceller (XPIC)

Table 3 *Capacity Activation Keys*

Marketing Model	Marketing Description	Notes
SL-Capacity-50M	PTP 820 SL - Capacity 50M	
N000082L123A	SL - Capacity 100M, per carrier	
SL-Capacity-150M	PTP 820 SL - Capacity 150M	
N000082L124A	SL - Capacity 200M, per carrier	
SL-Capacity-225M	PTP 820 SL - Capacity 225M	
SL-Capacity-250M	PTP 820 SL - Capacity 250M	
N000082L130A	SL - Capacity 300M, per carrier	
SL-Capacity-350M	PTP 820 SL - Capacity 350M	
SL-Capacity-400M	PTP 820 SL - Capacity 400M	
SL-Capacity-450M	PTP 820 SL - Capacity 450M	
N000082L125A	SL - Capacity 500M, per carrier	

Marketing Model	Marketing Description	Notes
N000082L126A	SL - Capacity 650M, per carrier	
C000082K177A	SL - Capacity 1G, per carrier	
C800082K004A	SL - Capacity 1.6G, per carrier	
C000082K178A	SL - Capacity 2G, per carrier	
SL-Upg-50M-100M	PTP 820 SL - Upg 50M - 100M	
SL-Upg-100M-150M	PTP 820 SL - Upg 100M - 150M	
SL-Upg-150M-200M	PTP 820 SL - Upg 150M - 200M	
SL-Upg-200M-225M	PTP 820 SL - Upg 200M - 225M	
SL-Upg-225M-250M	PTP 820 SL - Upg 225M - 250M	
SL-Upg-250M-300M	PTP 820 SL - Upg 250M - 300M	
SL-Upg-300M-350M	PTP 820 SL - Upg 300M - 350M	
SL-Upg-350M-400M	PTP 820 SL - Upg 350M - 400M	
SL-Upg-400M-450M	PTP 820 SL - Upg 400M - 450M	
SL-Upg-450M-500M	PTP 820 SL - Upg 450M - 500M	
SL-Upg-500M-650M	PTP 820 SL - Upg 500M - 650M	
SL-Upg-500M-2.5G	PTP 820 Act.Key - Upg 500M -2.5G	
SL-Upg-650M-1G	PTP 820 SL - Upg 650M - 1G	
SL-Upg-1G-1.6G	PTP 820 SL - Upg 1G - 1.6G	
SL-Upg-1.6G-2G	PTP 820 SL - Upg 1.6G - 2G	

Table 4 *Edge CET Node Activation Keys*

Marketing Model	# of Bundled GbE Ports for User Traffic	Management Service	# of Point-to-Point (L1) Ethernet Services	# of CET (L2) Ethernet Services
Default (No Activation Key)	1	Yes	Unlimited	-
N000082L037A	2	Yes	Unlimited	8
N000082L030A	2	Yes	Unlimited	64
SL-Agg-Lvl-2-CET-Node	2	Yes	Unlimited	1024

If a CET activation key is not generated on the PTP 850C device upon initial configuration, the device uses by default a base smart pipe activation key (SL-0311-0). If the operator later wants to upgrade from the base smart pipe activation key to a CET activation key, the customer must use a CET upgrade activation key. The following table lists the CET upgrade activation keys:

Table 5 *Edge CET Node Upgrade Activation Keys*

Marketing Model	Upgrade From	Upgrade To
SL-Upg Smart-Pipe/Edge-CET nod	SL-Smart-Pipe (SL-0311-0)	SL-Edge-CET-Node (SL-0312-0)
SL - Upg Edge/Agg-Lvl-1-CET no	SL-Edge-CET-Node (SL-0312-0)	SL-Agg-Lvl-1-CET-Node (SL-0313-0)
SL - Upg Agg-Lvl-1/Lvl-2-CET n	SL-Agg-Lvl-1-CET-Node (SL-0313-0)	SL-Agg-Lvl-2-CET-Node (SL-0314-0)

Note:

- ASD is planned for future release.
- Performance monitoring pursuant to Y.1731 is planned for future release.
- Frame Cut-Through is planned for future release.
- MIMO is planned for future release.
- Space Diversity is planned for future release.

Feature Description

This chapter describes the main PTP 850C features. The feature descriptions are divided into the categories listed below.

Note:

For information on the availability of specific features, refer to the PTP 850C rollout plan or consult your Cambium representative.

This chapter includes:

- Unique MultiCore Architecture
- Innovative Techniques to Boost Capacity and Reduce Latency
- Ethernet Features
- Synchronization
- Radio Payload Encryption and FIPS

Unique MultiCore Architecture

PTP 850C's MultiCore radio architecture is based on an advanced parallel radio processing engine built around Cambium's proprietary baseband modem and RFIC chipsets. This architecture is optimized for parallel processing of multiple radio signal flows, and enables PTP 850C to multiply capacity and increase system gain in comparison with current technology.

Utilizing common processing resources at the kernel of the radio terminal, the MultiCore system reduces power consumption and maintains a small form-factor. This makes PTP 850C an advantageous choice for deployment in numerous heterogeneous network scenarios, such as small cells and fronthaul.

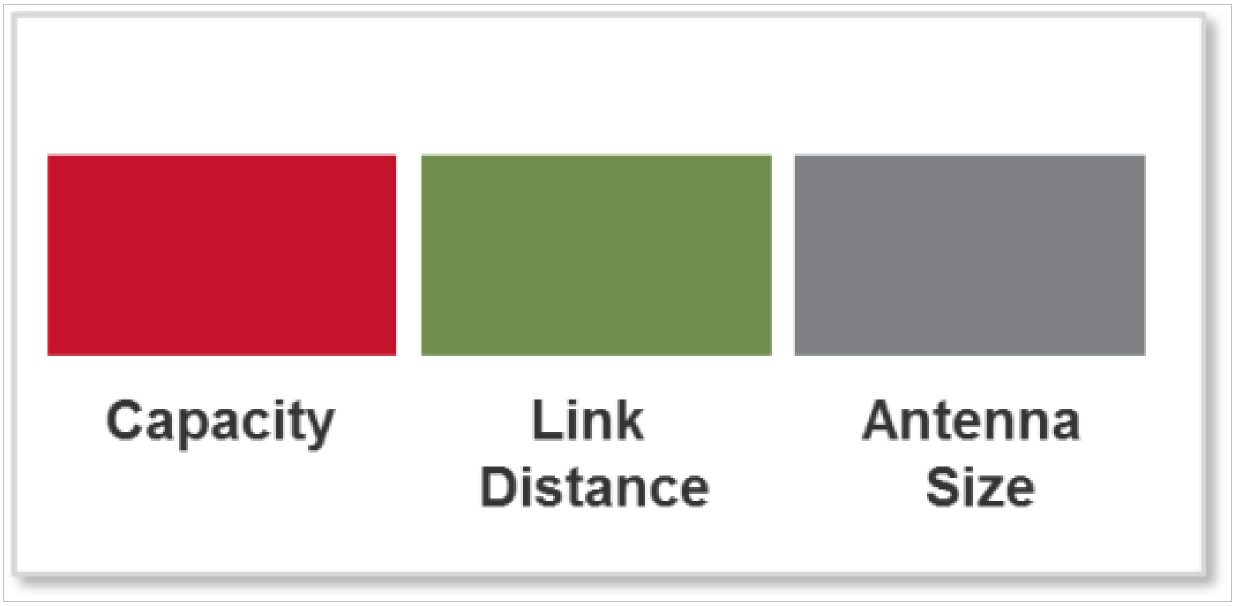
PTP 850C's parallel radio processing engine is what differentiates PTP 850C from other multiple-core solutions, which are really nothing more than multiple radio systems compacted into a single box. PTP 850C's MultiCore architecture enables PTP 850C to provide significant improvements in capacity and link distance, as well as low power consumption, smaller antennas, more efficient frequency utilization, less expensive frequency use, and a small form factor.

Flexible Operating Modes with MultiCore Architecture

PTP 850C's MultiCore architecture is inherently versatile and suitable for many different network deployment scenarios. PTP 850C can operate as a high-capacity, single-core solution. At any time in the network's growth cycle, the second core can be activated remotely for optimized performance.

To illustrate the many advantages of PTP 850C's MultiCore architecture, consider a generic, 1+0 single-core radio with high performance in terms of capacity, link distance, and antenna size.

Figure 11: *Performance Characteristics of Generic, 1+0 Single-Core Radio*



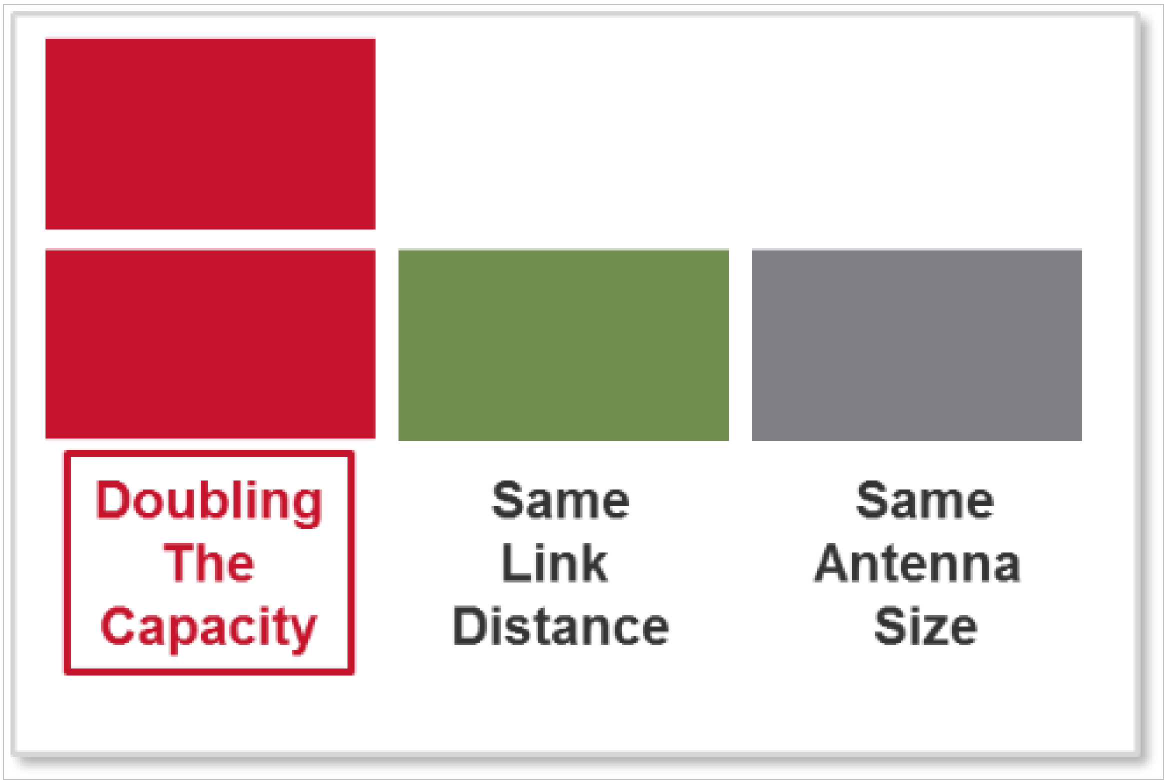
PTP 850C can operate in single-core mode, with similar parameters to a standard radio, but with additional capacity due to its ability to operate at 4096 QAM modulation.

Activating the second core does not simply double the capacity of the PTP 850C, but rather, provides a package of options for improved performance that can be utilized in a number of ways, according to the requirements of the specific deployment scenario.

- Doubling the Capacity

Turning on the PTP 850C's second core automatically doubles the PTP 850C's capacity. This doubling of capacity is achieved without affecting system gain or availability, since it results from the use of an additional core with the same modulation, Tx power, and Rx sensitivity. The PTP 850C also maintains the same small form-factor. Effectively, activating the second core provides a pure doubling of capacity without any tradeoffs.

Figure 12: *Doubling PTP 850C's Capacity by Activating Second Core*

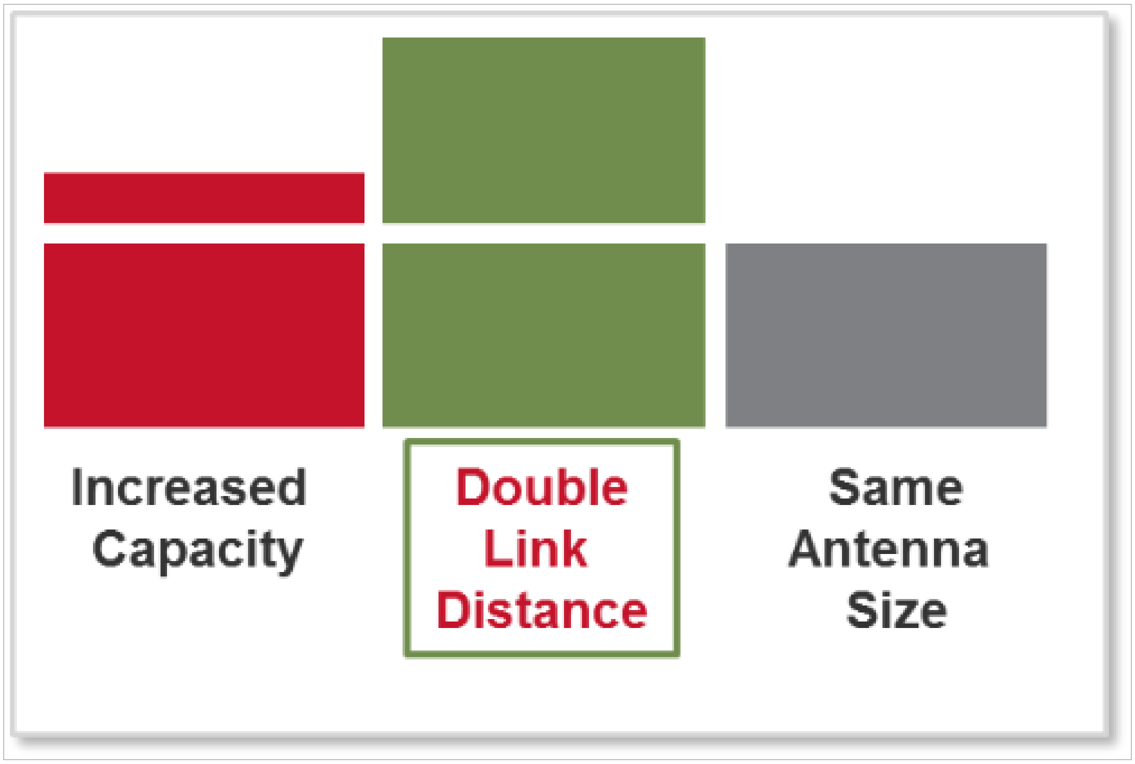


- Doubling the Link Distance

The increased performance that PTP 850C's MultiCore architecture provides can be leveraged to increase link distance. PTP 850C splits the bitstream between its two cores using Enhanced Multi-Carrier Adaptive Bandwidth Control (ABC). This makes it possible to utilize a lower modulation scheme that significantly increases system gain for Tx power and Rx sensitivity. This enables PTP 850C to support longer signal spans, enabling operators to as much as double their link spans.

For example, consider an PTP 850C in a 1+0 configuration with only one core activated, transmitting 260 Mbps over a 28 MHz channel with 2048 QAM modulation. Activating the second core makes it possible to reduce the modulation to 64 QAM and still add capacity, from 260 Mbps to 280 Mbps, consisting of 2 x 140 Mbps over the 28 MHz channel. Reducing the modulation from 2048 QAM to 64 QAM delivers a 4dB improvement in Tx power and a 15dB improvement in Rx sensitivity, for a total increase of 19dB in system gain. This improved system gain enables the operator to double the link distance, while benefiting from a 20 Mbps increase in capacity.

Figure 13: *Doubling Link Span While Increasing Capacity by Activating Second Core*

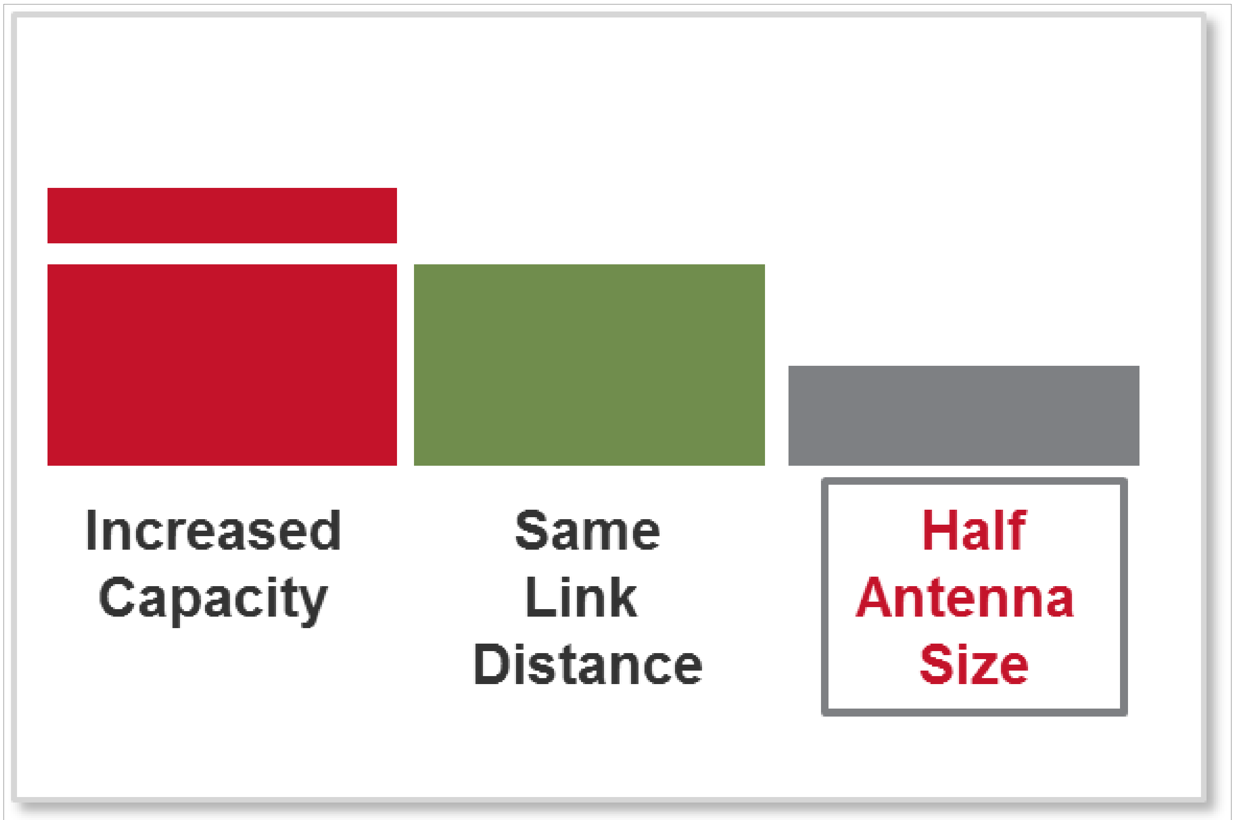


For additional information:

- Enhanced Multi-Carrier ABC
- Reducing Antenna Size by Half

The increased system gain that PTP 850C's MultiCore architecture makes possible can be leveraged to scale down antenna size by as much as half. In general, each doubling of antenna size on one side of the link translates into 6dB in additional link budget. The 19dB increase in system gain that PTP 850C's MultiCore architecture can provide can be exploited to halve the antenna size. This uses 12dB of the 19dB system gain, leaving 7dB to further reduce antenna size on either side of the link. This enables the operator to realize CAPEX savings from the MultiCore deployment.

Figure 14: *Utilizing Increased System Gain to Reduce Antenna Size*



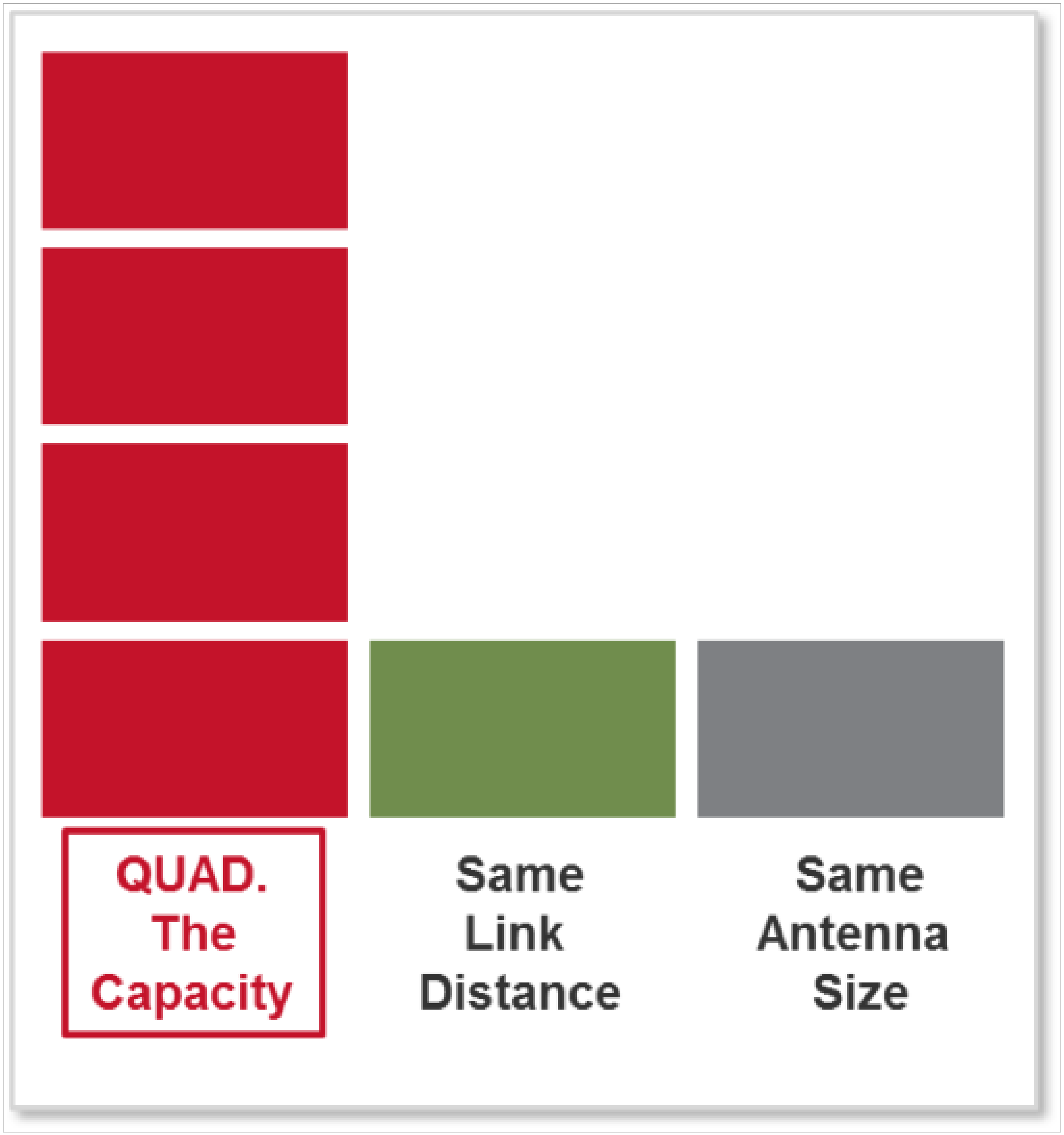
- Frequency Decongestion and Lower License Fees

Another way in which the increased system gain that PTP 850C's MultiCore architecture makes possible can be leveraged is by taking advantage of the increased system gain to shift from congested and expensive frequency bands to uncongested and less costly higher frequency bands. The loss in link budget incurred by moving to higher frequencies is absorbed by the increased system gain provided by PTP 850C's MultiCore architecture. Relatively long-span links, which previously required operation in lower, more congested, and more expensive frequencies such as 6, 7, and 8 GHz, can be shifted to higher, less congested, and less expensive frequency bands such as 13 GHz with the help of PTP 850C's MultiCore architecture.

- Quadrupling Capacity with PTP 850C's MultiCore Architecture and 4x4 MIMO

Two separate MultiCore PTP 850C units can be deployed in a MIMO configuration, making it possible to operate a very efficient Line-of-Sight (LoS) MIMO link by leveraging MIMO and XPIC technology together with PTP 850C's MultiCore architecture. With just two MultiCore PTP 850C units, four independent bitstreams can be transmitted over a single frequency channel, quadrupling capacity and spectral utilization. PTP 850C's 4x4 MIMO capabilities enable microwave to achieve gigabits of capacity, more than enough for small-cell and other heterogeneous network deployments.

Figure 15: *Quadrupling Capacity by Leveraging MIMO with PTP 850C's MultiCore Architecture*



For additional information:

- Line of Sight (LoS) MIMO
- Cross Polarization Interference Canceller (XPIC)

TCO Savings as a Result of MultiCore Architecture

The various ways described above in which PTP 850C MultiCore architecture can be leveraged to provide additional capacity, longer link distances, and smaller antenna side, all carry significant cost savings for operators.

Consider the common and practical scenario of a 1+0 link that must be upgraded to MultiCore 2+0 in order to accommodate growing demand for capacity. For a single-core system, the upgrade is a complicated process that requires:

- Purchasing a new radio unit.
- Sending an installation team to the site.
- Dismantling the existing radio unit.
- Replacing the single-mount radio-antenna interface with a coupler (for single polarization) or OMT (for dual polarization) to accommodate the two units.
- Re-installing the original radio unit along with the new radio unit.
- Connecting both radios to a switch in order to provide Layer 2 link aggregation (LAG), necessary to achieve a MultiCore 2+0 link.

These steps incur a high initial cost for re-installing and re-configuring the link, as well as high site leasing fees due to the additional equipment required, the larger footprint, and additional ongoing power consumption. The upgrade process involves hours of link down-time, incurring loss of revenue and impaired customer Quality of Experience (QoE) throughput the upgrade process. During its lifetime, the upgraded 2+0 single-core system will consume 100% more power than the 1+0 system and will be virtually twice as likely to require on-site maintenance.

With PTP 850C, network operators can initially install the MultiCore PTP 850C unit in single-core mode, with enough network capacity to meet current needs and the ability to expand capacity on the fly in the future. When an upgrade to MultiCore 2+0 becomes necessary, the operator merely needs to perform the following steps:

- Purchase an activation key for the second core.
- Remotely upload the activation key and activate the second core.

No site visits are required, and virtually no downtime is incurred, enabling customers to enjoy continuous, uninterrupted service. No additional switch is necessary, because PTP 850C can use Multi-Carrier ABC internally between the two cores to utilize the multi-channel capacity, in a much more efficient manner than with Layer 2 LAG. Network operators benefit from much lower power consumption than 2+0 systems made up of separate, single-core radio units, and site leasing fees do not increase since no additional hardware is required.

The following table summarizes the cost benefits of PTP 850C's MultiCore technology in terms of TCO.

Table 6 *TCO Comparison Between Single-Core and MultiCore Systems*

	Single-Core system	MultiCore system
Initial Installation	1+0 link with 1+0 antenna mediation device (remote or direct mount).	2+0 installation (remote or direct mount). Only one core has an

	Single-Core system	MultiCore system
		activation key and is activated.
Upgrade to 2+0	• Obtain new radio equipment • Send technical team to both ends of the link (at least two site visits). • Dismantle existing radio and mediation device. • Install new mediation device (OMT or splitter). • Re-install old radio with new radio. • Obtain and install Ethernet switch for 2+0 L2 LAG.	• Obtain activation key for second core. • Activate second core remotely. • Remotely define the link as 2+0 with L1 Multi-Carrier ABC (more efficient than LAG).
Downtime	Hours of downtime for complete reconfiguration of the link. Negative impact on end-user QoE.	Negligible downtime.
Power consumption	100% more than 1+0 link (even more with external switch).	Only 55% more power consumption than 1+0 configuration (single core).
Site leasing fees	Approximately double, since equipment is doubled.	No impact, MultiCore system within same small form factor unit
Warehouse management	Complicated, with different equipment for different deployment scenarios (standard/high power, low/high capacity).	Simple with single-spare, versatile radio for many deployment scenarios.

Innovative Techniques to Boost Capacity and Reduce Latency

PTP 850C utilizes Cambium's innovative technology to provide a high-capacity low-latency solution. The total switching capacity of PTP 850C is 16 Gbps, with a system capacity of 8 Gbps in a 4+0 configuration. PTP 850C also utilizes established Cambium technology to provide low latency, representing a 50% latency reduction for Ethernet services compared to the industry benchmark for wireless backhaul.

PTP 850C supports Line-of-Sight (LoS) Multiple Input Multiple Output (MIMO), which is the latest leap in microwave technology, enabling operators to double spectral efficiency. PTP 850C's MultiCore architecture enables operators to double and quadruple capacity over a single frequency channel with 2x2 and 4x4 MIMO configurations.

Cambium was the first to introduce hitless and errorless Adaptive Coding Modulation (ACM) to provide dynamic adjustment of the radio's modulation. ACM shifts modulations instantaneously in response to changes in fading conditions. PTP 850C utilizes Cambium's advanced ACM technology, and extends it to the range of BPSK to 4096 QAM.

In a 4+0 Layer 1 Link Bonding configuration, two PTP 850C units operate together to form a single link connected to the switch via a single cable. When utilizing XPIC and high-modulation ACM profiles, 4+0 Link Bonding can provide capacity of up to 4 Gbps over 112 MHz channels or 8 Gbps over 224 MHz channels.

Layer 1 Link Bonding can also be used to add an PTP 850C to existing PTP 820C or PTP 820C-HP deployments, thereby significantly increasing the capacity of existing PTP 820 links. A Link Bonding node with PTP 850C and PTP 820C or PTP 820C-HP can provide capacity of up to 5 Gbps when both units are utilizing their widest supported channels and highest modulations.

PTP 850C can also be used in Multiband configurations with Layer 1 Link Bonding. Multiband configurations pair PTP 850C with an PTP 850E or PTP 850EX to provide robust links that combine microwave with E-band transmissions, for capacity of up to 14 Gbps. With PTP 850E, the PTP 850E is the main unit and the PTP 850C is the attached unit. With PTP 850EX, the PTP 850C is the main unit and the PTP 850EX is the attached unit.

PTP 850C also supports Cross Polarization Interference Canceller (XPIC). XPIC enables operators to double their capacity with a single PTP 850C unit directly mounted to the antenna. The dual core PTP 850C utilizes dual-polarization radio over a single-frequency channel, thereby transmitting two separate carrier waves over the same frequency, but with alternating polarities. XPIC can be used in standard MultiCore 2+0 dual polarization configurations. XPIC is also an essential building block for 4x4 MIMO, enabling each PTP 850C unit to operate with two cores over the same frequency channel using dual polarization.

PTP 850C can be used in MultiCore 1+1 and 2+2 HSB configurations. A 1+1 configuration can easily be scaled up into a 2+2 configuration by activating the second core on each PTP 850C unit.

Note:

Not all of these features are supported in the initial PTP 850C release. For details, refer to the sections below or the Release Notes for the System Release version you are using.

This section includes:

- Capacity Summary
- Layer 1 Link Bonding and Layer 1 Link Bonding with Multiband
- Line of Sight (LoS) MIMO
- Space Diversity
- Advanced Space Diversity (ASD)
- Advanced Frequency Reuse (AFR)
- Frame Cut-Through
- Enhanced Multi-Carrier ABC
- Adaptive Coding Modulation (ACM)
- Cross Polarization Interference Canceller (XPIC)
- Unit Redundancy
- ATPC

- Radio Signal Quality PMs
- Radio Utilization PMs

Capacity Summary

Each of the two cores in an PTP 850C unit can provide the following radio capacity:

- **Supported Channels (ETSI)** –14/28/40/56/70/80/112/140/224· MHz channels

> **Note**:
>
> 224 MHz is only supported with certain hardware versions. For details, ask your Cambium representative.

- **Supported Channels (FCC)** –20/25/28/30/40/56/80/112/150/160/200/22411 MHz channels
- **All licensed bands** –L6, U6, 7, 8, 10, 11, 13, 15, 18, 23, 26, 28, 32, 38, 42 GHz
- **High Modulation** – BPSK to 4096 QAM

For additional information:

- Radio Capacity Specifications

Layer 1 Link Bonding and Layer 1 Link Bonding with Multiband

Layer 1 Link Bonding provides an efficient way to group radio links with an Ethernet interface so as to combine the radio links into a single high-capacity link, connected by a single cable to the external switch. The links can include different channels and frequencies, enabling the use of creative solutions that optimize the available frequency spectrum.

Layer 1 Link Bonding configurations include a main unit and an attached unit. The main unit is connected to the switch and performs traffic distribution based on the Link Bonding technology embedded in the unit's modem. Traffic separation is implemented by segmenting and re-assembling the data stream and dividing it between the radio channels. This takes place in the main unit.

> **Note**:
>
> Because the Link Bonding technology adds a small overhead, when planning links that use Link Bonding, please consult your Pre-Sales manager and/or use the link capacity calculator to determine the expected capacity.

The main unit and the attached unit are connected to each other via a single cable or two cables to carry traffic and L2 protocol data between the two units. The following PTP 850C Layer 1 Link Bonding configurations are available:

- 4+0 Layer 1 Link Bonding using two PTP 850C units
- Link Bonding with PTP 850C (main unit) and PTP 820C or PTP 820C-HP (attached unit)

- Multiband with Layer 1 Link Bonding using PTP 850C (main unit) and PTP 850EX (attached unit)
- Multiband with Layer 1 Link Bonding using PTP 850C (attached unit) and PTP 850E (main unit)

Note:

PTP 850C can also be used in Link Bonding configurations with PTP 820N and PTP 820A units using TCC-U. For more information, refer to the Technical Description for PTP 820N and PTP 820A.

Multiband with Layer 1 Link Bonding

PTP 850C can be used in Multiband configurations with PTP 850E or PTP 850EX.

- In configurations with PTP 850E, the PTP 850E acts as the main unit and the PTP 850C acts as the attached unit.
- In configurations with PTP 850EX, the PTP 850C acts as the main unit and the PTP 850EX acts as the attached unit.

Multiband bundles E-Band and microwave radios in a single group that is shared with an Ethernet interface.

Layer 1 Link Bonding enables operators to optimize the capacity of a Multiband link by combining the capacity of the E-Band and Multiband links into a single link of up to 14 Gbps. This is achieved when the PTP 850E or PTP 850EX is used in 2000 MHz channels, providing 10 Gbps, while the PTP 850C is operating in XPIC mode over 224 MHz channels, providing 4 Gbps at high profiles.

A Multiband link with Layer 1 Link Bonding is highly resilient because it combines the high capacity of E-Band with the high resiliency of Microwave. The advantage of Link Bonding is that it enables the E-Band and Microwave links to aggregate their capacity, rather than utilizing the Microwave link as more of a backup to the E-Band link. In the event of radio failure in one device, the other device continues to operate to the extent of its available capacity. Thus, operators benefit from both the high capacity of E-Band and the high reliability of microwave.

A special Multiband antenna can be used for Multiband configurations. This antenna transmits and receives both E-band and microwave signals. Both units (PTP 850E/PTP 850EX and PTP 850C) are connected to this antenna via direct mount.

The marketing model for Multiband antennas uses the following syntax:

Am-B3-d-ff/80-pl/ph-vn

Where:

- d – Size of the antenna (1 or 2 ft)
- ff – The microwave band (11, 13, 15, 18, 23, 28, etc.)
- pl – Interface of the microwave antenna
  - SP – single polarization (rectangular interface)
  - DP – dual polarization (circular interface)

- ph – Interface of the E-Band antenna:
  - SP – single polarization (rectangular interface)
  - DP – dual polarization (circular interface)
- vn – Antenna Vendor (MT: MTI, A: Commscope, RS: Rosenberger, etc.)

For example, the following marketing model applies to a 2-foot antenna for an 18 GHz Microwave radio together with an E-band device, where both radios are operating with Single Polarization. The manufacturer is MTI.

Am-2-18/80-SP/SP-MT

For a full list of available Multiband antennas, refer to the Price List or check with your Cambium representative.

Layer 1 Link Bonding and Line Redundancy

Line redundancy is available for the following PTP 850C Link Bonding configurations:

- 4+0 Layer 1 Link Bonding with PTP 850C
- Multiband PTP 850E and PTP 850C with Layer 1 Link Bonding

Line Redundancy means the external switch is connected to both the main and the attached units via an optical splitter. The optical splitter routes traffic between the Ethernet port on the external switch and an Ethernet port on both the main and the attached unit.

Optionally, Line Redundancy can include management redundancy for external management, using an additional split cable between the management ports of each unit and an external management station.

> **Note**:
>
> Configurations with Line Redundancy should use Enhanced Link Bonding Mode and a single cable for traffic and protocols. See Requirements and Limitations for Enhanced Link Bonding Mode.

In normal operation, traffic and management pass only between the external switch and the main unit, and the interface between the switch and the attached unit is turned off. In the event of switchover, the link between the external switch and the attached unit is automatically activated by switching off the interface between the external switch and the main unit and switching on the interface between the external switch and the attached unit so that traffic and management are passed between the external switch and the attached unit.

A set of services for traffic and management must be configured on the attached unit in parallel to the services on the main unit. These services are configured in Operational state. The Line Redundancy mechanism deactivates the services in normal operating state based on the Line Redundancy role configurations, and activates them only in the event of switchover to support the flow of traffic and management from the external switch to the attached unit's radio.

Figure 16: *4+0 PTP 850C with Layer 1 Link Bonding and Line Redundancy*

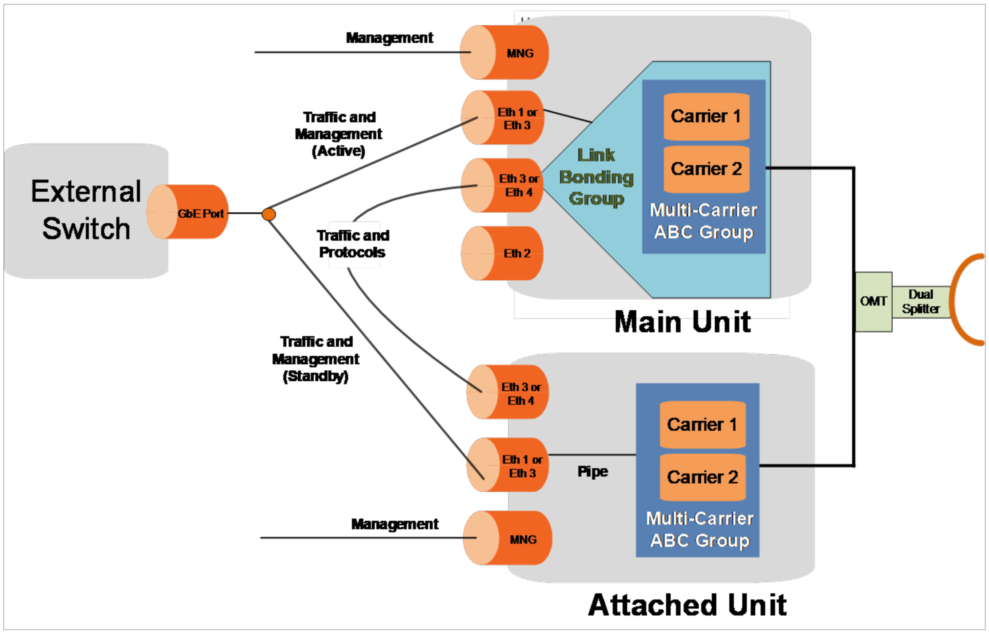


Figure 17: *Multiband with Layer 1 Link Bonding and Line Redundancy – Multiband Antenna*

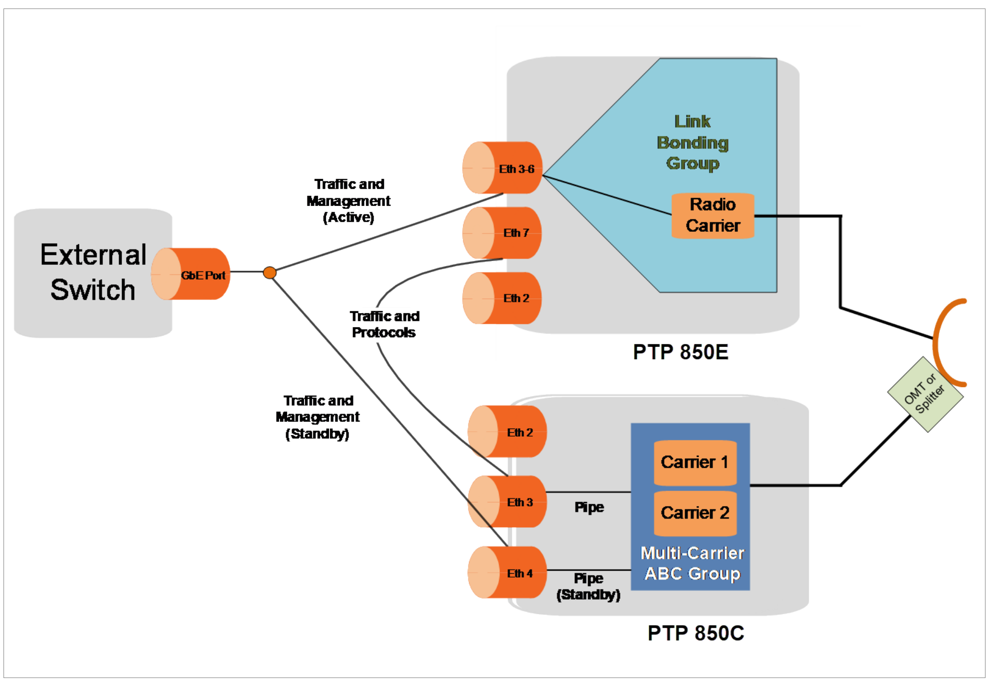
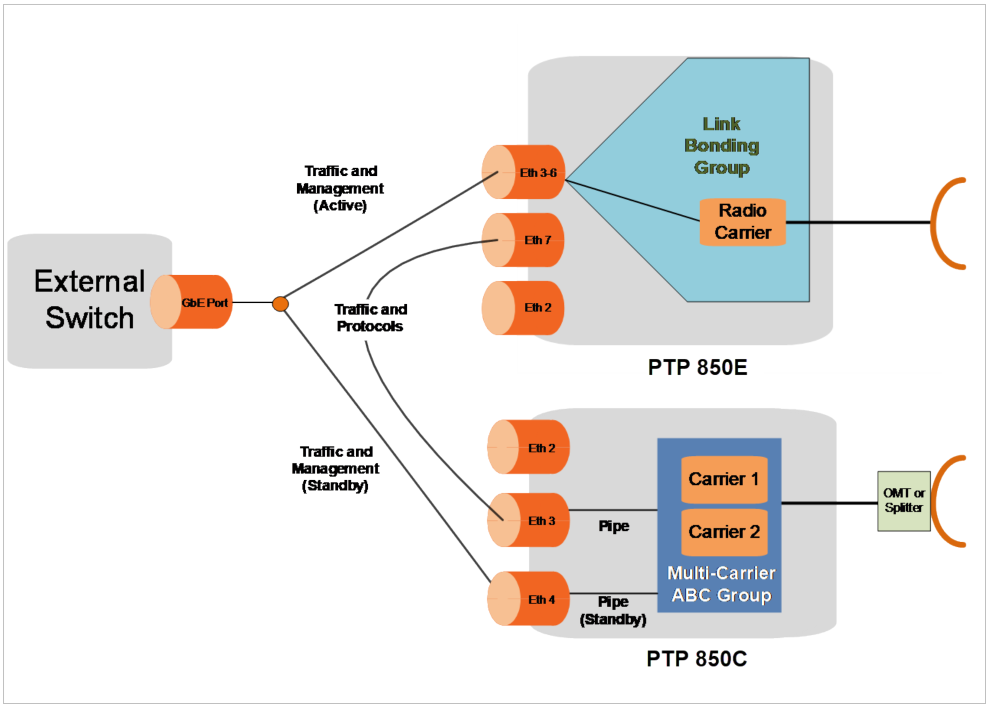


Figure 18: *Multiband with Layer 1 Link Bonding and Line Redundancy – Separate Antennas*



The following events trigger traffic switchover:

Note:

Radio failure on the main unit does not trigger switchover. Since traffic continues to be passed between the main unit and the attached unit, the attached unit's radio link continues to operate.

- Failure of traffic cable between external switch and main unit:
  - Traffic interfaces with the external switch on local and remote main units are automatically set to Down.
  - Traffic services are automatically disabled on the local and remote main units.
  - Traffic interfaces with the external switch on local and remote attached units are automatically set to Up.
  - Traffic services are automatically enabled on the local and remote attached units.
  - The management service points on the radio of the local and remote attached units are automatically enabled.
- Traffic cable between the main and attached unit fails:
  - The management service points on the radio of the local and remote attached units are automatically enabled.
  - On the remote side of the link, the interfaces connecting the traffic cable between the main and attached unit are automatically set to Down.

- Failure of main unit:
  - Traffic interfaces with the external switch on the remote main unit is automatically set to Down.
  - Traffic services are automatically disabled on the remote main unit.
  - Traffic interfaces with the external switch on local and remote attached units are automatically set to Up.
  - Traffic services are automatically enabled on the local and remote attached units.
  - The management service points on the radio of the local and remote attached units are automatically enabled.
  - On the remote side of the link, the interfaces connecting the traffic cable between the main and attached unit are automatically set to Down.

When the failure is rectified, the configuration automatically reverts to its normal operational configuration after expiration of a Wait to Restore (WTR) timer. Revertive mode cannot be disabled. However, the WTR timer is user-configurable.

Lockout and forced switch are available to manually change the state of the configuration (force-switch) or to manually force the configuration to remain in its current state (lockout). Lockout can be used to override Revertive mode and keep the configuration in switchover mode, should this be necessary.

Redundancy for external management operates independently of Line Redundancy for traffic. Using a split management cable attached to the management ports of each unit and an external management station, you can ensure that external management remains available even if management connectivity to one of the units is lost.

The following table lists the cable recommended for external management redundancy.

Table 7 *Cable for External Management Redundancy*

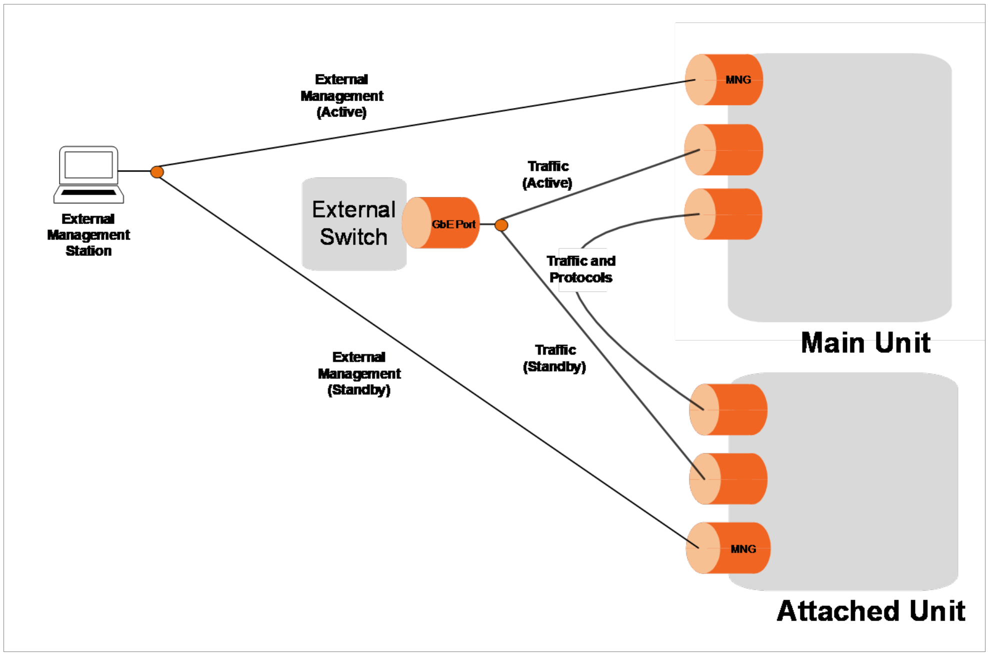
Cable	Marketing Model	Description
Management Splitter Cable (P2 to P2 and External Management Station)	CBL-IP20-EXT-PROT+MGMT	CABLE,RJ45F TO 2XRJ45,1.34M,CAT-5E,WITH MALE TO MALE CONNECTION

- Traffic cable between the main and attached unit fails:
- The management service points on the radio of the local and remote attached units are automatically enabled.

With external management redundancy, only one management port is up at any one time. External management switching is independent of traffic switchover. The following events trigger external management switchover:

- Management interface failure
- Unit failure
- On main unit, Link Bonding group operational status is Down

Figure 19: *Layer 1 Link Bonding with Line and External Management Redundancy*



Requirements and Limitations for Enhanced Link Bonding Mode

Enhanced Link Bonding mode is required for configurations that use a single cable to carry traffic and L2 protocol data between and main unit and the attached unit. There are several requirements and limitations for Enhanced Link Bonding Mode, as described below.

Hardware Requirements for Enhanced Link Bonding Mode

Most PTP 850C devices support a single-cable configuration. However, some units produced prior to the middle of 2021 may not. It is possible to determine whether or not a particular PTP 850C device supports this configuration by checking the Enhanced Mode Supported field in the General Parameters section of the Link Bonding page. If the field displays Yes, the device supports the single-cable configuration.

If an PTP 850C device does not support the single-cable configuration, the customer can contact a Cambium representative to discuss alternative solutions.

Enhanced Link Bonding Mode Limitations

Users must be aware of the following limitations when using Enhanced Link Bonding mode:

- Link Bonding groups must be configured to the same Link Bonding mode on both sides of the link. In other words, a Link Bonding group configured for Standard mode can only operate with another Link Bonding group configured for Standard mode and a Link Bonding group configured for Enhanced mode can only operate with another Link Bonding group configured for Enhanced mode.
- When a Link Bonding group is configured for Enhanced mode, the interfaces in the group are displayed as Logical Interfaces and services can be configured on these interfaces. This is to enable

configuration of protocols on these interfaces. Make sure to avoid configuring traffic services on interfaces that belong to a Link Bonding group; traffic services should only be configured on the Link Bonding group logical interface.

Synchronization in a Link Bonding Node

SyncE and 1588 PTP can be used with Link Bonding. SyncE and 1588 PTP can be configured for both the main unit and the attached unit. Synchronization messages are passed between the units via the cable carrying L2 protocols data between the units. This can be the traffic cable or a separate Protocols cable.

1588 PTP can be passed directly between the main units. This requires that the Link Bonding group be configured for Enhanced Link Bonding mode. See Requirements and Limitations for Enhanced Link Bonding Mode.

Alternatively, 1588 PTP can be passed between the attached units. This is possible in both Enhanced and Standard Link Bonding mode. However, if the attached unit goes down, 1588 packets will not be transmitted to the other side of the link.

Layer 1 Link Bonding PMs

PMs are available for L2 user traffic throughput and utilization for Link Bonding groups and their individual members. Group-level PMs exclude Link Bonding overhead. Member-level PMs include Link Bonding overhead.

Link Bonding PMs include peak counters and average counters. Thresholds can also be configured. The number of seconds during which these thresholds are exceeded are among the displayed PMs.

Peak counters display the maximum data rate and utilization percentage for each interval, with a resolution of one second. This means the PM mechanism records the number of bits sent during each second of the interval and displays the throughput (in Mbps) and utilization percentage for the highest one-second period during that interval. So, for example, when measuring 15-minute intervals, the PM mechanism chooses the peak value from 900 recorded values in that interval (60 seconds multiplied by 15 60-second record periods).

Average counters display the average data rate and utilization percentage for each interval, with a resolution of one second. For throughput, this means the PM mechanism divides the total number of bits received during the interval by the total number of seconds in the interval. So, for example, when measuring 15-minute intervals, the PM mechanism divides the total number of bits received during the 15-minute interval by 900.

By default, Link Bonding PMs are disabled. They can be enabled separately for each Link Bonding group configured on the device, and for each Link Bonding group member.

Link Bonding Configurations with PTP 850C

4+0 Layer 1 Link Bonding

4+0 Link Bonding aggregates an Ethernet link and four radio carriers into a single link with a single-cable connection to the switch, enabling operators to double the capacity of a 2+0 link. When utilizing XPIC and high-modulation ACM profiles, 4+0 Link Bonding can provide capacity of up to 4 Gbps over 112 MHz channels or 8 Gbps over 224 MHz channels.

In a 4+0 Link Bonding configuration, each PTP 850C unit can use a different frequency, providing operators with more flexibility to utilize the available frequency spectrum in whatever way is most efficient.

4+0 Layer 1 Link Bonding Operation

TBDDDA 4+0 Link Bonding node consists of two PTP 850C units, a main unit and an attached unit. The main unit is attached to the external switch via either Eth 1 (P2, the PoE port) or Eth 3 (P4, the MIMO port).

> **Note**:
>
> Although MIMO is not currently supported with PTP 850C, it is planned for future release. Therefore, any customer considering adding MIMO capabilities to the link in the future should use Eth 1 for connection to the external switch in order to leave Eth 3 available for future upgrade to MIMO.

Traffic is passed between the two PTP 850C units via an optical cable that connects Eth 3 (P4, the MIMO port) or Eth 4 (P5) of each unit. This is a 10 Gbps connection with a bidirectional capacity of up to 4 Gbps. The same cable can be used to carry L2 protocol data between the two units.

Alternatively, a separate optical Protocols cable can be connected between Eth 2 (P3) of each unit to carry L2 protocol data between the two units. If a separate Protocols cable is used, the ports to which it is connected must be configured to 2.5 Gbps.

Single-cable configurations require Enhanced Link Bonding mode. Although most PTP 850C devices support Enhanced Link Bonding mode, some do not. For details, see Requirements and Limitations for Enhanced Link Bonding Mode.

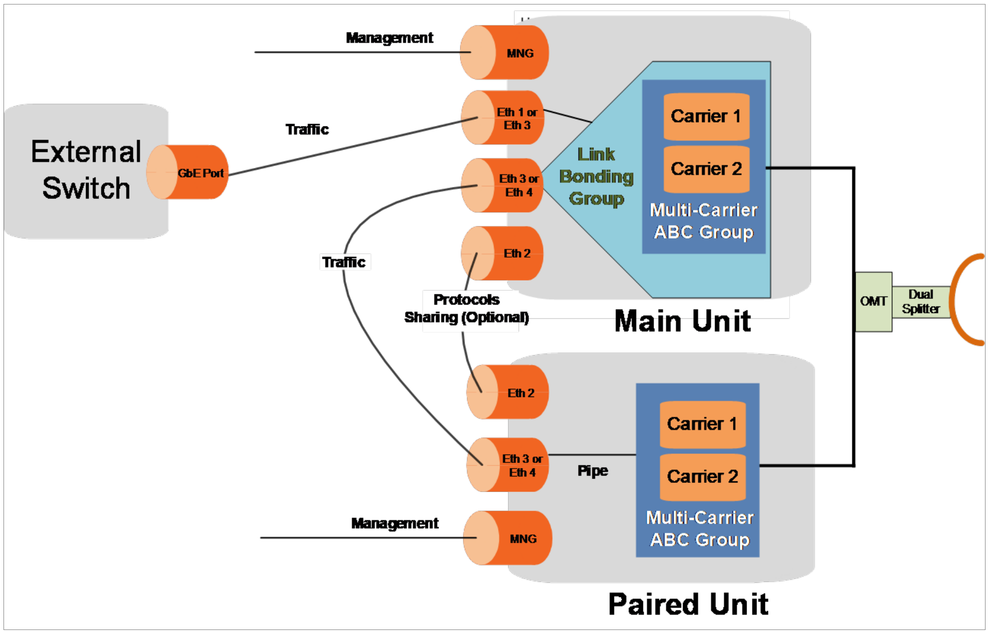
It is important to note that special SFP+ transceivers must be used for both the inter-unit traffic ports (Eth 3/P4 or Eth 4/P5) and the Protocols ports (Eth 2, P3). For details and the marketing models of the required SFP+ transceivers, as well as the optical cables, see the Installation Guide for PTP 850C.

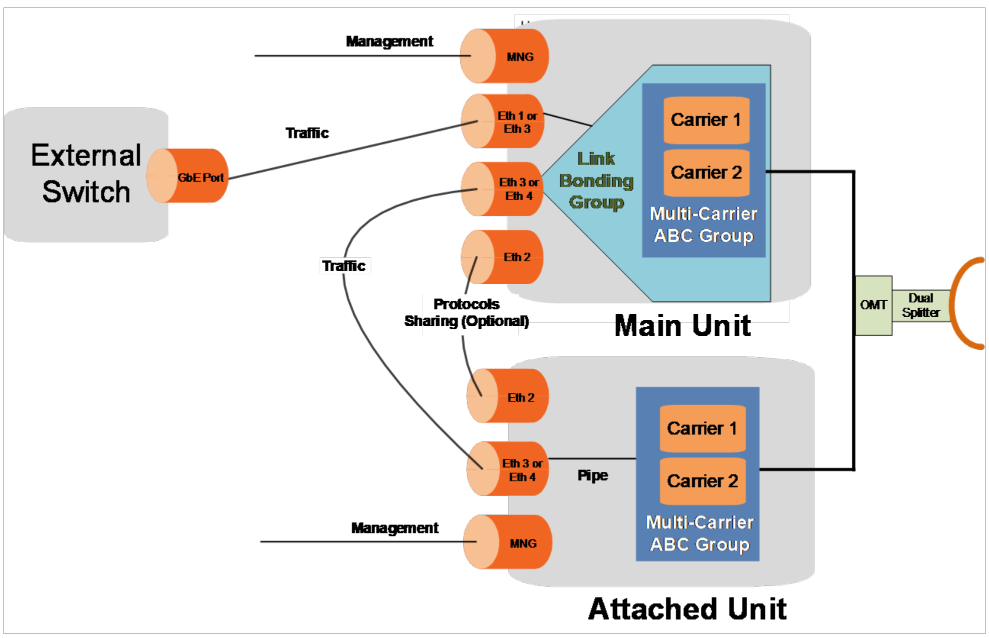
A Multi-Carrier ABC group must be configured on each PTP 850C unit. Each group should include both of the unit's radio carriers.

A Link Bonding group must be configured on the main unit. The Link Bonding group must include the main Unit's Multi-Carrier ABC group and the port connecting the main unit with the attached unit (Eth 4).

Each PTP 850C unit is managed separately and independently. In-band management can be configured so that both units are managed over the link.

Figure 20: *Layer 1 Link Bonding Operation – 4+0 PTP 850C*





4+0 Layer 1 Link Bonding Hardware Configuration

The two PTP 850C units can be connected to a single antenna using a Dual Splitter and an OMT. Remote-mount configurations are also available.

The hardware configuration for 4+0 Link Bonding uses the same mediation devices as PTP 820C. In addition, 4+0 Link Bonding requires one or two cables between the two PTP 850C units:

- Traffic cable – An optical cable used to pass traffic between the two PTP 850C units. The Traffic cable connects Eth 3 (P4, the MIMO port) or Eth 4 (P5) of each unit, using a 10 Gbps connection with a bidirectional capacity of up to 4 Gbps. The same cable can be used to carry L2 protocol data between the two units.

- Protocols cable – Alternatively, a separate optical cable can be used to carry L2 protocol data between the two units. The Protocols cable connects Eth 2 (P3) of each unit, using a 2.5 Gbps connection.

> **Note**:
>
> Although most PTP 850C devices support Enhanced Link Bonding mode, some do not. For details, see Requirements and Limitations for Enhanced Link Bonding Mode.

For details, including the marketing models of the cables and SFP transceivers that must be used for the inter-unit connections, refer to the Installation Guide for PTP 850C.

Multiband with Layer 1 Link Bonding – PTP 850C and PTP 850EX

PTP 850C can be used as the main unit with PTP 850EX as the attached unit in a Multiband configuration with Layer 1 Link Bonding.

> **Note**:
>
> This configuration is supported with PTP 850EX and PTP 850EX-P. For PTP 850EXA, support of this configuration is planned for future release.

Operation of Multiband PTP 850C and PTP 850EX with Layer 1 Link Bonding

In a Multiband node with Link Bonding that consists of an PTP 850C and an PTP 850EX, the PTP 850C is the main unit and the PTP 850EX is the attached unit. The PTP 850C can be attached to the external switch via any of its Ethernet interfaces.

Traffic is passed between the two units via an optical cable that connects any 10G Gbps interface on each of the two units. This 10 Gbps connection has a bidirectional capacity of up to 10 Gbps. The same cable can be used to carry L2 protocol data between the two units.

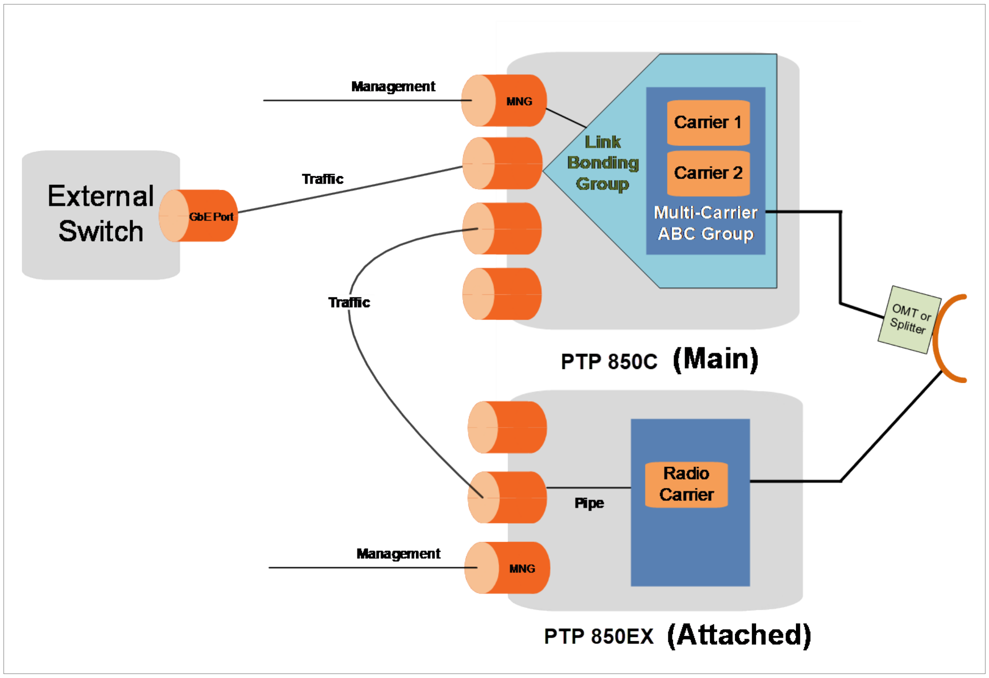
Alternatively, a separate optical Protocols cable can be connected between any two optical ports on the two units via another optical cable. This connection carries L2 protocol data between the two units. The ports can be configured to any speed of 1 Gbps or more, but they must be configured to the same speed.

A Multi-Carrier ABC group should be configured on the PTP 850C to include both of the unit’s radio carriers.

A Link Bonding group must be configured on the PTP 850C. The Link Bonding group must include the PTP 850C’s Multi-Carrier ABC group and the PTP 850C Ethernet port connected to the PTP 850EX (the Traffic port).

Each unit in the Multiband node is managed separately and independently. In-band management can be configured so that both units are managed over the link.

Figure 21: *Multiband with Layer 1 Link Bonding – PTP 850C and PTP 850EX with Multiband Antenna*



Multiband PTP 850C and PTP 850EX with Layer 1 Link Bonding – Hardware Configuration

Multiband node with PTP 850C and PTP 850EX can be configured with a single, Multiband Antenna.

Alternatively, each unit can be configured with separate antennas, making sure that the distance between the units does not exceed the length of either the Traffic or the Protocols cable.

In either case, the PTP 850C is connected to the antenna via an OMT (for dual polarization) or a Splitter (for single polarization).

For details, including the marketing models of the cables and SFP transceivers that must be used for the inter-unit connections, refer to the Installation Guide for PTP 850C and the Installation Guide for PTP 850EX.

Multiband with Layer 1 Link Bonding – PTP 850E and PTP 850C

PTP 850E can be used as the main unit with PTP 850C as the attached unit in a Multiband configuration with Layer 1 Link Bonding:

Operation of Multiband with PTP 850E as the Main Unit with Layer 1 Link Bonding

In a Multiband node with Link Bonding that uses PTP 850E as the main unit, the PTP 850E is attached to the external switch via Port 4, the QSFP port. This port can be used in QSFP mode (40 Gbps, Eth 3) or in SFP+ mode (10 Gbps, any of Eth 3, Eth 4, Eth 5, or Eth 6).

Note:

If the configuration includes Line Redundancy, you must configure this port to 10 Gbps.

Traffic is passed between the PTP 850E and the PTP 850C via an optical cable that connects Eth 7 (P5) of the PTP 850E to Eth 4 (P5) of the PTP 850C. This is a 10 Gbps connection with a bidirectional capacity of up to 4 Gbps. The same cable can be used to carry L2 protocol data between the two units.

Alternatively, a separate optical Protocols cable can be connected between Eth 2 (P3) of the PTP 850E and Eth 2 (P3) of the PTP 850C. This connection carries L2 protocol data between the two units. The ports must be configured to 2.5 Gbps.

It is important to note that special SFP+ modules must be used for both the inter-unit traffic ports and the Protocols ports on the PTP 850E and PTP 850C. For details and the marketing models of the required SFP+ modules, as well as the optical cables, see the Installation Guide for PTP 850E.

A Multi-Carrier ABC group should be configured on the PTP 850C to include both of the unit's radio carriers.

A Link Bonding group must be configured on the PTP 850E. The Link Bonding group must include the PTP 850E unit's radio interface and the PTP 850E Ethernet port connecting the PTP 850E with the PTP 850C for traffic.

Each unit in the Multiband node is managed separately and independently. In-band management can be configured so that both units are managed over the link.

Figure 22: *Multiband with Layer 1 Link Bonding – Multiband Antenna*

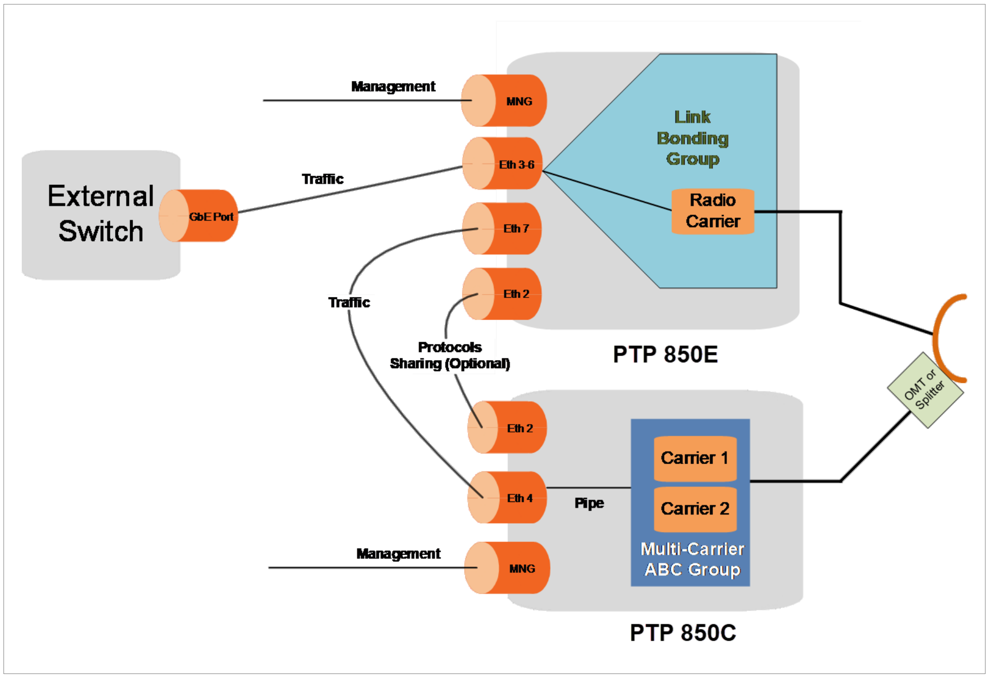
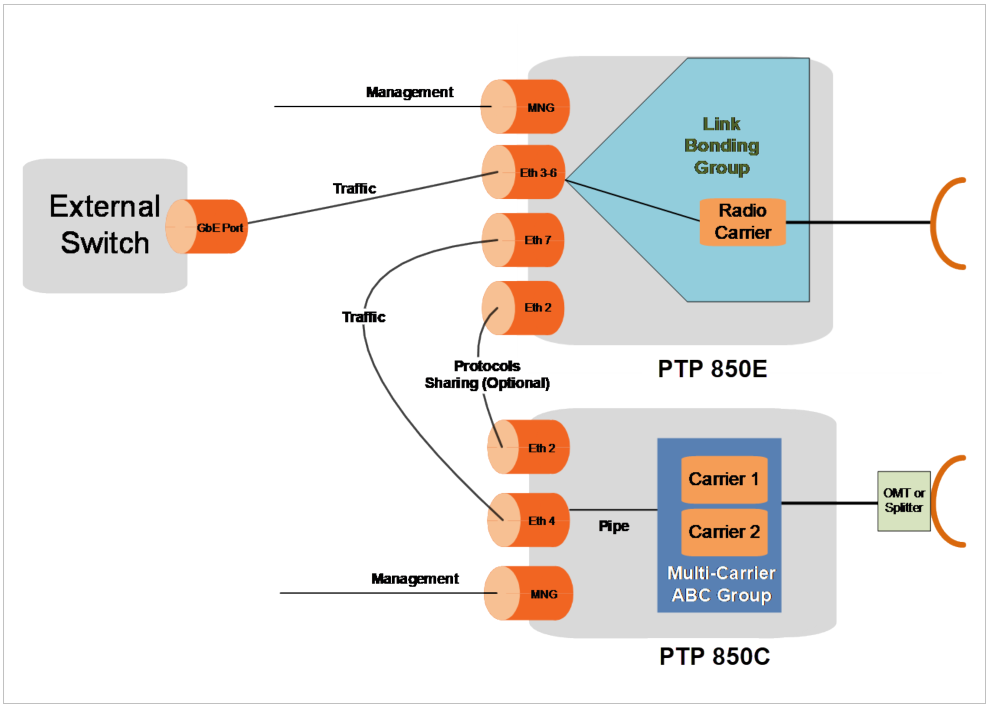


Figure 23: *Multiband with Layer 1 Link Bonding – Separate Antennas*



Multiband with Layer 1 Link Bonding – Hardware Configuration

A Multiband node with PTP 850E and PTP 850C can be configured with a single Multiband Antenna.

Alternatively, each unit can be configured with separate antennas, making sure that the distance between the units does not exceed the length of either the Traffic or the Protocols cable.

In either case, the PTP 850C is connected to the antenna via an OMT (for dual polarization) or a Splitter (for single polarization).

For details, including the marketing models of the cables and SFP transceivers that must be used for the inter-unit connections, refer to the Installation Guide for PTP 850E.

Layer 1 Link Bonding with PTP 850C and PTP 820C or PTP 820C-HP

Layer 1 Link Bonding can be used to pair an PTP 850C with an PTP 820C. This enables operators to add an PTP 850C to existing PTP 820C or PTP 820C-HP deployments in order to add significantly to node capacity utilizing the same physical footprint, adding to rather than replacing the existing PTP 820C and its capacity. A node using PTP 850C and PTP 820C or PTP 820C-HP with Link Bonding can provide capacity of up to 5 Gbps when both units are utilizing both of their carriers, XPIC, and their widest supported channels and highest modulations.

Note:

Only PTP 820C ESS and ESX hardware versions are supported with this configuration.

Layer 1 Link Bonding with PTP 850C and PTP 820C/PTP 820C-HP– Operation

In a Layer 1 Link Bonding configuration with an PTP 850C and an PTP 820C or PTP 820C-HP, the PTP 850C serves as the main unit. The PTP 820C or PTP 820C-HP is the attached unit. The main unit is attached to the external switch via either Eth 1 (P2, the PoE port), Eth 3 (P4, the MIMO port), or Eth 4 (P5).

> **Note**:
>
> If you are using a separate Protocols cable, Eth 1 cannot be used if the attached unit is an PTP 820C ESX, because Eth 1 must be used for the Protocols cable, as described below.

Traffic is passed between the two units via an optical cable that connects Eth 2 of each unit. This is a 1 Gbps connection. The same cable can be used to carry L2 protocol data between the two units.

Alternatively, an optical Protocols cable can be used to carry L2 protocol data between the two units. The Protocols cable must be connected between the following ports:

- PTP 850C with PTP 820C (ESS hardware version) or PTP 820C-HP – Eth 3 (P4) or Eth 4 (P5)
- PTP 850C with PTP 820C (ESX hardware version) – Eth1 (P2)
- PTP 820C (ESS hardware version) or PTP 820C-HP – Eth 3
- PTP 820C (ESX hardware version) – Eth 1

> **Note**:
>
> These connections must all use optical cables, except in the case of an PTP 820C ESX hardware version, for which the Protocols Cable must be an electrical cable connected to RJ-45 ports on each of the two units.

The ports must be configured to 1 Gbps.

A Multi-Carrier ABC group that includes both radio carriers must be configured on the PTP 850C. When the attached unit is an PTP 820C, a Multi-Carrier ABC group that includes both radio carriers must also be configured on the PTP 820C.

A Link Bonding group must be configured on the PTP 850C. The Link Bonding group must include the PTP 850C's Multi-Carrier ABC group and the port connecting the PTP 850C with the attached unit (Eth 2).

Each PTP 850C unit is managed separately and independently. In-band management can be configured so that both units are managed over the link.

Figure 24: *Layer 1 Link Bonding Operation – PTP 850C and PTP 820C (ESS)*

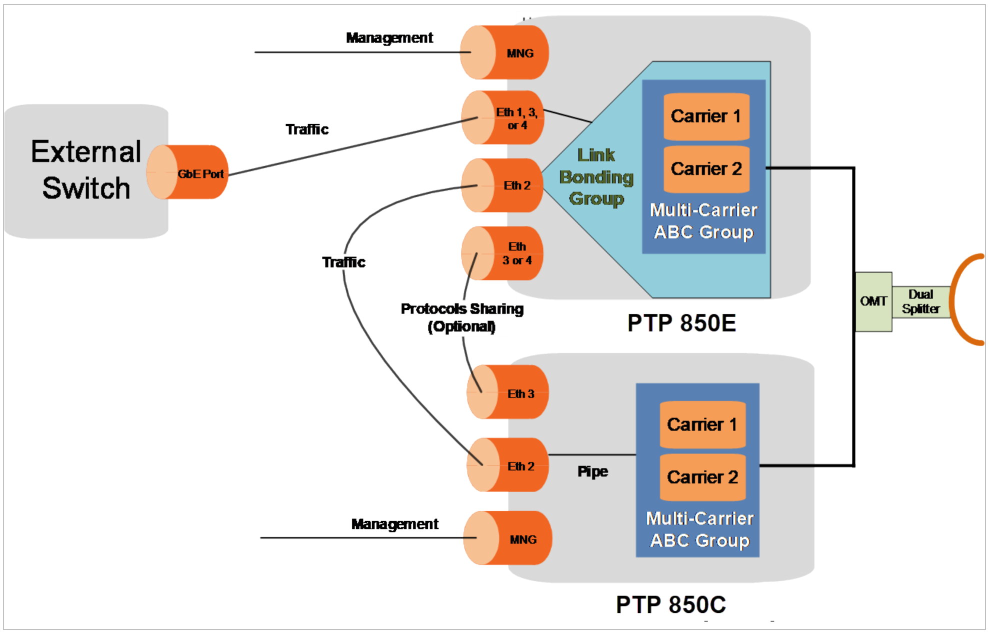


Figure 25: *Layer 1 Link Bonding Operation – PTP 850C and PTP 820C (ESX)*

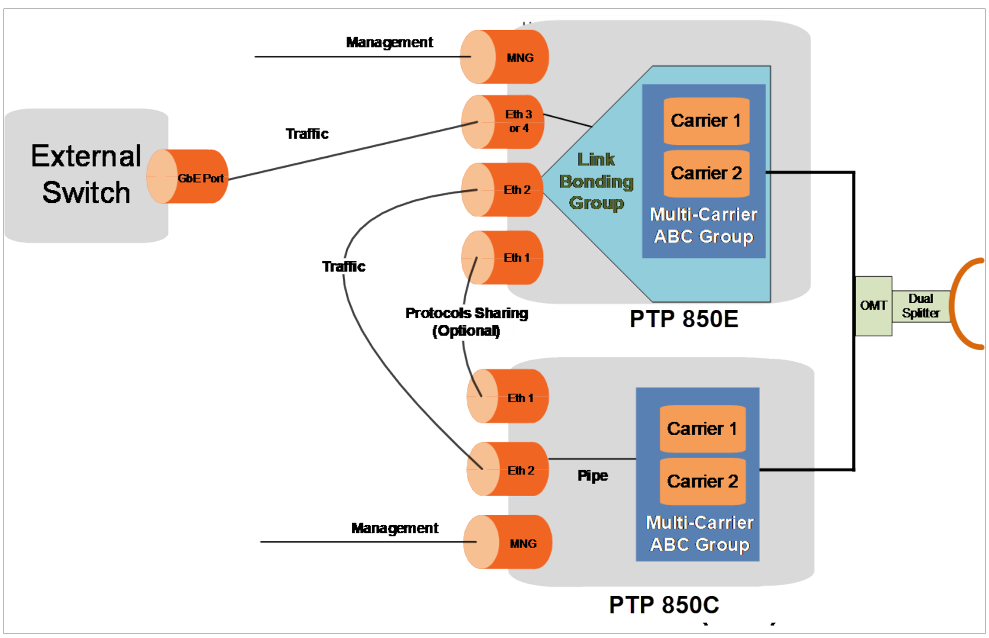
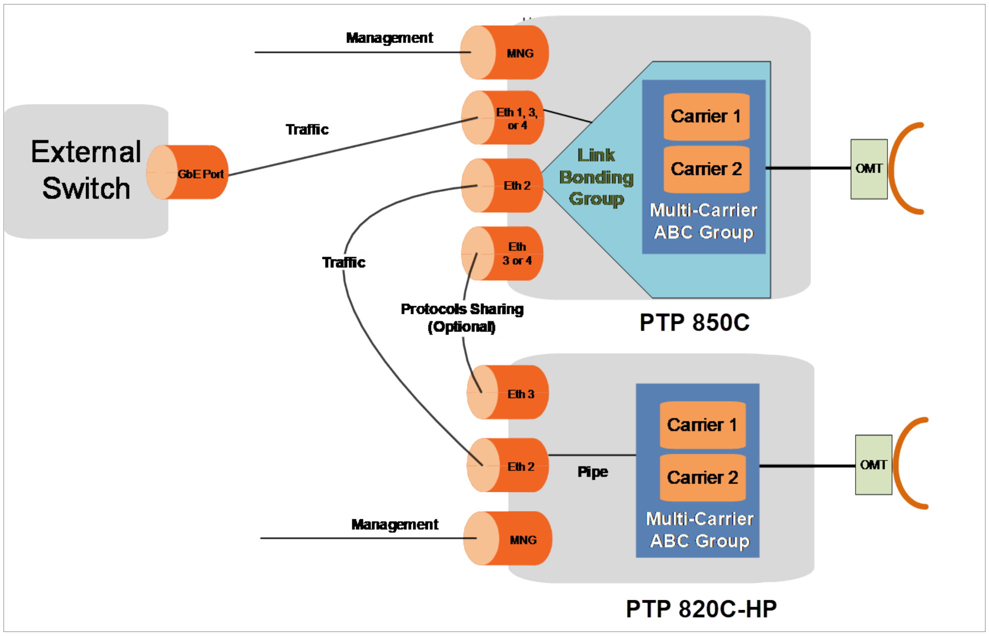


Figure 26: *Layer 1 Link Bonding Operation – PTP 850C and PTP 820C-HP*



Note:

Line protection with Layer 1 Link Bonding is planned for future release.

Layer 1 Link Bonding with PTP 850C and PTP 820C or PTP 820C-HP – Hardware Configuration

With PTP 820C, the two units can be connected to a single antenna using a Dual Splitter and an OMT. Remote-mount configurations are also available.

With PTP 820C-HP, two separate antennas must be used. Each unit is configured in a 2+0 or 1+0 configuration with its own antenna, and the units are connected only by the Traffic and Protocols cables described above.

Line of Sight (LoS) MIMO

Note:

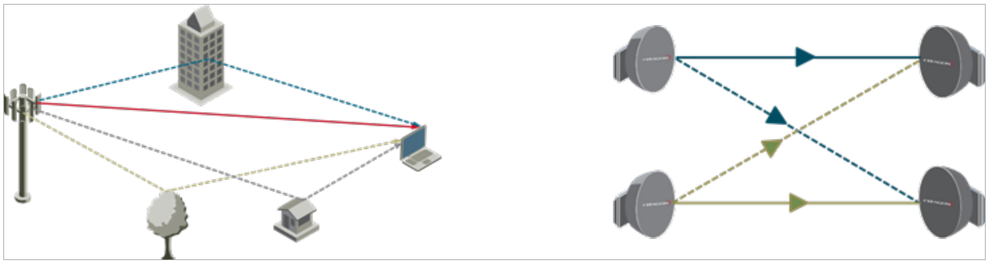
LoS MIMO is planned for future release.

Line-of-Sight (LoS) Multiple Input Multiple Output (MIMO) is the latest leap in microwave technology, enabling operators to double or quadruple spectral efficiency.

MIMO originated as a non-line-of-sight (NLoS) technology, exploiting signal multi-path caused by reflections from various physical obstacles by using multiple transmitters and receivers to increase spectral efficiency by spatially multiplexing multiple bitstreams over the same frequency channel.

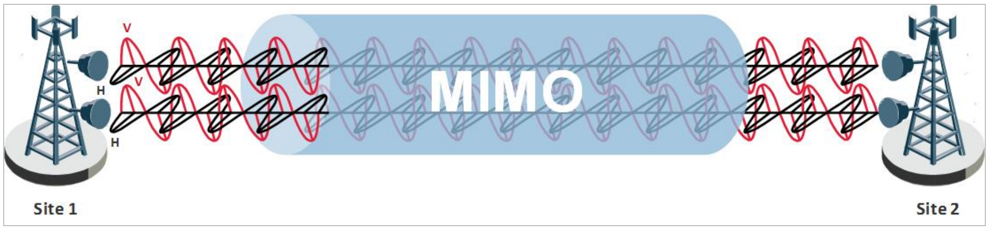
In LoS microwave, the non-LoS multipath signal is weak and unusable for the purpose of MIMO. Instead, LoS MIMO achieves spatial multiplexing by creating an artificial phase de-correlation by deliberate antenna distance at each site in deterministic constant distance.

Figure 27: *NLoS MIMO (Left) and LoS MIMO (Right) Compared*



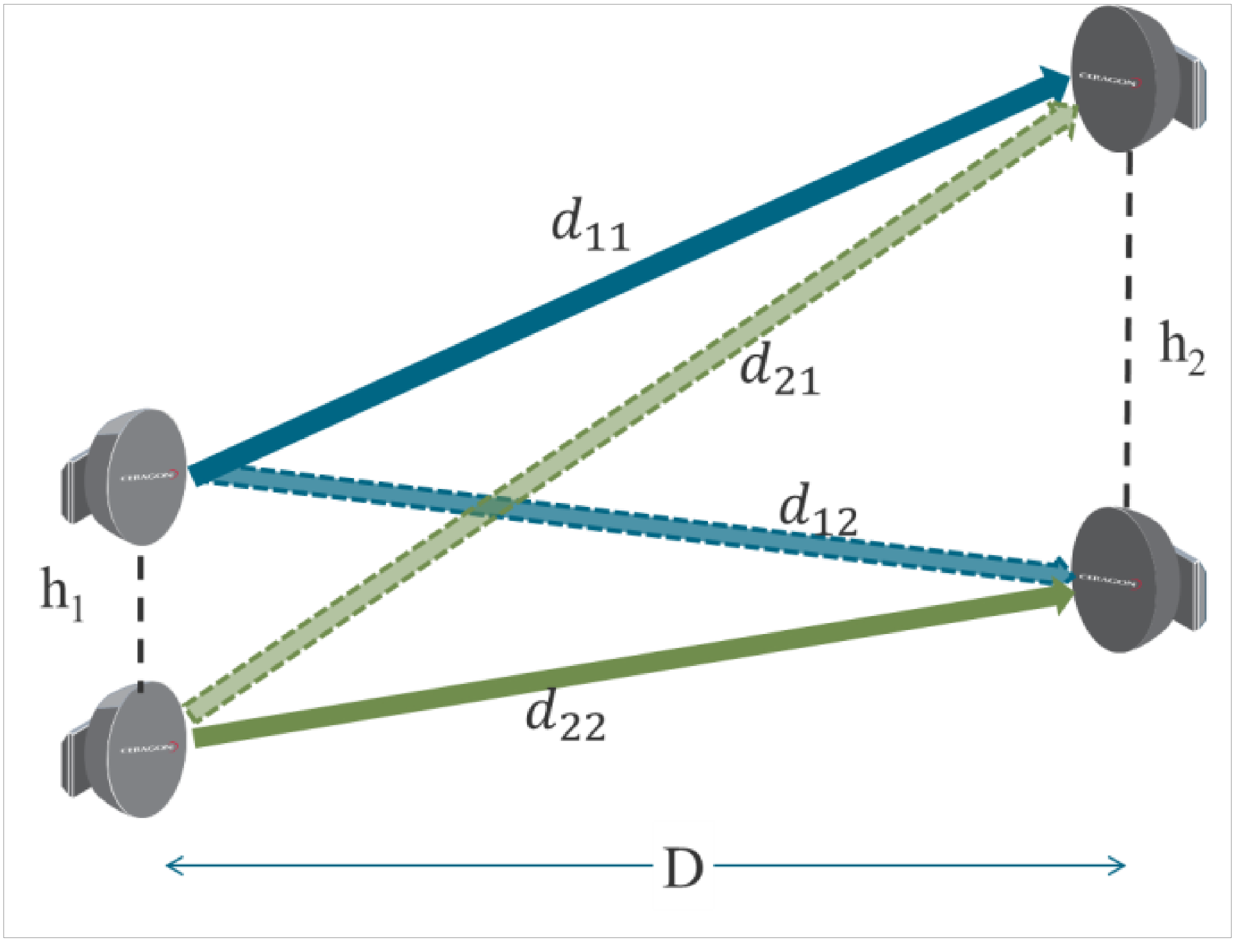
At each site in an LoS MIMO configuration, data to be transmitted over the radio link is split into two bit streams (2x2 MIMO) or four bit streams (4x4 MIMO). These bit streams are transmitted via two antennas. In 2x2 MIMO, the antennas use a single polarization. In 4x4 MIMO, each antenna uses dual polarization. The phase difference caused by the antenna separation enables the receiver to distinguish between the streams.

Figure 28: *LoS MIMO – Transmitting and Receiving on a Single Frequency Channel*



The following figure illustrates a 2x2 MIMO configuration consisting of two transmitters and two receivers on each side of the link, transmitting via two antennas on each side of the link. The antenna pairs on either side of the link are spaced at specific distances from each other based on the calculations described in [Antenna Separation Criteria for LoS MIMO](#).

Figure 29: *General LoS MIMO Antenna Setup*



In this illustration:

- h1 and h2 represent the spatial separation between the antenna pairs at each side of the link.
- d11, d21, d12, and d22 represent the signal path lengths.
- D represents the link distance.

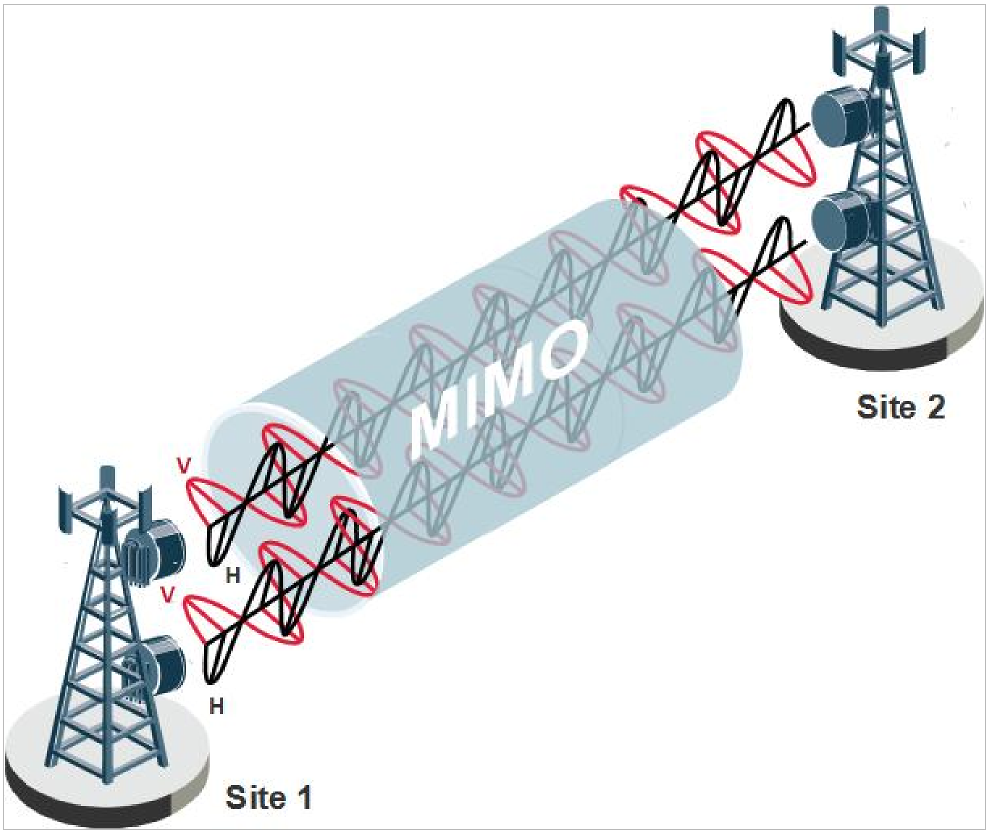
Each signal arrives at the other side of the link at a different phase. The phases are determined by the varying path lengths which, in turn, are configurable by adjusting the degree of antenna separation.

4x4 MIMO

Although the illustration above uses 2x2 MIMO for the sake of simplicity, the same basic principles apply to 4x4 MIMO.

PTP 850C utilizes its MultiCore architecture to achieve 4x4 MIMO with two PTP 850C units supporting four cores at each side of the link. By utilizing dual vertical and horizontal polarization, the 4x4 MIMO configuration can utilize a single frequency and just two antennas to achieve the benefits of a 4x4 configuration. This enables operators to quadruple radio throughput using the same spectrum, with half the form factor of a conventional system.

Figure 30: *4x4 MIMO: Two MultiCore Units Directly Mounted to the Antenna*



MIMO Resiliency

In hardware failure scenarios, 4x4 MIMO provides a resiliency mechanism that enables the link to continue functioning as a 2+0 XPIC link. This enables continued flow of traffic on the link until full MIMO service can be restored.

Each pair of PTP 850C units in a 4x4 MIMO configuration consists of a master and a slave unit, as shown in the following figure.

Figure 31: *4x4 MIMO Configuration – Master and Slave Units*

The following scenarios trigger the MIMO resiliency mechanism:

- Cable failure of the Cat5 management cable used for inter-CPU communication between the two PTP 850C units
- Cable failure of the coaxial cable used for clock source sharing between the two PTP 850C units
- Cable failure of the data sharing optical cable between the two PTP 850C units

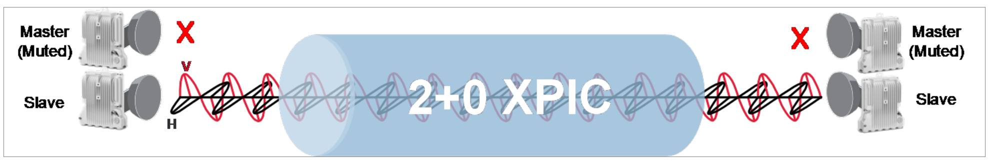
- Master unit hardware fault
- Slave unit hardware fault
- Clock source failure in the master unit

In the event of a cable failure or total loss of the slave unit, the local and remote slave units are muted and the master units continue to function as a 2+0 XPIC link, with half the capacity of the original MIMO link.

Figure 32: *MIMO Resiliency – Master Unit Half-Capacity Link*

In the event of a total loss of the master unit or a clock source failure in the master unit, the local and remote master units are muted and the slave units continue to function as a 2+0 XPIC link, with half the capacity of the original MIMO link.

Figure 33: *MIMO Resiliency – Slave Unit Half-Capacity Link*



Switchover to half-capacity operation is automatic, and takes approximately 30 seconds.

To restore full MIMO operation, the faulty equipment must be replaced. The replacement equipment must be pre-configured to the same configuration as the equipment being replaced. Once the new equipment has been properly installed and, if necessary, powered up, the system automatically reverts to full 4x4 MIMO operation, with no user intervention required.

Benefits of LoS MIMO

Increased Capacity

2x2 MIMO enables transmission of two independent bitstreams over the same frequency channel, using the same polarization, doubling the capacity of a single SISO Link (same capacity as XPIC but using only one polarization).

4X4 MIMO, with dual polarization, enables transmission of four independent bitstreams over the same frequency channel, quadrupling the capacity of a single SISO link.

Reduced Spectrum License Fees

Beyond the increase in capacity that MIMO provides, MIMO enables operators to multiply spectral efficiency, thereby spending up to 50% less on frequency licensing fees.

Improved System Gain

Combining received signals from both antennas in a MIMO system boosts system gain by 3dB. This is similar to the improvement that can be achieved by space diversity systems with IF combining.

Further improvement to system gain can be achieved as a tradeoff for some of the increased capacity MIMO provides by reducing the modulation scheme, thereby increasing both Tx power and Rx sensitivity. In this way, system gain can be increased by up to 20dB. This increase can be used to increase link distances or reduce antenna size. It can also enable the operator to utilize higher frequencies for long-distance links.

Antenna Separation Criteria for LoS MIMO

The following equation provides the criterion for optimal antenna separation in a LoS MIMO configuration:

Figure 34: *LoS MIMO: Criterion for Optimal Antenna Separation*

$$h_1 \cdot h_2 = \frac{D \cdot c}{2f}$$

In this equation:

- *h1* and *h2* denote the respective lengths of antenna separation on both sides of the link (in meters).
- *D* denotes the link distance (in meters).
- *c* denotes the speed of light ($3 \times 10^8 \frac{m}{sec}$).
- *f* denotes the link frequency (in Hz).

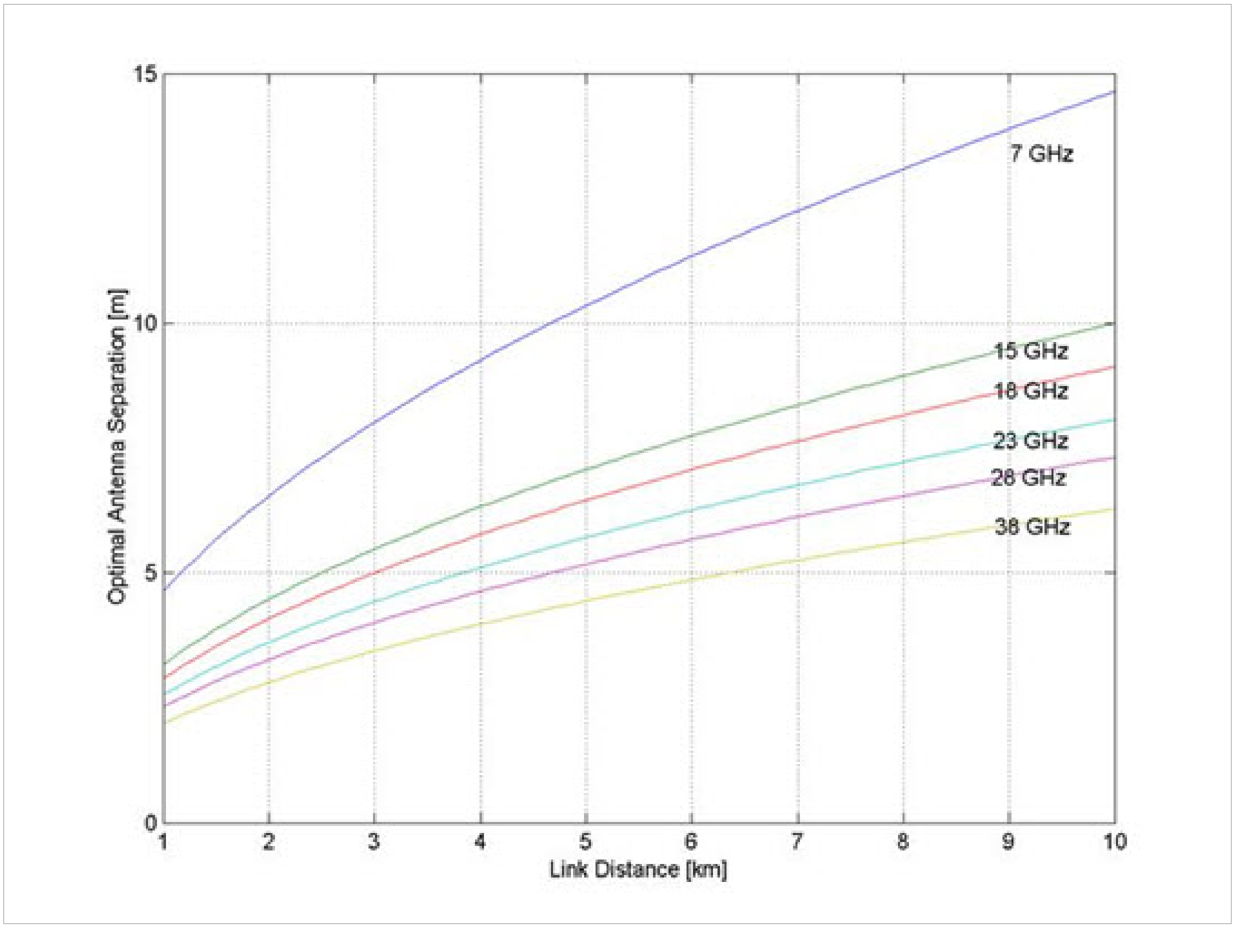
In a symmetrical topology, that is, a link topology in which the antenna separation is equal on both sides of the link, the following equation provides the optimal antenna separation distance:

LoS MIMO: Criterion for Optimal Antenna Separation in Symmetrical Topology

$$h_{optimal} = \sqrt{\frac{D \cdot c}{2f}}$$

The following diagram provides a rough idea of the separation required between antennas for different link spans using different frequencies.

Figure 35: *LoS MIMO: Optimal Antenna Separation vs. Link Distance*

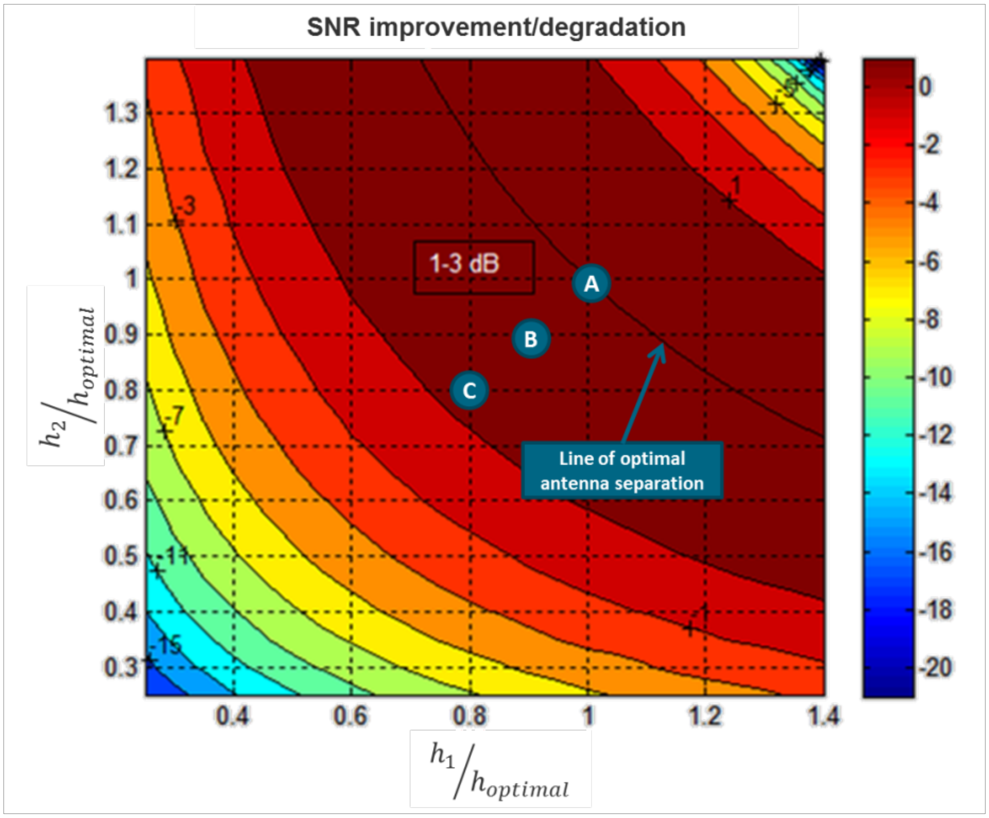


It is important to note that antenna separation does not have to be symmetrical. Link topologies will often be constrained by factors that limit antenna separation on one side of the link, such as tower space and mechanical load. Link planners can compensate for such constraints by adjusting the antenna separation on the other side of the link so that the product of the antenna separation length satisfies the equation for Optimal Antenna Separation. Refer to Figure 34.

LoS MIMO Link Robustness

One of the main considerations with LoS MIMO operation is the sensitivity of the link to the accuracy of the installation: how does inaccurate antenna separation affect the quality of the MIMO link? The following figure shows antenna separation sensitivity in PTP 850C's MIMO implementation.

Figure 36: *Continuum of Optimal LoS MIMO Installation Scenarios*



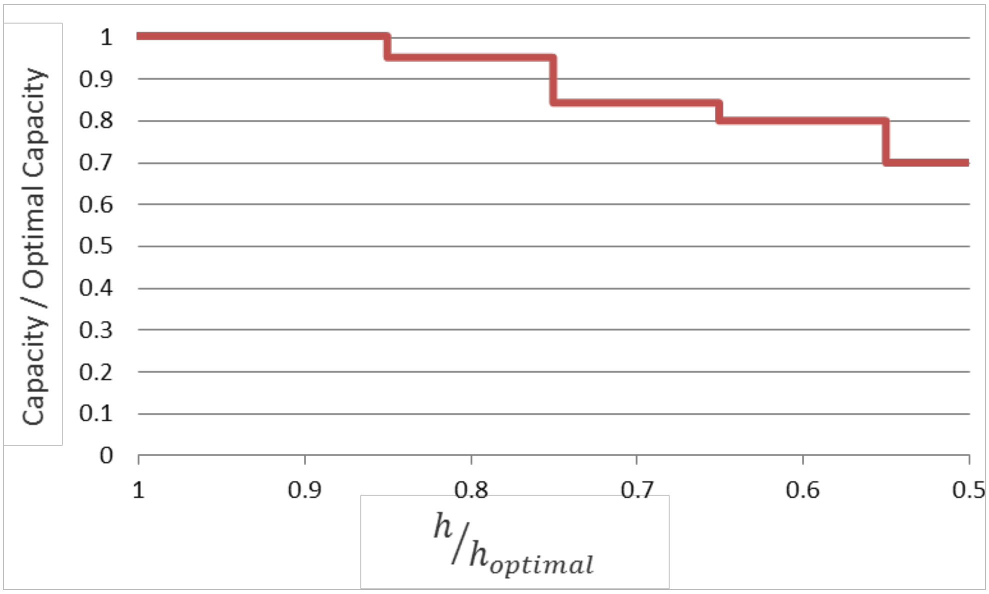
This figure shows how signal-to-noise ratio (SNR) or equivalently, mean square error (MSE), is affected by using sub-optimal antenna separation, relative to the optimal separation, $h_{optimal}$. In the case of optimal installation (point A), a 3dB MSE improvement is achieved compared to a 1+0 SISO link. It also demonstrates that the tradeoff between antenna separation on both sides of the link yields a continuous line of optimal installation scenarios, and that sub-optimal antenna separation on one side can be offset by the separation on the opposite side.

So, for example, in cases where deviation in antenna separation is 10% on each side (point B), approximately 1dB in MSE may be lost compared to an optimal installation, yielding only a 2dB MIMO gain (compared to a 1+0 SISO link).

A second example demonstrates that 20% deviation on each side (point C) will lead to a similar MSE as in the SISO reference (3dB decline cancelling the 3dB MIMO gain), but still enjoying most of the capacity gain of MIMO. This shows that PTP 850C's LoS MIMO implementation is quite immune to sub-optimal antenna installation, and perfect accuracy does not have to be established during installation in order to gain the capacity benefit.

The following figure further demonstrates how sub-optimal antenna separation affects capacity relative to an optimal installation.

Figure 37: *Effect of Sub-Optimal Installation on Capacity (Maximum Capacity is at 1024 QAM)*



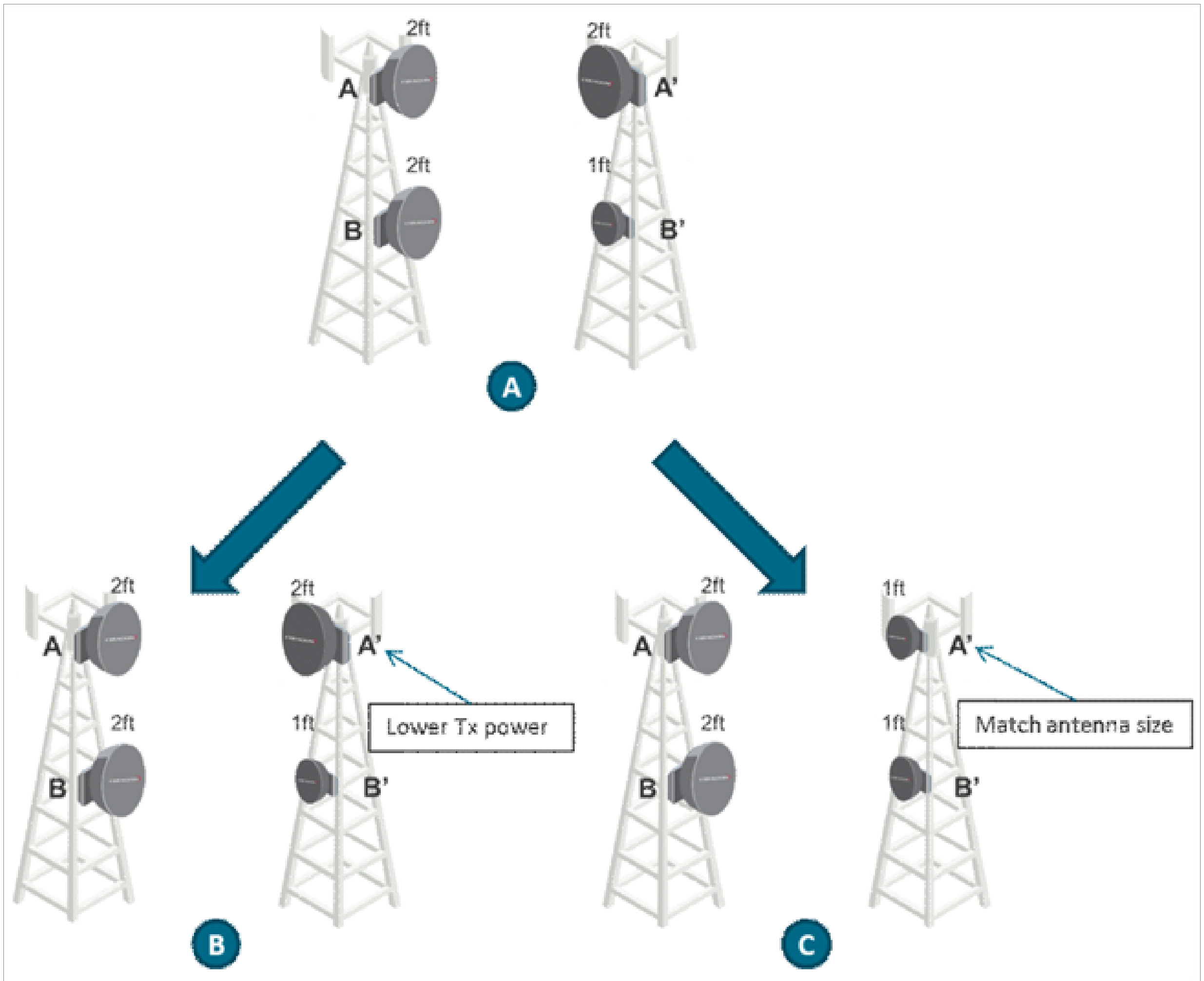
Antenna Characteristics for LoS MIMO

Although it may be convenient to separate antennas vertically in certain deployments, such as on masts and poles, MIMO antenna separation does not need to be vertical. Horizontal or diagonal separation provide the same performance as vertical separation, as long as the separation distances adhere to the formula for optimal antenna separation. Both sides of the link must be consistent in this regard, e.g., both horizontal, both diagonal, or both vertical.

For each signal, both signal paths must be received at the same power level. This means that if, for any reason, the size of one of the antennas needs to be smaller, the link budget must be compensated. As shown in the figure below, this can be achieved in either of the following ways:

- Lowering TX power on the antenna that is attached with the smaller antenna, as shown in Figure B below.
- Matching the size of both antennas in the pair, as shown in Figure C below.

Figure 38: *Asymmetrical Antenna Setup*



Space Diversity

> **Note**:
>
> Space Diversity is planned for future release.

PTP 850C's MIMO capabilities can also be utilized, with minor adjustments, to provide Baseband Combining (BBC) Space Diversity (SD). An SD configuration is based on either a 2x2 MIMO installation (for 1+0 SD) or a 4x4 MIMO installation (for 2+2 HSB SD, using two PTP 850C units), with antenna separation based on SD requirements.

Alternatively, a 1+1 HSB-SD configuration is available. Instead of using a MIMO installation, 1+1 HSB-SD uses two PTP 850C units combined and connected to the primary and diversity antennas via a dual coupler and two flexible waveguides. The link is protected via Unit Redundancy, so that if a switchover occurs, the standby unit becomes the activate unit, and the link continues to function with full space diversity.

In all SD modes, the transmitter or transmitters connected to the diversity antenna is muted to achieve a configuration that consists of a single transmitter and two receivers.

When PTP 850C is configured for SD operation, the signal is combined at the Baseband level to improve signal quality selective fading.

1+0 Space Diversity

A 1+0 Space Diversity configuration utilizes a single PTP 850C on each side of the link, with both radio carriers activated. The second carrier is muted. On the receiving side, the signals are combined to produce a single, optimized signal.

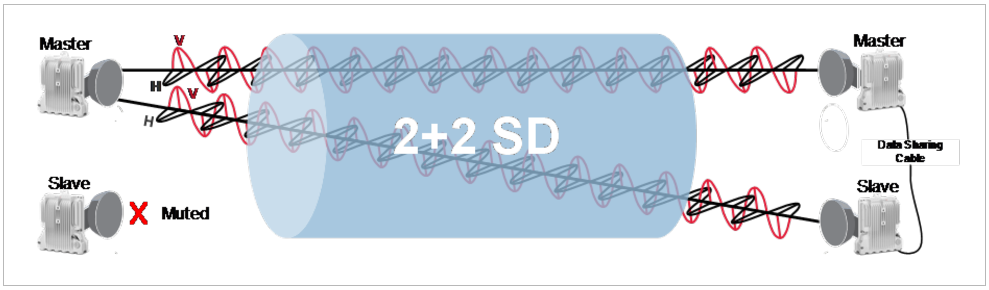
Figure 39: *1+0 Space Diversity*

2+2 Space Diversity

A 2+2 Space Diversity configuration utilizes two PTP 850C units on each side of the link, with both radio carriers activated in each unit. In each PTP 850C unit, both radio carriers are connected to a single antenna. One GbE port on each PTP 850C is connected to an optical splitter. Traffic must be routed to an optical GbE port on each PTP 850C unit.

Both carriers of the slave unit are muted. On the RX side, each unit receives a dual polarization signal from the remote master unit, which includes the data streams from both carriers. The slave unit shares the data stream it receives with the master unit, and the master unit combines each data stream to produce a single, optimized signal for each carrier.

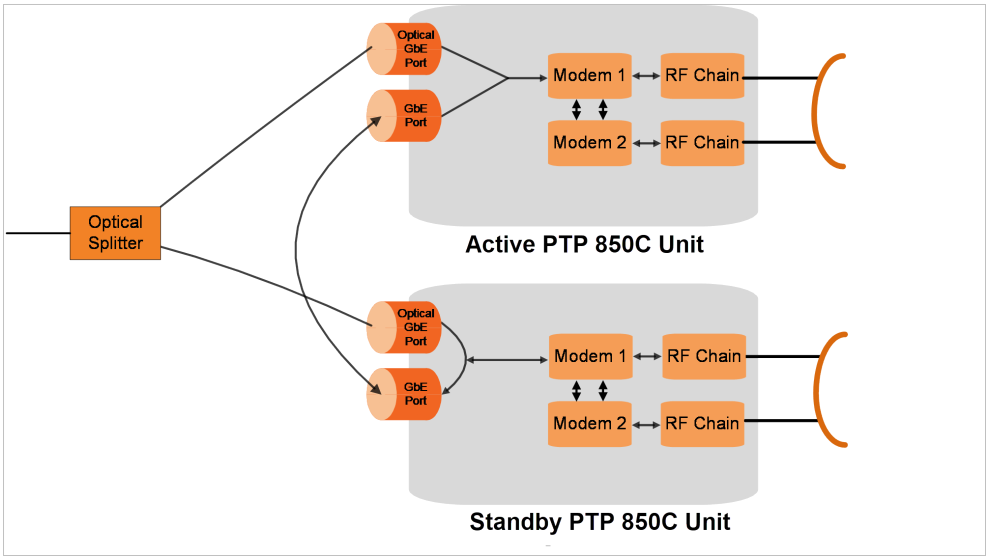
Figure 40: *2+2 Space Diversity*



2+2 Space Diversity provides equipment protection as well as signal protection. If one unit goes out of service, the other unit takes over and maintains the link until the failed unit is restored to service and Space Diversity operation resumes.

In effect, a 2+2 HSB configuration is a protected 2+0 Space Diversity configuration. Each PTP 850C monitors both of its cores. If the active PTP 850C detects a radio failure in either of its cores, it initiates a switchover to the standby PTP 850C.

Figure 41: *MultiCore 2+2 Space Diversity*



1+1 HSB with Space Diversity

A 1+1 HSB-SD configuration utilizes two PTP 850C units on each side of the link, with both radio carriers activated. On each unit, the carrier connected to the diversity antenna is muted. On the receiving side, the signals are combined in the active unit to produce a single, optimized signal. The link is protected via Unit Redundancy, so that if a switchover occurs, the standby unit becomes the activate unit, and the link continues to function with full space diversity.

Figure 42: *1+1 HSB with Space Diversity*

Advanced Space Diversity (ASD)

> **Note**:
>
> ASD is planned for future release.

Advanced Space Diversity (ASD) provides significant savings by enabling space diversity with only three PTP 850C units and three antennas. This means a 25% reduction from standard space diversity implementations with corresponding savings in CAPEX and OPEX due to the reduction in equipment and tower load made possible by ASD.

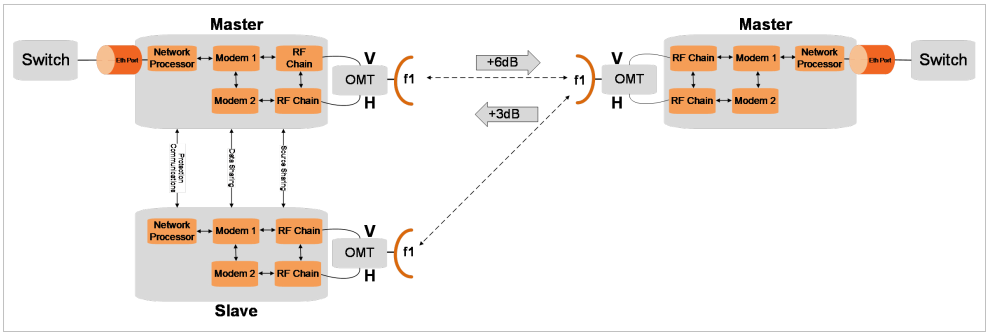
ASD provides significant increases in system gain and reduces or eliminates the effects of fading and multipath.

ASD Implementation

ASD is implemented as an asymmetrical link with three antennas and three PTP 850C units, as shown in Figure 43.

- In one direction, two transmitters transmit to one receiver. ASD increases system gain in this direction by 6 dB.
- In the other direction, transmissions from one transmitter are received by two receivers. This is a simple case of Space Diversity, and provides a 3 dB increase in system gain.

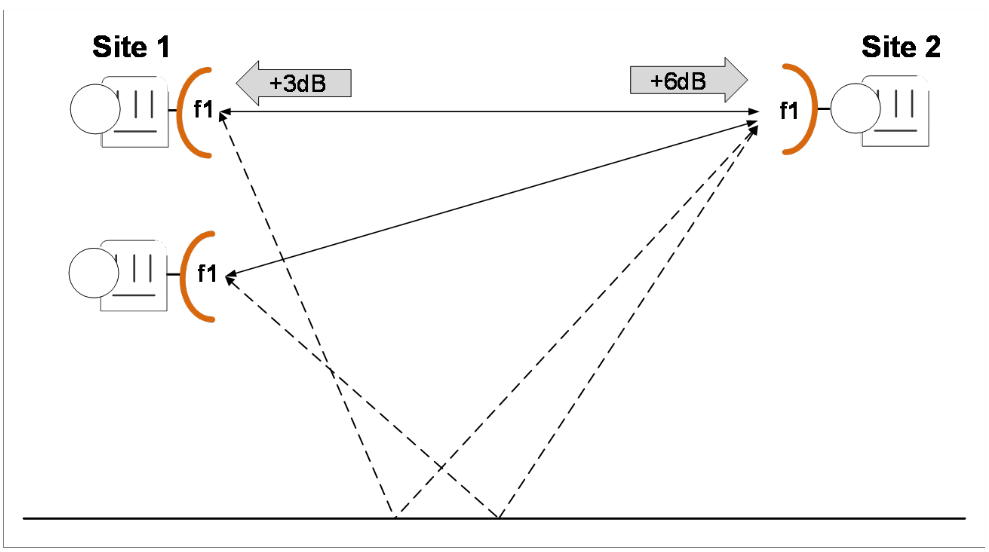
Figure 43: *Advanced Space Diversity (ASD)*



The ability to implement space diversity with only three PTP 820 units and three antennas is made possible by the use of standard space diversity in one direction and a phase-synchronized beam-forming mechanism in the other direction. Each PTP 850C unit is installed in a 2+0 XPIC configuration, with an OMT as the mediation device and a dual-polarization antenna. Alignment is performed using an XPIC script. Following alignment, the ASD groups are configured and a special ASD script is applied to each of the three ASD groups.

Figure 44 shows the data paths between Site 1, with two PTP 850C units and two antennas, and Site 2, with one PTP 850C unit and one antenna.

Figure 44: *ASD Data Paths*



The data path from Site 1 to Site 2 includes the same TX signals being sent from the main and diversity radios at Site 1 (RX diversity). PTP 820 uses beam forming technology to achieve optimal reception by the PTP 850C unit at Site 2. This quadruples the signal's strength, adding 6dB in system gain and resilience to selective fading.

The data path from Site 2 to Site 1 is similar to that of a standard space diversity configuration. The signal transmitted from Site 2 is received by the main and diversity antennas at Site 1 (RX diversity). These signals are combined using Baseband Combining (BBC). This adds 3dB in system gain since the signal practically doubles its level as it is received in a phase-synchronized manner by two receivers.

Benefits of ASD

ASD provides the benefits of space diversity with 25% less equipment. These benefits include:

- Up to 25% savings in CAPEX and OPEX by reducing equipment and tower load.
- Ability to use ASD in links with tower space limitations. The side of the link with tighter space restriction can be utilized for the single unit installation, while the other side contains two PTP 820 units and two antennas.
- 6dB increase in system gain from the side of the link with two antennas to the side of the link with one antenna.
- 3dB increase in system gain from the side of the link with one antenna to the side of the link with two antennas.
- Mitigation of fading and multipath.

ASD is especially useful for long-haul links, in which mitigating the effects of fading and multipath are particularly important. But the increased system gain and mitigation of fading and multipath that ASD provides brings significant value for all types of links.

Advanced Frequency Reuse (AFR)

Note:

AFR is planned for future release

To thrive in the increasingly competitive, hyper-connected world, network operators must offer new revenue-generating services while constantly upgrading their delivery capabilities. Operators must rapidly expand the capacity of their networks by densifying their networks, which means effectively adding many new cell sites.

Because backhaul is a major component of sustainable network infrastructure, backhaul spectrum management is a crucial ingredient for success. A lack of available backhaul frequencies can restrict new cell-site deployment or dramatically increase the deployment cost due to use of alternative technologies.

Advanced Frequency Reuse (AFR), based on Cambium's unique Multicore technology, breaks through deployment restrictions to give operators the freedom to deploy cell sites wherever and whenever they are needed. AFR enables reuse of frequencies and establishment of wider channels in much denser deployment scenarios than possible through conventional link-spacing parameters.

AFR Overview

AFR enables operators to reduce the angular separation requirement between links at the same frequency channel and the same polarization from the currently required 90-120° range to angular separation as low as 10-40°. This enables operators to deploy an additional adjacent link at the same frequency spot, thereby simplifying network deployment.

AFR can also be used to boost the capacity of existing links operating in adjacent channels by enabling wider channels in AFR mode.

By enabling operators to reuse the same frequency spots with nominal interference at angles that are significantly narrower than would otherwise be possible, AFR provides real value in congested network scenarios in which spectrum can be a significant expense and a bottleneck.

AFR works in conjunction with ACM to enable links to achieve high modulations and high capacities despite the presence of adjacent links transmitting at the same frequency. By mitigating the effects of side lobe interference (SLI), AFR can reduce adjacent link interference to levels that enable links that would otherwise be limited to QPSK modulation to transmit at modulations of up to 2048 QAM. This enables deployment of links that would otherwise be impractical to deploy due to high interference.

Figure 45: *Deployment Scenario without AFR*

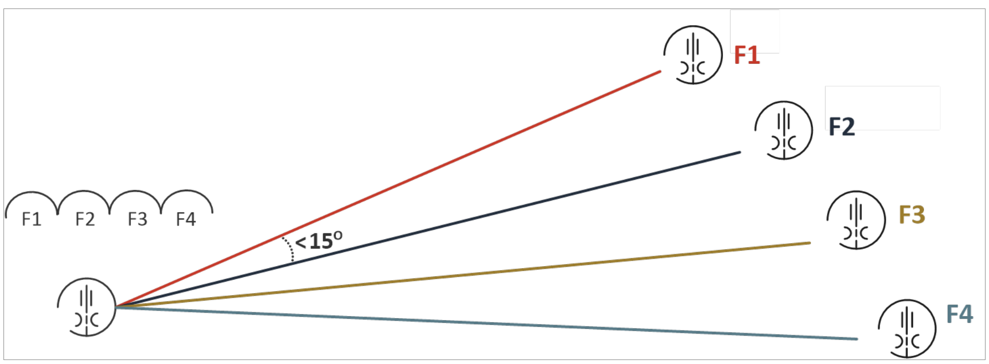
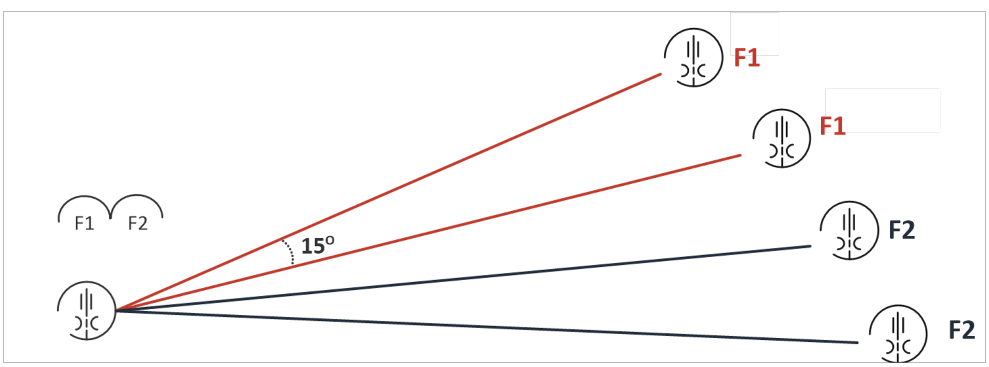


Figure 46: *Deployment Scenario with AFR*

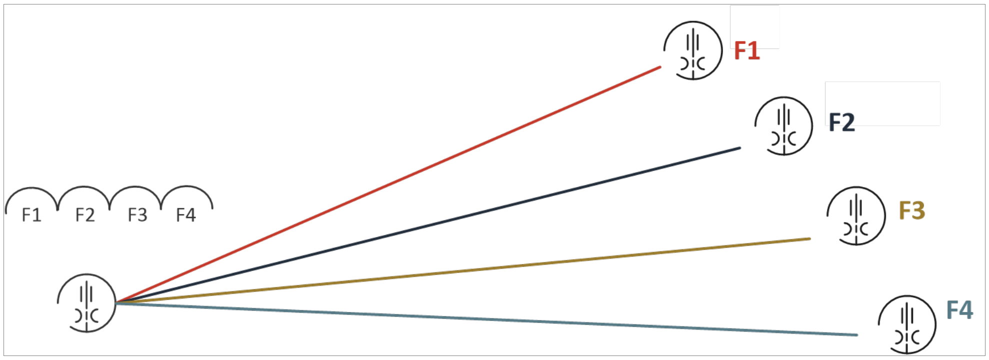


AFR can also help operators increase the capacity of existing networks by increasing the channel allocation of adjacent links so that a single, wider channel can be used side-by-side in place of two separate, narrow channels.

Deployment of wider frequency channels is increasingly being required by operators in order to achieve better utilization of allocated frequency blocks. With wider channels, fewer guard bands are required, enabling more spectrum to be used for actual signal. However, spectrum for these wider bands is not always available, and when it is available, it can be expensive and time-consuming to obtain.

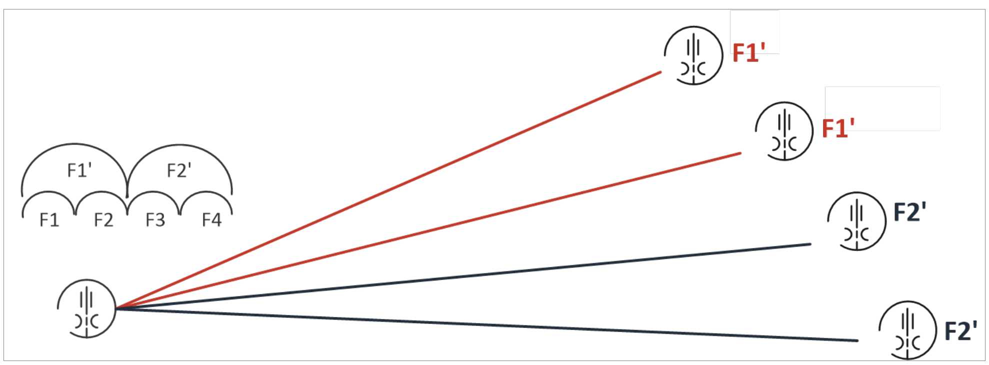
The following figure depicts a deployment scenario in which Link 1 uses channel 1 (f1), Link 2 uses channel 2 (f2), Link 3 uses channel 3 (f3), and Link 4 uses channel 4 (f4).

Figure 47: *Network Using Four Narrow Channels*



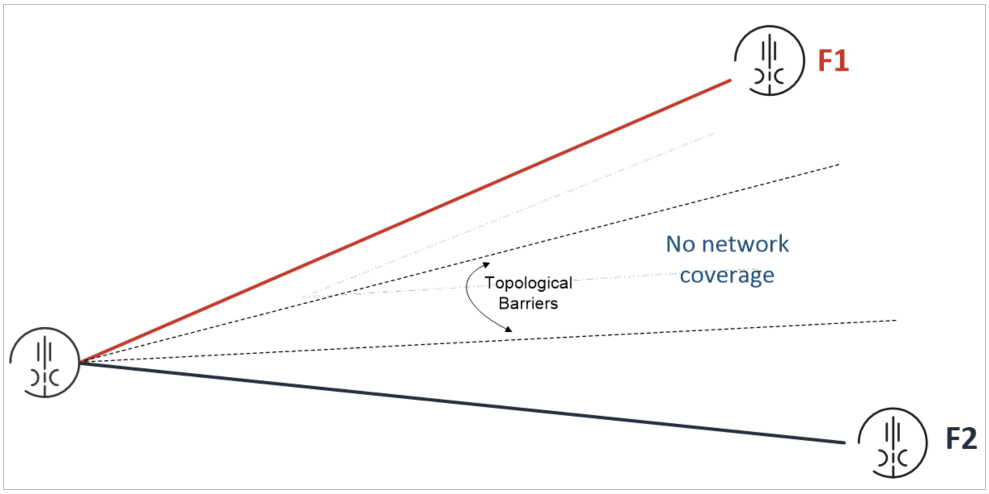
The following figure depicts the same network following AFR implementation. AFR has enabled the operator to reconfigure the network so that Link 1 and Link 2 *share* a wider channel (f1[1]) consisting of channel 1 and channel 2, and Link 3 and Link 4 *share* a wider channel (f2[1]) consisting of channel 3 and channel 4. By enabling each pair of links to share spectral resources that were previously separate, AFR enables the operator to double the capacity of the network deployment.

Figure 48: *Converting to Wider Channels with AFR*



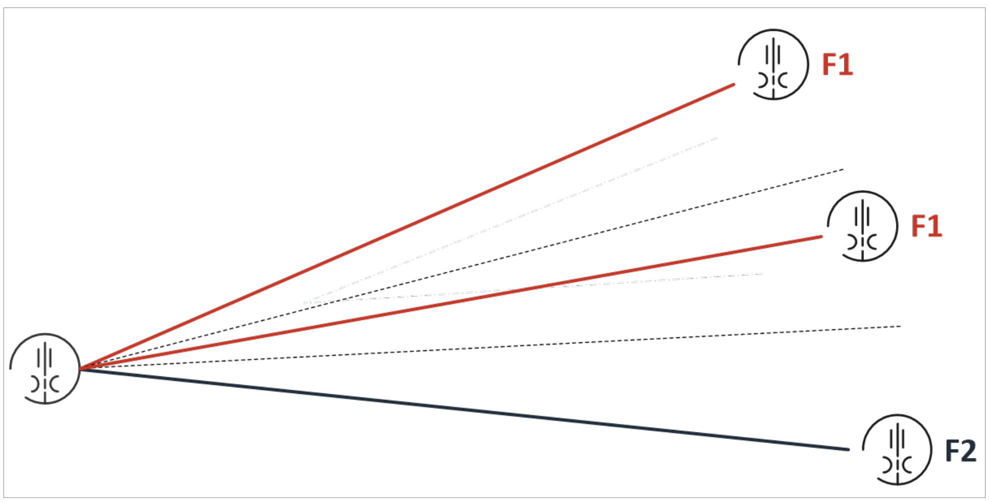
In some cases, an operator may need to densify a network by placing an additional site between two existing sites, each transmitting at a different frequency spot. In the example shown in the following figure, topological or other factors may prevent the operator from simply increasing the coverage area and/or the capacity of the existing inks, and spectrum for a third frequency spot for an additional link might not be available.

Figure 49: *Network Requiring Densification*



In the scenario depicted in the following figure, AFR enables the operator to reuse one of the existing frequency spots, despite the narrow angular separation between the links.

Figure 50: *Densification Example with AFR*



AFR Configurations

AFR can be used in the following configurations:

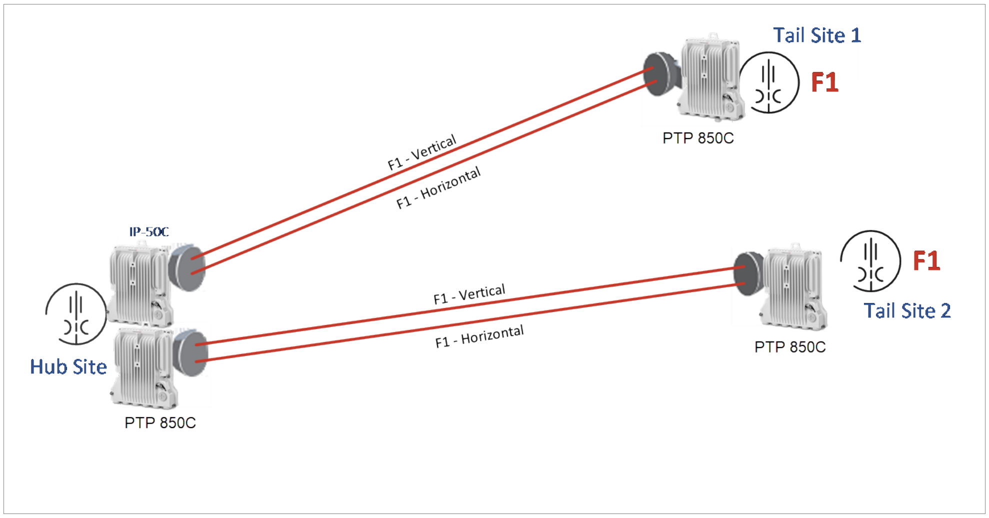
- AFR 2+0 (Single or Dual Polarization)

AFR 2+0 Single or Dual (XPIC) Polarization

AFR 2+0 with XPIC combines the benefits of both XPIC and AFR to enable high-density links while minimizing the required number of frequency spots.

AFR 2+0 uses two PTP 850C units at the hub site and one PTP 850C unit at each tail site. For XPIC configurations, both carriers in each unit form an XPIC link with one of the tail sites, using a dual-polarization antenna. The two units at the hub site are connected via a source sharing cable, a 10GB optic cable, and a management cable, enabling the units to calculate the interference cancellation necessary for both XPIC and AFR, as well as enabling common management of the entire hub site.

Figure 51: *AFR 2+0 (XPIC)*



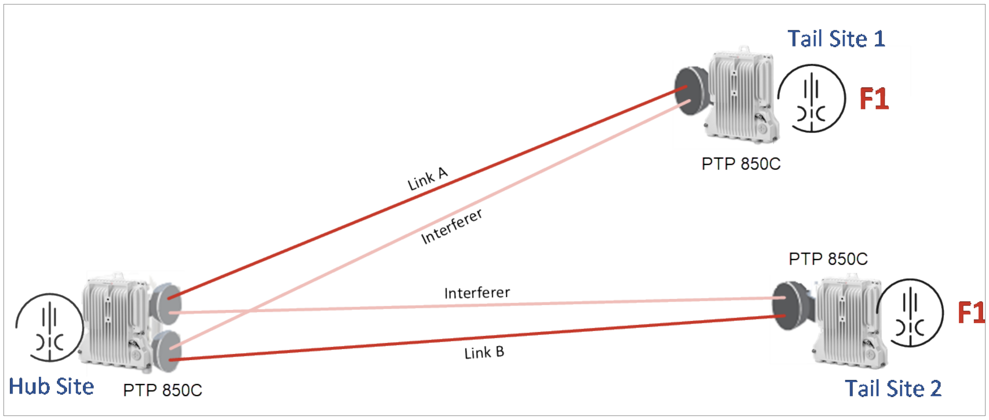
AFR Mode of Operation

Without AFR, links using the same frequency must generally be angularly separated by at least 90-120° in order to reduce the interference between the links. AFR enables the placement of links using the same frequency at much smaller angular separation by adjusting for the effect of the interference in such a way as to compensate for the reciprocal interference at the tail site antennas.

AFR implements interference cancelation techniques at the hub site. There are separate interference cancellation methods for the Tx path and the Rx path. At the Tx path, the two cores work together to cancel the interferences for each of the tail sites. On the Rx path of the hub site, the interference compensation is implemented by interference cancellation, similar to the XPIC mechanism, in each of the cores.

The AFR interference cancellation is done entirely in at the hub site. Therefore, there is no need for any connection between the tail sites in order to enable the operation of these links with AFR.

Figure 52: *Interference Mitigation in AFR*



AFR Calculation Application

Cambium has developed the AFR Calculation application to help network planners maximize the value AFR can provide to Cambium customers. This application helps the network planner identify links that can be deployed using AFR.

The AFR Calculation application is a standalone application that runs on the user's PC or laptop. It is completely independent from System Release and the PTP 850C device.

A detailed explanation of network planning using AFR, including step-by-step instructions for using the AFR Calculation application, is provided in a separate document, the *Advanced Frequency Reuse (AFR) Link Planning Guide*.

Frame Cut-Through

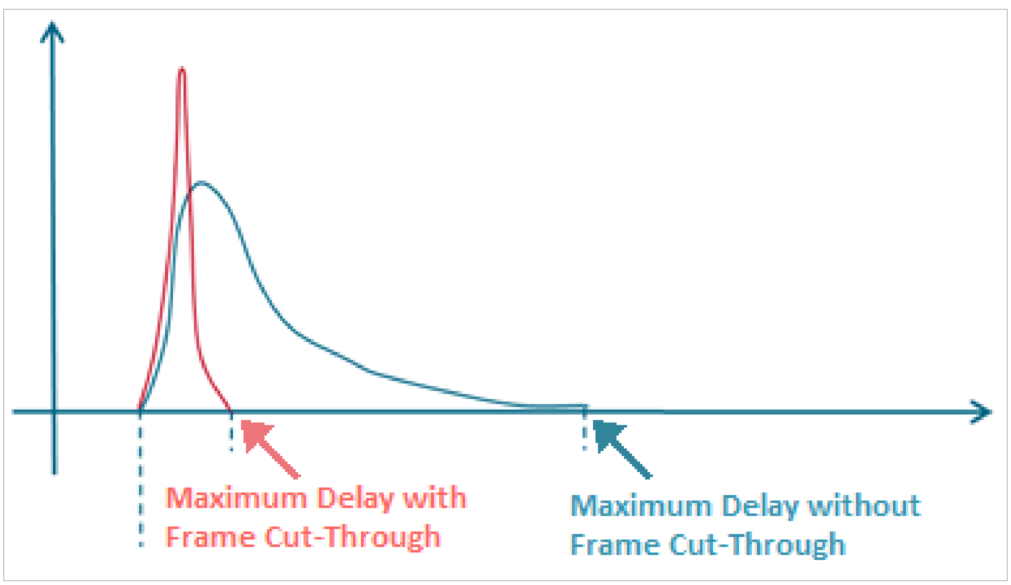
Note:

Frame Cut-Through is planned for future release.

Frame Cut-Through is a unique and innovative feature that ensures low latency for delay-sensitive services, such as CES, VoIP, and control protocols. With Frame Cut-Through, high-priority frames are pushed ahead of lower priority frames, even if transmission of the lower priority frames has already begun. Once the high priority frame has been transmitted, transmission of the lower priority frame is resumed with no capacity loss and no re-transmission required. This provides operators with:

- Immunity to head-of-line blocking effects – key for transporting high-priority, delay-sensitive traffic.
- Reduced delay-variation and maximum-delay over the link:
- Improved QoE for VoIP and other streaming applications.
- Expedited delivery of critical control frames.

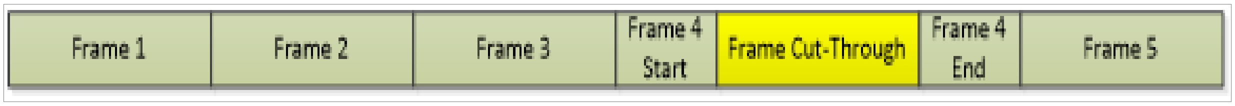
Figure 53: *Propagation Delay with and without Frame Cut-Through*



Frame Cut-Through Basic Operation

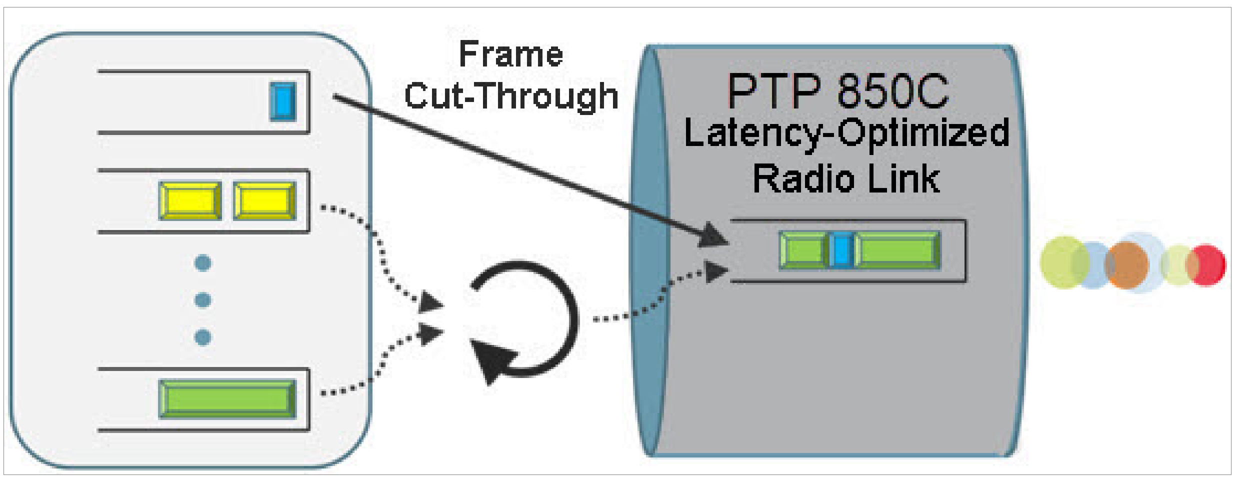
Using Frame Cut-Through, frames assigned to high priority queues can pre-empt frames already in transmission over the radio from other queues. Transmission of the pre-empted frames is resumed after the cut-through with no capacity loss or re-transmission required. This feature provides services that are sensitive to delay and delay variation, such as VoIP, with true transparency to lower priority services, by enabling the transmission of a high priority, low-delay traffic stream.

Figure 54: *Frame Cut-Through*



When enabled, Frame Cut-Through applies to all high priority frames, i.e., all frames that are classified to a CoS queue with 4th (highest) priority.

Figure 55: *Frame Cut-Through*



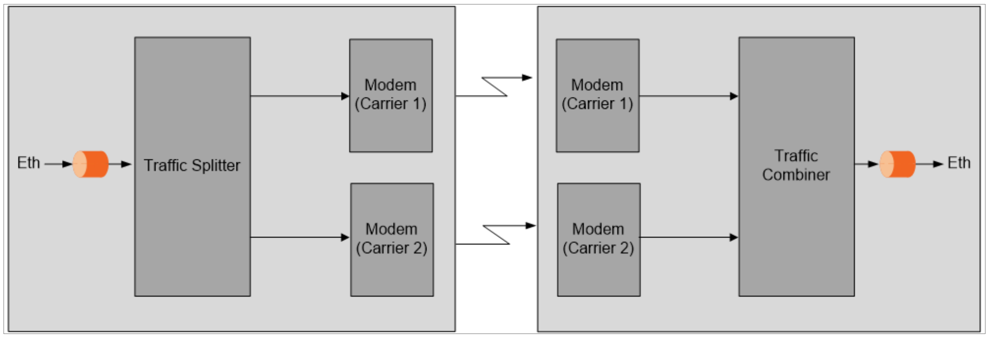
Enhanced Multi-Carrier ABC

Multi-Carrier Adaptive Bandwidth Control (ABC) is an innovative technology that creates logical bundles of multiple radio links and optimizes them for wireless backhaul applications. Multi-Carrier ABC enables separate radio carriers to be shared by a single Ethernet port. This provides an Ethernet link over the radio with double capacity, while still behaving as a single Ethernet interface.

PTP 850C utilizes Enhanced Multi-Carrier ABC, which provides excellent traffic distribution among the carriers in the group. In Enhanced Multi-Carrier ABC mode, traffic is divided among the carriers optimally at the radio frame level without requiring Ethernet link aggregation (LAG). Load balancing is performed without regard to the number of MAC addresses or the number of traffic flows. During fading events which cause ACM modulation changes, each carrier fluctuates independently with hitless switchovers between modulations, increasing capacity over a given bandwidth and maximizing spectrum utilization. The result is close to 100% utilization of radio resources in which traffic load is balanced based on instantaneous radio capacity per carrier.

The following diagram illustrates the Enhanced Multi-Carrier ABC traffic flow.

Figure 56: *Enhanced Multi-Carrier ABC Traffic Flow*



Enhanced Multi-Carrier ABC Operation

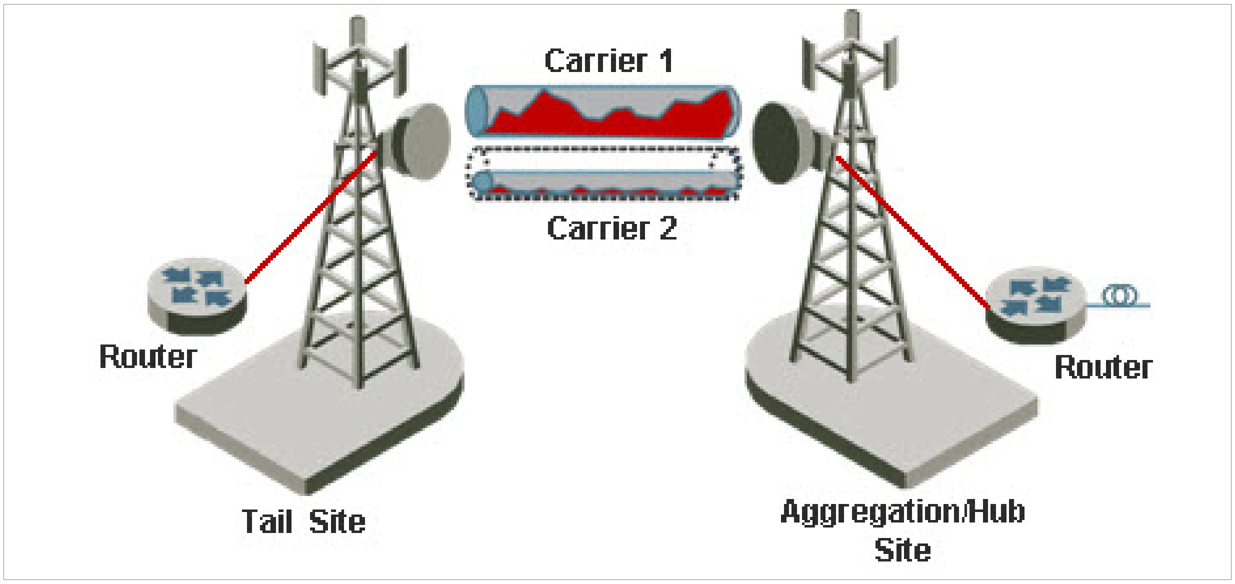
Multi-Carrier ABC is designed to achieve 100% utilization of available radio resources by optimizing the way traffic is distributed between the multiple wireless links. Traffic is forwarded over available radio carriers using proprietary Layer 1 distribution. This enhances load balancing.

Traffic distribution is proportional to the available bandwidth in every link:

- If both links have the same capacity, half the data is sent through each link.
- In ACM conditions, the links could be in different modulations; in this case, data is distributed proportionally in order to maximize the available bandwidth.

PTP 850C's proprietary Layer 1 distribution mechanism enables PTP 850C's Enhanced Multi-Carrier ABC implementation to maintain optimal load balancing that accounts for the condition of each radio link at any given moment. This means that if a link shifts to a lower ACM modulation point, the Enhanced Multi-Carrier ABC load balancing mechanism is notified immediately and adjusts the traffic distribution by sending less traffic over the link with the lower modulation and more traffic to links operating at a higher modulation. If there is a failure in one or more of the links, the load balancing mechanism implements graceful degradation by directing traffic to the operational links.

Figure 57: *Enhanced Multi-Carrier ABC Load Balancing with Different ACM Points*



Graceful Degradation of Service

Enhanced Multi-Carrier ABC provides for protection and graceful degradation of service in the event that one of the links fails. This ensures that if one link is lost, not all data is lost. Instead, bandwidth is simply reduced until the link returns to service.

Graceful degradation in Enhanced Multi-Carrier ABC is achieved by blocking one of the radio links from Enhanced Multi-Carrier ABC data. When a link is blocked, the transmitter does not distribute data to this link and the receiver ignores it when combining.

The minimum profile of the two radio carriers in the Enhanced Multi-Carrier ABC group can be set to any value, as long as they are set to the same value. This enables the user to determine the point at which the group is placed in a Down state. This can be used in conjunction with Automatic State Propagation (ASP) to ensure that link degradation is propagated to an upstream switch whenever the link provides less than the desired capacity.

Each carrier can change its ACM profile, with a maximum of 30 msec between each switch in modulation. There is no limitation upon the profile difference between carriers, so that one carrier can be operating at the lowest possible profile (BPSK) while the other is operating at the highest possible profile (4096 QAM).

Configuring Enhanced Multi-Carrier ABC

It is recommended to use the same radio script and ACM settings on both radio carriers in the Multi-Carrier ABC group. The user must create an Enhanced Multi-Carrier ABC group containing both radio carriers.

To delete the Enhanced Multi-Carrier ABC group, the user must first remove the members from the group, and then delete the group.

Adaptive Coding Modulation (ACM)

Related topics:

- Cross Polarization Interference Canceller (XPIC)
- Quality of Service (QoS)

PTP 850C employs full-range dynamic ACM. PTP 850C's ACM mechanism copes with 100 dB per second fading in order to ensure high transmission quality. PTP 850C's ACM mechanism is designed to work with PTP 850C's QoS mechanism to ensure that high priority voice and data frames are never dropped, thus maintaining even the most stringent service level agreements (SLAs).

The hitless and errorless functionality of PTP 850C's ACM has another major advantage in that it ensures that TCP/IP sessions do not time-out. Without ACM, even interruptions as short as 50 milliseconds can lead to timeout of TCP/IP sessions, which are followed by a drastic throughout decrease while these sessions recover.

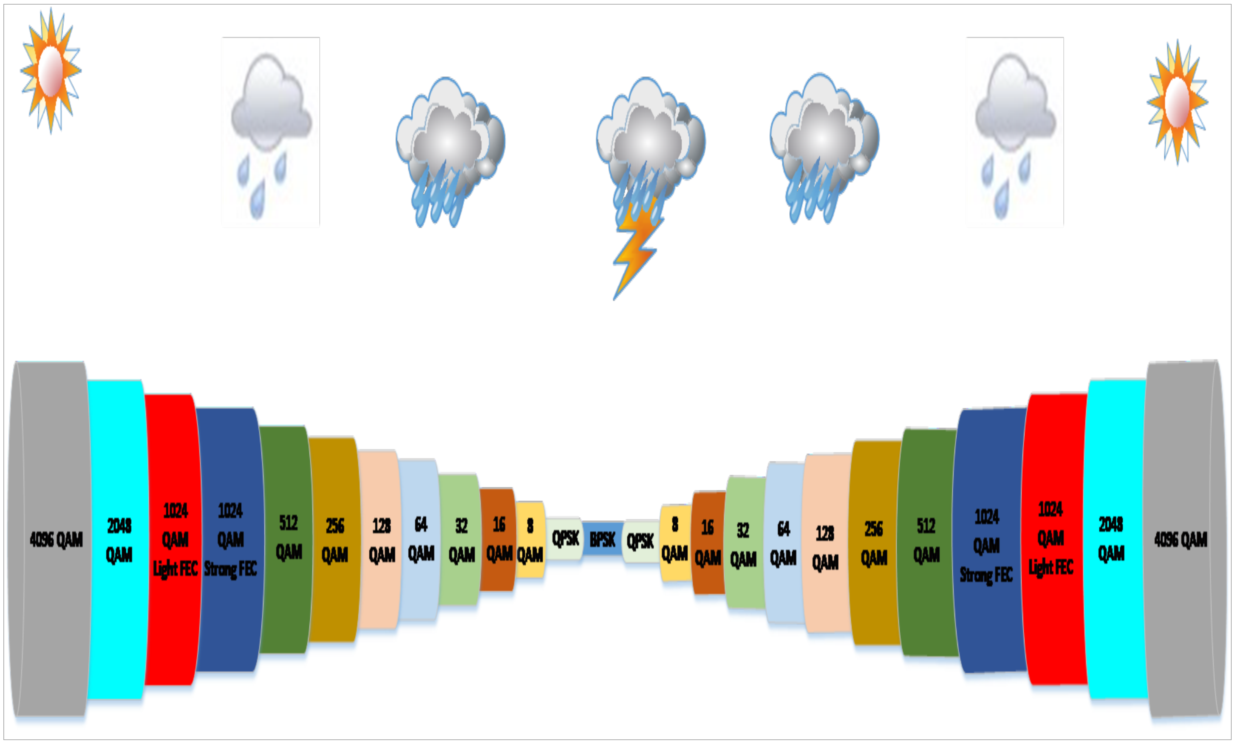
Eleven Working Points

PTP 850C implements ACM with 13 available working points, as shown in the following table:

Table 8 *ACM Working Points (Profiles)*

Working Point (Profile)	Modulation
Profile 0	BPSK
Profile 1	QPSK
Profile 2	8 QAM
Profile 3	16 QAM
Profile 4	32 QAM
Profile 5	64 QAM
Profile 6	128 QAM
Profile 7	256 QAM
Profile 8	512 QAM
Profile 9	1024 QAM (Strong FEC)
Profile 10	1024 QAM (Light FEC)
Profile 11	2048 QAM
Profile 12	4096 QAM

Figure 58: *Adaptive Coding and Modulation with 13 Working Points*



Hitless and Errorless Step-by Step Adjustments

ACM works as follows. Assuming a system configured for 128 QAM with ~170 Mbps capacity over a 28 MHz channel, when the receive signal Bit Error Ratio (BER) level reaches a predetermined threshold, the system preemptively switches to 64 QAM and the throughput is stepped down to ~140 Mbps. This is an errorless, virtually instantaneous switch. The system continues to operate at 64 QAM until the fading condition either intensifies or disappears. If the fade intensifies, another switch takes the system down to 32 QAM. If, on the other hand, the weather condition improves, the modulation is switched back to the next higher step (e.g., 128 QAM) and so on, step by step. The switching continues automatically and as quickly as needed, and can reach all the way down to QPSK during extreme conditions.

In PTP 850C units that are utilizing two cores, ACM profile switches are performed independently for each core.

ACM Radio Scripts

An ACM radio script is constructed of a set of profiles. Each profile is defined by a modulation order (QAM) and coding rate, and defines the profile's capacity (bps). When an ACM script is activated, the system automatically chooses which profile to use according to the channel fading conditions.

The ACM TX profile can be different from the ACM RX profile.

The ACM TX profile is determined by remote RX MSE performance. The RX end is the one that initiates an ACM profile upgrade or downgrade. When MSE improves above a predefined threshold, RX generates a request to the remote TX to upgrade its profile. If MSE degrades below a predefined threshold, RX generates a request to the remote TX to downgrade its profile.

ACM profiles are decreased or increased in an errorless operation, without affecting traffic.

ACM scripts can be activated in one of two modes:

- **Fixed Mode.** In this mode, the user can select the specific profile from all available profiles in the script. The selected profile is the only profile that will be valid, and the ACM engine will be forced to be OFF. This mode can be chosen without an ACM activation key.
- **Adaptive Mode.** In this mode, the ACM engine is running, which means that the radio adapts its profile according to the channel fading conditions. Adaptive mode requires an ACM activation key.

In the case of XPIC/ACM scripts, all the required conditions for XPIC apply.

The user can define a minimum and maximum profile. For example, if the user selects a maximum profile of 10, the system will not climb above the profile 10, even if channel fading conditions allow it.

Hysteresis Value

When stepping down to a lower profile, the switch is initiated when the RSL is approximately 3.5 dB higher than the threshold for the current profile. When stepping up to a higher profile, the switch is initiated when the RSL is approximately 5 dB higher than the threshold for the higher profile.

ACM PMs

Users can configure two thresholds, per radio carrier, for the ACM profile. These thresholds enable users to monitor ACM profile fluctuations by displaying the number of seconds, per 15-minute or 24-hour interval, that the ACM profile drops beneath each profile threshold.

In addition, these thresholds trigger the following alarms:

- Threshold 1 – When the ACM profile goes beneath this threshold, Alarm ID 1313 (Major) is raised. The alarm is cleared when the ACM profile is at or above this threshold.
- Threshold 2 – When the ACM profile goes beneath this threshold, Alarm ID 1314 (Critical) is raised. The alarm is cleared when the ACM profile is at or above this threshold.

ACM Benefits

The advantages of PTP 850C's dynamic ACM include:

- Maximized spectrum usage
- Increased capacity over a given bandwidth
- 13 modulation/coding work points (~3 db system gain for each point change)
- Hitless and errorless modulation/coding changes, based on signal quality
- An integrated QoS mechanism that enables intelligent congestion management to ensure that high priority traffic is not affected during link fading

ACM and Built-In QoS

PTP 850C's ACM mechanism is designed to work with PTP 850C's QoS mechanism to ensure that high priority voice and data frames are never dropped, thus maintaining even the most stringent SLAs. Since QoS provides priority support for different classes of service, according to a wide range of criteria, you can configure PTP 850C to discard only low priority frames as conditions deteriorate.

If you want to rely on an external switch's QoS, ACM can work with the switch via the flow control mechanism supported in the radio.

ACM in MultiCore HSB Configurations

When ACM is activated in a protection scheme such as 1+1 HSB, the following ACM behavior should be expected:

Note:

1+1 and 2+2 HSB are planned for future release.

- In the TX direction, the Active TX will follow the remote Active RX ACM requests (according to the remote Active Rx MSE performance).
- The Standby TX might have the same profile as the Active TX, or might stay at the lowest profile (profile 0). That depends on whether the Standby TX was able to follow the remote RX Active unit's ACM requests (only the active remote RX sends ACM request messages).
- In the RX direction, both the active and the standby units follow the remote Active TX profile (which is the only active transmitter).

ACM with Adaptive Transmit Power

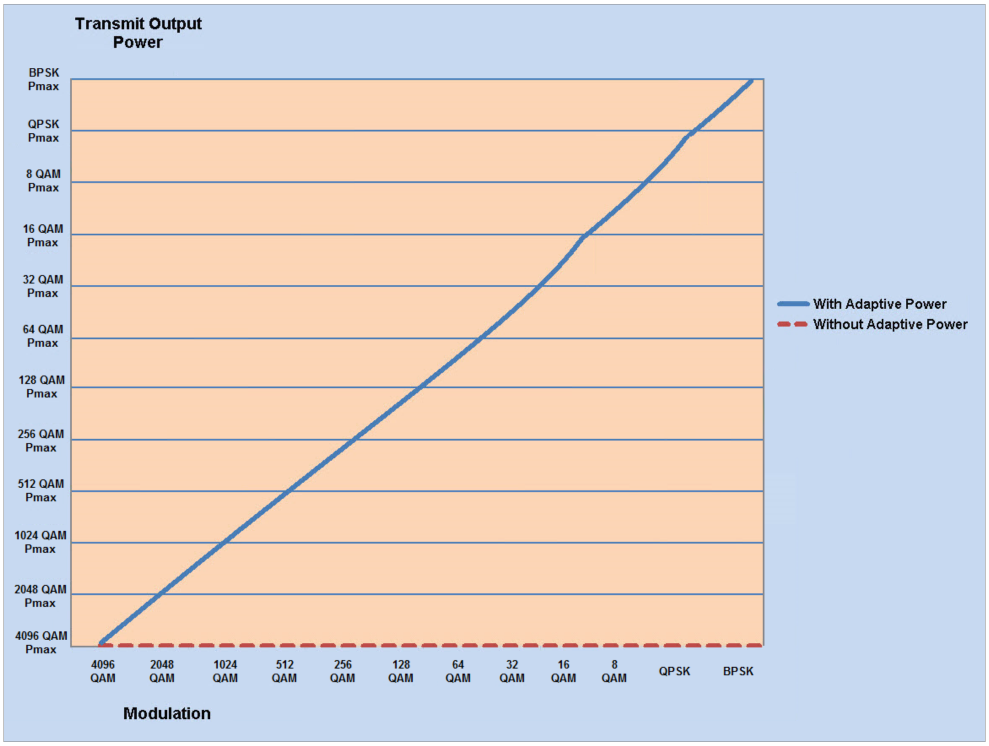
This feature requires:

- ACM script

When planning ACM-based radio links, the radio planner attempts to apply the lowest transmit power that will perform satisfactorily at the highest level of modulation. During fade conditions requiring a modulation drop, most radio systems cannot increase transmit power to compensate for the signal degradation, resulting in a deeper reduction in capacity. PTP 850C is capable of adjusting power on the fly, and optimizing the available capacity at every modulation point.

The following figure contrasts the transmit output power achieved by using ACM with Adaptive Power to the transmit output power at a fixed power level, over an 18-23 GHz link. This figure shows how without Adaptive Transmit Power, operators that want to use ACM to benefit from high levels of modulation (e.g., 2048 QAM) must settle for low system gain, in this case, 16 dB, for all the other modulations as well. In contrast, with PTP 850C's Adaptive Transmit Power feature, operators can automatically adjust power levels, achieving the extra system gain that is required to maintain optimal throughput levels under all conditions.

Figure 59: *PTP 850C ACM with Adaptive Power Contrasted to Other ACM Implementations*



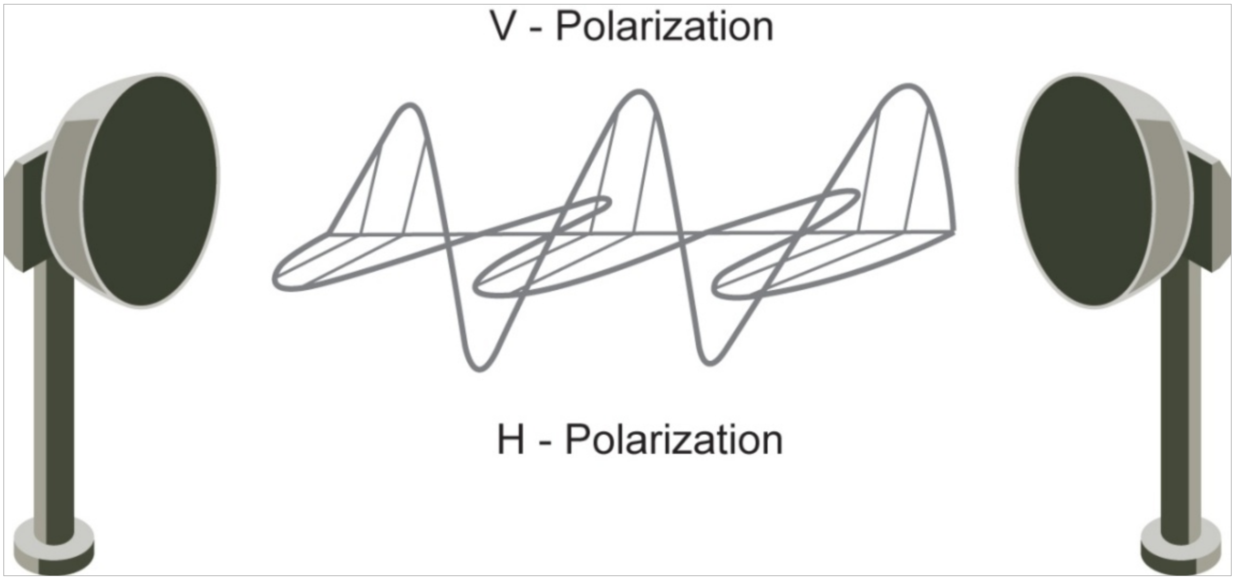
Cross Polarization Interference Canceller (XPIC)

This feature requires:

- 2+0, 2+2, or 4x4 (MIMO) configuration
- Enhanced Multi-Carrier ABC for each XPIC pair
- XPIC script

XPIC is one of the best ways to break the barriers of spectral efficiency. Using dual-polarization radio over a single-frequency channel, a single dual core PTP 850C unit transmits two separate carrier waves over the same frequency, but using alternating polarities. Despite the obvious advantages of dual-polarization, one must also keep in mind that typical antennas cannot completely isolate the two polarizations. In addition, propagation effects such as rain can cause polarization rotation, making cross-polarization interference unavoidable.

Figure 60: *Dual Polarization*



The relative level of interference is referred to as cross-polarization discrimination (XPD). While lower spectral efficiency systems (with low SNR requirements such as QPSK) can easily tolerate such interference, higher modulation schemes cannot and require XPIC. PTP 850C's XPIC algorithm enables detection of both streams even under the worst levels of XPD such as 10 dB. PTP 850C accomplishes this by adaptively subtracting from each carrier the interfering cross carrier, at the right phase and level. For high-modulation schemes such as 2048 QAM, operating at a frequency of 28 GHz, an improvement factor of more than 23 dB is required so that cross-interference does not adversely affect performance. In this scenario, PTP 850C's XPIC implementation provides an improvement factor of approximately 26 db.

XPIC Benefits

The advantages of PTP 850C's XPIC option include BER of 10e-6 at a co-channel sensitivity of 10 dB.

XPIC enables PTP 850C links of up to 2 Gbps, consisting of 1 Gbps per carrier. XPIC can be installed in either of the following configurations:

> Note:
>
> With 224 MHz channels, each carrier can achieve up to 2 Gbps, for a total of 4 Gbps. 224 MHz channel support is only supported with certain hardware versions. For details, ask your Cambium representative.

- Direct Mount – The PTP 850C unit is connected to the antenna via an OMT.
- Remote Mount – The PTP 850C unit is connected to the antenna via two flexible waveguides. Some configurations also require an OMT.

XPIC-Ready 1+0 Links

An PTP 850C can be installed initially in single-core mode, hardware ready for 2+0 Dual Polarization (XPIC). Later, when the operator is ready to expand network capacity, the link can be converted to a 2+0

XPIC link remotely by uploading and installing the activation keys for XPIC and for the second core and activating the second core and XPIC.

When installing a 1+0 link which is hardware ready for 2+0 XPIC, the operator must plan and install the link as if it is immediately being configured as an XPIC link. This includes both link budget calculation and hardware installation.

The OMTs must be carefully aligned according to the XPIC alignment procedure. Activation key Demo Mode can be used to activate the second radio interface for purposes of alignment. After completing alignment, the regular activation key should be installed and the link configured for 1+0 operation.

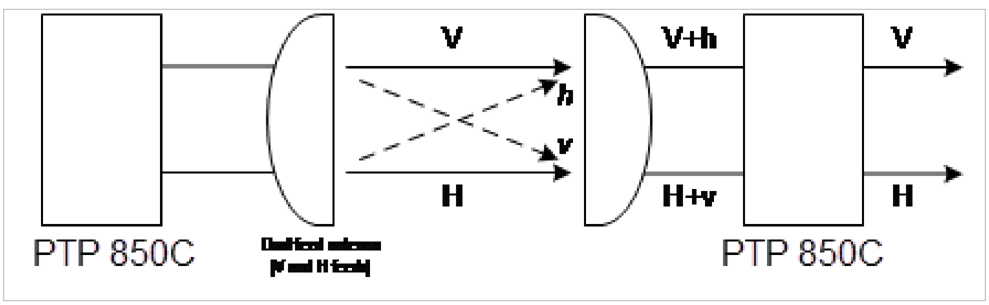
Failure to follow these steps may limit the ability to remotely upgrade a 1+0 link to a 2+0 XPIC link at a later date.

XPIC Implementation

The XPIC mechanism utilizes the received signals from the V and H modems to extract the V and H signals and cancel the cross polarization interference due to physical signal leakage between V and H polarizations.

The following figure is a basic graphic representation of the signals involved in this process.

Figure 61: *XPIC Implementation*

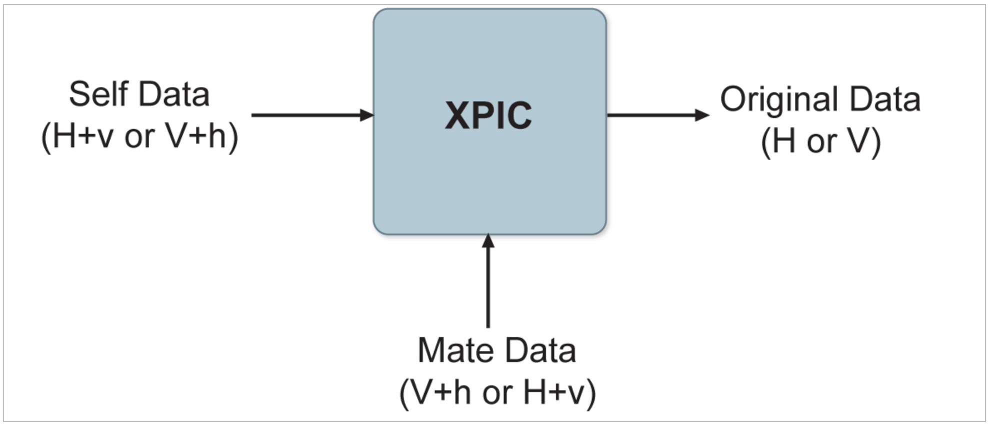


Note:

For the sake of simplicity, a dual feed V and H antenna is depicted. PTP 850C can be directly mounted using a mediation device in this configuration.

The H+v signal is the combination of the desired signal H (horizontal) and the interfering signal V (in lower case, to denote that it is the interfering signal). The same happens with the vertical (V) signal reception= V+h. The XPIC mechanism uses the received signals from both feeds and, manipulates them to produce the desired data.

Figure 62: *XPIC – Impact of Misalignments and Channel Degradation*



PTP 850C's XPIC reaches a BER of 10e-6 at a co-channel sensitivity of 10 dB. The improvement factor in an XPIC system is defined as the SNR@threshold of 10e-6, with or without the XPIC mechanism.

Conditions for XPIC

Most PTP 850C radio scripts support XPIC. See Radio Scripts.

The user must enable XPIC, after loading the script.

In order for XPIC to be operational, all the following conditions must be met:

- The frequency of both carriers should be equal.
- The same script must be loaded in both carriers.

If any of these conditions is not met, an alarm will alert the user. In addition, events will inform the user which conditions are not met.

Unit Redundancy

PTP 850C offers 1+1 and 2+2 HSB protection configurations, which include HSB radio protection and Unit Redundancy. 1+1 HSB can also be implemented with Space Diversity. See 1+1 HSB with Space Diversity.

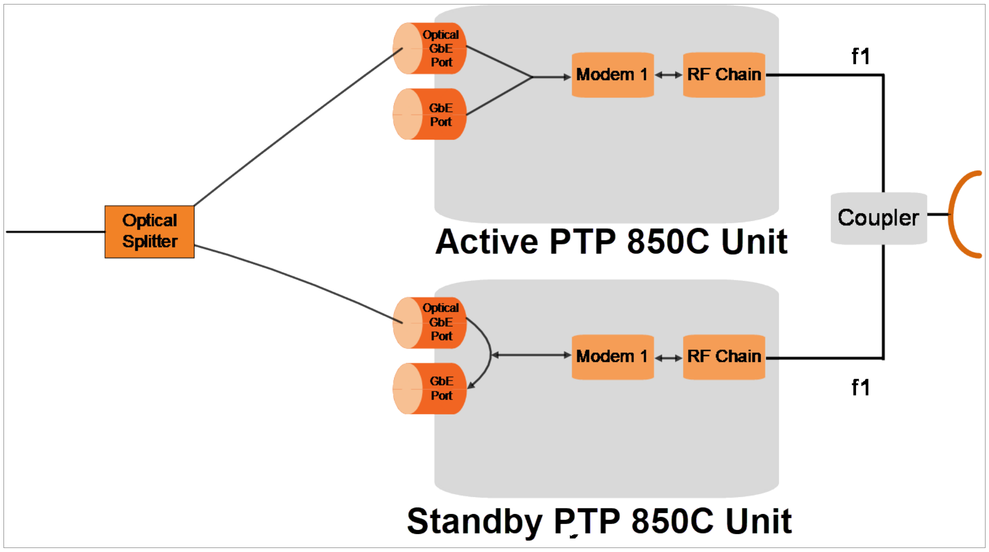
> **Note**:
>
> HSB protection, Unit Redundancy, and Space Diversity are planned for future release.

1+1 HSB protection utilizes two PTP 850C units operating in single core mode, with a single antenna. 1+1 HSB-SD utilizes PTP 850C units operating in MultiCore mode, with two antennas. Both configurations provide hardware redundancy for Ethernet traffic. One PTP 850C operates in active mode and the other operates in standby mode. If a switchover occurs, the roles are switched. The active unit goes into standby mode and the standby unit goes into active mode.

The standby unit is managed by the active unit. The standby unit's transmitter is muted, but the standby unit's receiver is kept on in order to monitor the link. However, the received signal is terminated at the switch level.

In Split Protection mode, an optical splitter is used to route traffic to an optical GbE port on each PTP 850C unit. Both ports on each PTP 850C unit belong to a LAG, with 100% distribution to the port connected to the optical splitter on each PTP 850C unit. Split Protection mode is only available for optical GbE ports on the PTP 850C.

Figure 63: *1+1 HSB Protection – Split Protection Mode*



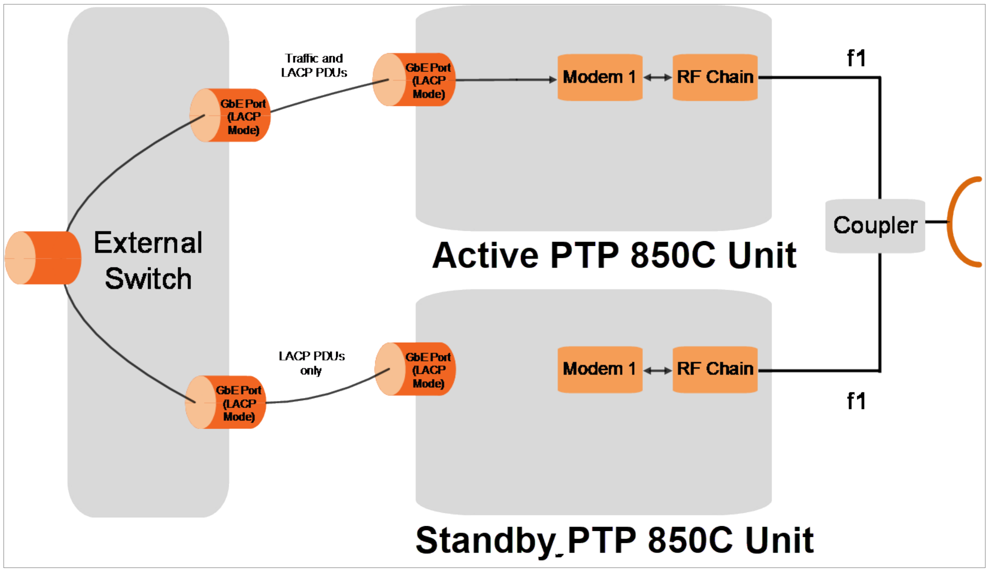
Alternatively, traffic can be routed to the PTP 850C units via an external switch. This is called Line Protection mode.

Line Protection mode can be used for electrical as well as optical GbE ports. Traffic is routed from two GbE ports on an external switch to a GbE port on the active and a GbE port on the standby PTP 850C unit. LACP protocol is used to determine which PTP 850C port is active and which port is standby, and traffic is only forwarded to the active port.

Note:

The external switch must support LACP.

Figure 64: *1+1 HSB Protection – Line Protection Mode*



In a 1+1 HSB configuration, each PTP 850C monitors its own radio. If the active PTP 850C detects a radio failure, it initiates a switchover to the standby PTP 850C.

2+2 HSB protection utilizes two PTP 850C units operating in dual core mode, with a single antenna, to provide hardware redundancy for Ethernet traffic in a dual core configuration. In effect, a MultiCore 2+2 HSB configuration is a protected MultiCore 2+0 configuration.

In a 2+2 HSB configuration, each PTP 850C monitors both of its cores. If the active PTP 850C detects a radio failure in either of its cores, it initiates a switchover to the standby PTP 850C.

Figure 65: *2+2 HSB Protection – Split Protection Mode*

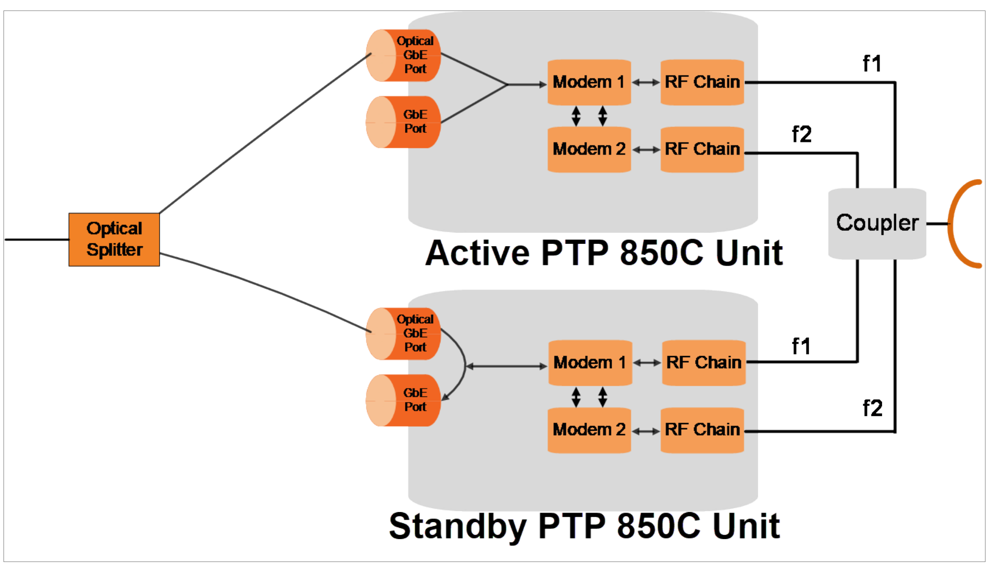
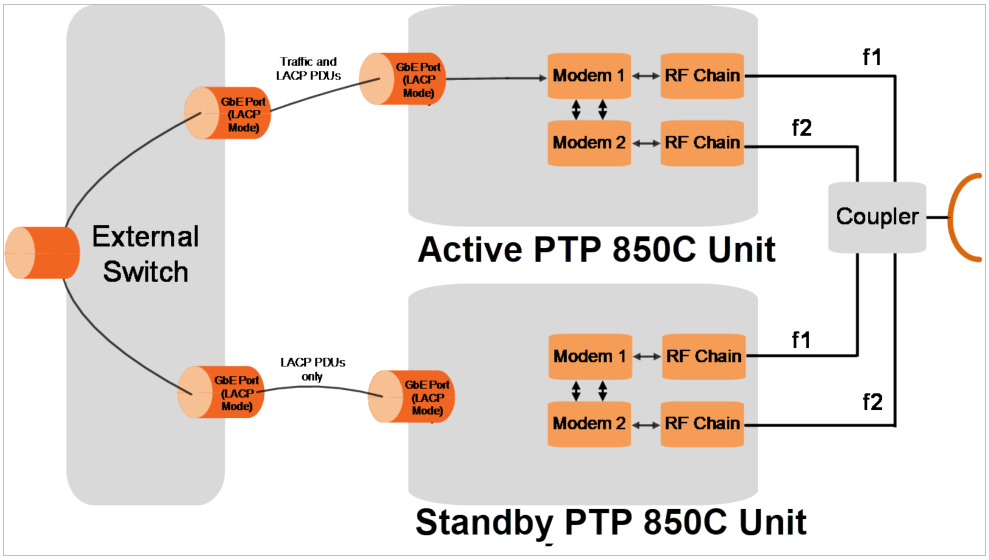


Figure 66: *2+2 HSB Protection – Line Protection Mode*



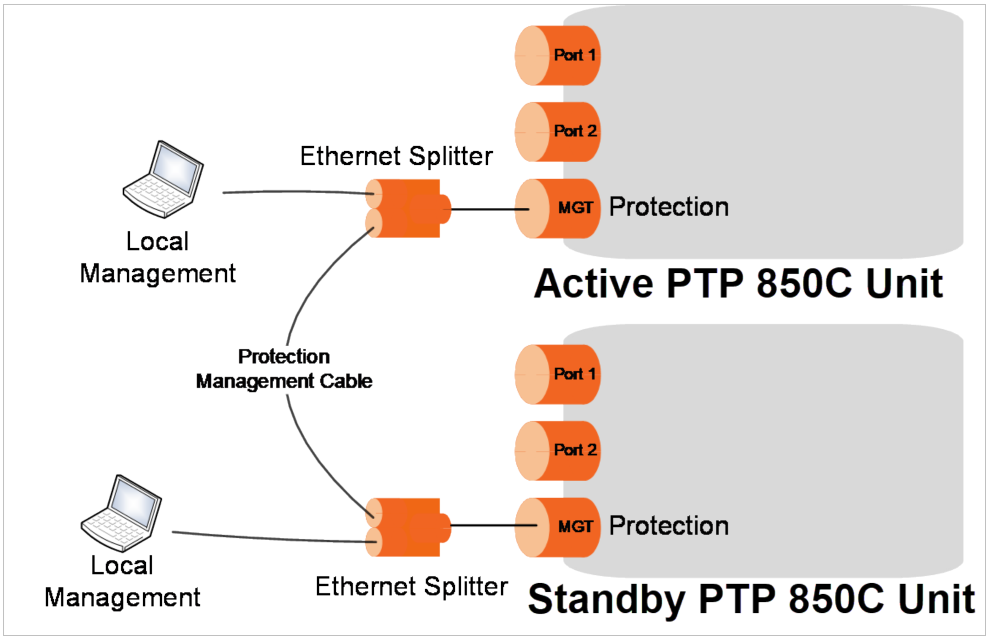
Management for Unit Redundancy

In a Unit Redundancy configuration, the standby unit is managed via the active unit. A protection cable connects the two PTP 850C units via their management ports. This cable is used for internal management. By placing an Ethernet splitter on the protection port, the user can add another cable for local management (for a detailed description, refer to Management Connection for 4x4 MIMO and 1+1/2+2 HSB Configurations). A single IP address is used for both PTP 850C units, to ensure that management is not lost in the event of switchover.

Note:

If in-band management is used, no splitter is necessary.

Figure 67: *Internal and Local Management*



The active and standby units must have the same configuration. The configuration of the active unit can be manually copied to the standby unit. Upon copying, both units are automatically reset. Therefore, it is important to ensure that the units are fully and properly configured when the system is initially brought into service.

Note:

Dynamic and hitless copy-to-mate functionality is planned for future release.

Note:

Switchover

In the event of switchover, the standby unit becomes the active unit and the active unit becomes the standby unit. Switchover takes less than 50 msec.

The following events trigger switchover for HSB protection according to their priority, with the highest priority triggers listed first:

1. Loss of active unit
2. Lockout
3. Radio/Ethernet interface failure
4. Manual switch

ATPC

ATPC is a closed-loop mechanism by which each carrier changes the TX power according to the indication received across the link, in order to achieve a desired RSL on the other side of the link.

ATPC enables the transmitter to operate at less than maximum power for most of the time. When fading conditions occur, TX power is increased as needed until the maximum is reached.

The ATPC mechanism has several potential advantages, including less power consumption and longer amplifier component life, thereby reducing overall system cost.

ATPC is frequently used as a means to mitigate frequency interference issues with the environment, thus allowing new radio links to be easily coordinated in frequency congested areas.

ATPC Override Timer

This feature complies with NSMA Recommendation WG 18.91.032. With ATPC enabled, if the radio automatically increases its TX power up to the configured maximum it can lead to a period of sustained transmission at maximum power, resulting in unacceptable interference with other systems.

To minimize interference, PTP 850C provides an ATPC override mechanism. When ATPC override is enabled, a timer begins when ATPC raises the TX power to its maximum. When the timer expires, the ATPC maximum TX power is overridden by the user-configured ATPC override TX power level until the user manually cancels the ATPC override. The unit then returns to normal ATPC operation.

The following parameters can be configured:

- **ATPC Override Admin** – Determines whether the ATPC override mechanism is enabled.
- **Override TX Level** – The TX power, in dBm, used when the unit is in an ATPC override state.
- **Override Timeout** – The amount of time, in seconds, the timer counts from the moment the radio reaches its maximum configured TX power until ATPC override goes into effect.

When the radio enters ATPC override state, the radio transmits no higher than the pre-determined ATPC override TX level, and an ATPC override alarm is raised. The radio remains in ATPC override state until the ATPC override state is manually cancelled by the user (or the unit is reset).

In a configuration with Unit Redundancy, the ATPC override state is propagated to the standby unit in the event of switchover.

Note:

When canceling an ATPC override state, the user should ensure that the underlying problem has been corrected. Otherwise, ATPC may be overridden again.

Radio Signal Quality PMs

PTP 850C supports the following radio signal quality PMs. For each of these PM types, users can display the minimum and maximum values, per radio, for every 15-minute interval. Users can also define thresholds and display the number of seconds during which the radio was not within the defined threshold.

- RSL (users can define two RSL thresholds)
- TSL
- MSE
- XPI

Users can display BER PMs, including the current BER per radio, and define thresholds for Excessive BER and Signal Degrade BER. Alarms are issued if these thresholds are exceeded. See Configurable BER Threshold for Alarms and Traps. Users can also configure an alarm that is raised if the RSL falls beneath a user-defined threshold. See RSL Threshold Alarm.

Radio Utilization PMs

PTP 850C supports the following counters, as well as additional PMs based on these counters:

- Radio Traffic Utilization – Measures the percentage of radio capacity utilization, and used to generate the following PMs for every 15-minute interval:
  - Peak Utilization (%)
  - Average Utilization (%)
  - Over-Threshold Utilization (seconds). Up to three utilization thresholds can be defined by users (0-100%).
- Radio Traffic Throughput – Measures the total effective Layer 2 traffic sent through the radio (Mbps), and used to generate the following PMs for every 15-minute interval:
  - Peak Throughput
  - Average Throughput
  - Over-Threshold Utilization (seconds). The threshold is defined as 0.
- Radio Traffic Capacity – Measures the total L1 bandwidth (payload plus overheads) sent through the radio (Mbps), and used to generate the following PMs for every 15-minute interval:
  - Peak Capacity
  - Average Capacity
  - Over-Threshold Utilization (seconds). The threshold is defined as 0.

Ethernet Features

PTP 850C's service-oriented Ethernet paradigm enables operators to configure VLAN definition and translation, CoS, and security on a service, service-point, and interface level.

PTP 850C provides personalized and granular QoS that enables operators to customize traffic management parameters per customer, application, service type, or in any other way that reflects the operator's business and network requirements.

This section includes:

- PTP 850C's Ethernet Capabilities
- Ethernet Service Model
- Ethernet Interfaces
- Quality of Service (QoS)
- Global Switch Configuration

- Automatic State Propagation and Link Loss Forwarding
- Adaptive Bandwidth Notification (EOAM)
- Network Resiliency
- OAM

PTP 850C's Ethernet Capabilities

PTP 850C is built upon a service-based paradigm that provides rich and secure frame backhaul services over any type of transport, with unified, simple, and error-free operation. PTP 850C's services core includes a rich set of tools that includes:

- Service-based Quality of Service (QoS).
- Service OAM, including granular PMs, and service activation.
- Carrier-grade service resiliency using G.8032

The following are PTP 850C's main Carrier Ethernet transport features. This rich feature set provides a future-proof architecture to support backhaul evolution for emerging services.

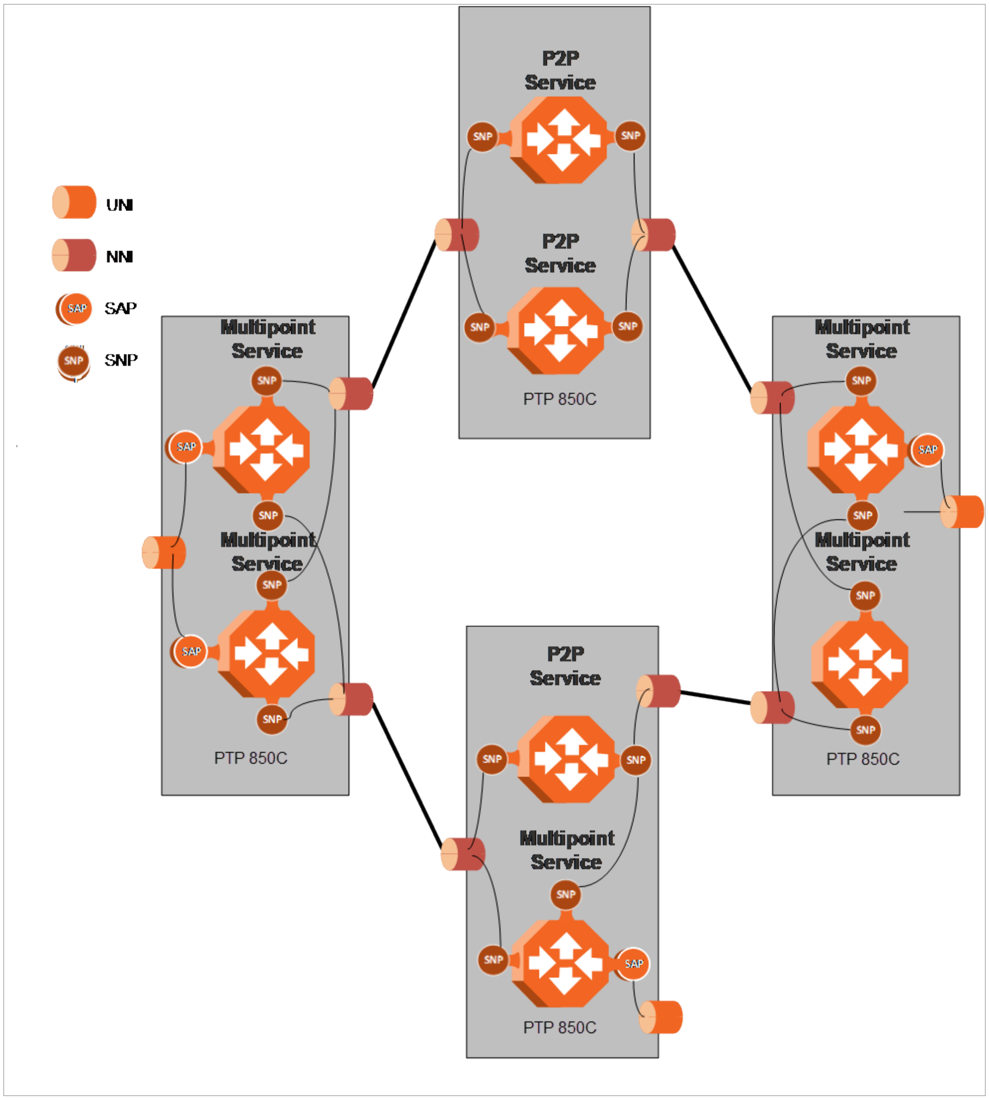
- Up to 1024 services
- Up to 32 service points per service
- All service types:
  - Multipoint (E-LAN)
  - Point-to-Point (E-Line)
  - Management
- 64K MAC learning table, with separate learning per service (including limiters)
- Flexible transport and encapsulation via 802.1q and 802.1ad (Q-in-Q), with tag manipulation possible at ingress and egress
- High precision, flexible frame synchronization solution combining SyncE and 1588v2
- Hierarchical QoS with 64 queues per interface, deep buffering, hierarchical scheduling via WFQ and Strict priority, and shaping at each level
- 1K hierarchical two-rate three-Color policers
  - Port based – Unicast, Multicast, Broadcast, Ethertype
  - Service-based
  - CoS-based
- Up to four link aggregation groups (LAG)
  - Hashing based on L2, L3, and MPLS
- Enhanced <50msec network level resiliency (G.8032) for ring/mesh support

Ethernet Service Model

PTP 850C's service-oriented Ethernet paradigm is based on Carrier-Ethernet Transport (CET), and provides a highly flexible and granular switching fabric for Ethernet services.

PTP 850C's virtual switching/forwarding engine is based on a clear distinction between user-facing service interfaces and intra-network service interfaces. User-facing interfaces (UNIs) are configured as Service Access Points (SAPs), while intra-network interfaces (E-NNIs or NNIs) are configured as Service Network Points (SNPs).

Figure 68: *PTP 850C Services Model*



The PTP 850C services core provides for fully flexible C-VLAN and S-VLAN encapsulation, with a full range of classification, preservation, and translation options available. Service security and isolation is provided without limiting the C-VLAN reuse capabilities of different customers.

Users can define up to 1024 services on a single PTP 850C. Each service constitutes a virtual bridge that defines the connectivity and behavior among the network element interfaces for the specific virtual bridge.

In addition to user-defined services, PTP 850C contains a pre-defined management service (Service ID 1025). If needed, users can activate the management service and use it for in-band management.

To define a service, the user must configure virtual connections among the interfaces that belong to the service. This is done by configuring service points (SPs) on these interfaces.

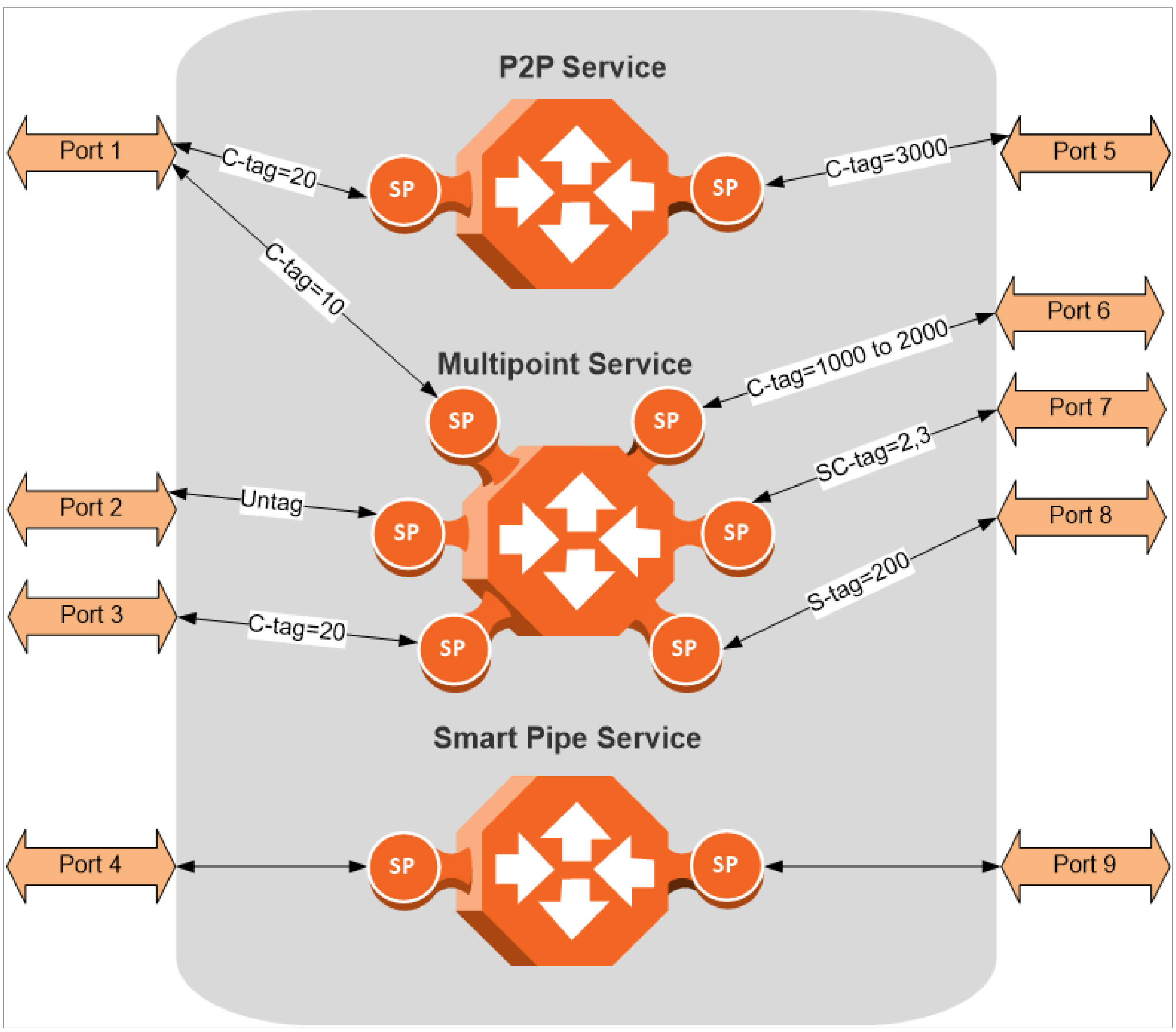
A service can hold up to 32 service points. A service point is a logical entity attached to a physical or logical interface. Service points define the movement of frames through the service. Each service point includes both ingress and egress attributes.

Note:

Management services can hold up to 30 SPs.

The following figure illustrates the PTP 850C services model, with traffic entering and leaving the network element. PTP 850C's switching fabric is designed to provide a high degree of flexibility in the definition of services and the treatment of data flows as they pass through the switching fabric.

Figure 69: *PTP 850C Services Core*



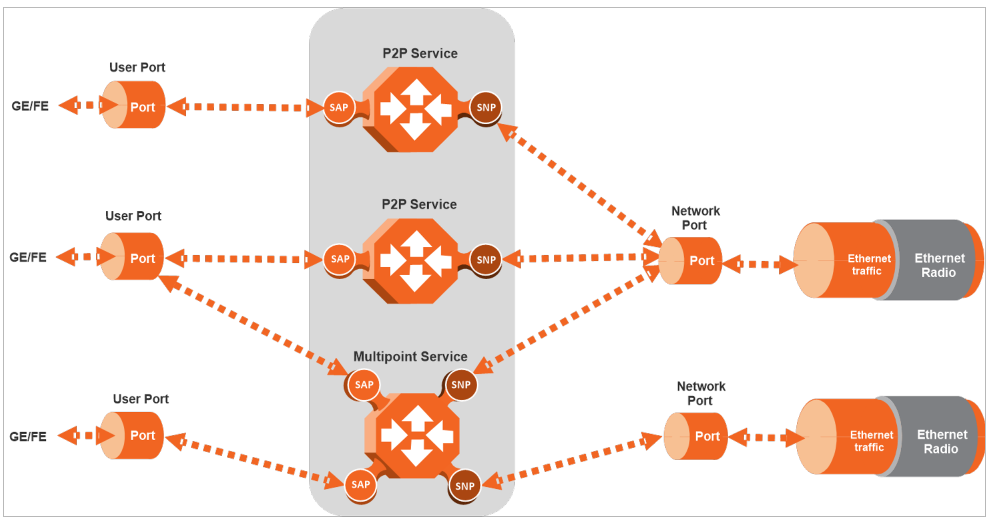
Frame Classification to Service Points and Services

Each arriving frame is classified to a specific service point, based on a key that consists of:

- The Interface ID of the interface through which the frame entered the PTP 850C.
- The frame's C-VLAN and/or S-VLAN tags.

If the classification mechanism finds a match between the key of the arriving frame and a specific service point, the frame is associated to the specific service to which the service point belongs. That service point is called the ingress service point for the frame, and the other service points in the service are optional egress service points for the frame. The frame is then forwarded from the ingress service point to an egress service point by means of flooding or dynamic address learning in the specific service. Services include a MAC entry table of up to 65,536 entries, with a global aging timer and a maximum learning limiter that are configurable per-service.

Figure 70: *PTP 850C Services Flow*



PTP 850C supports the following service types:

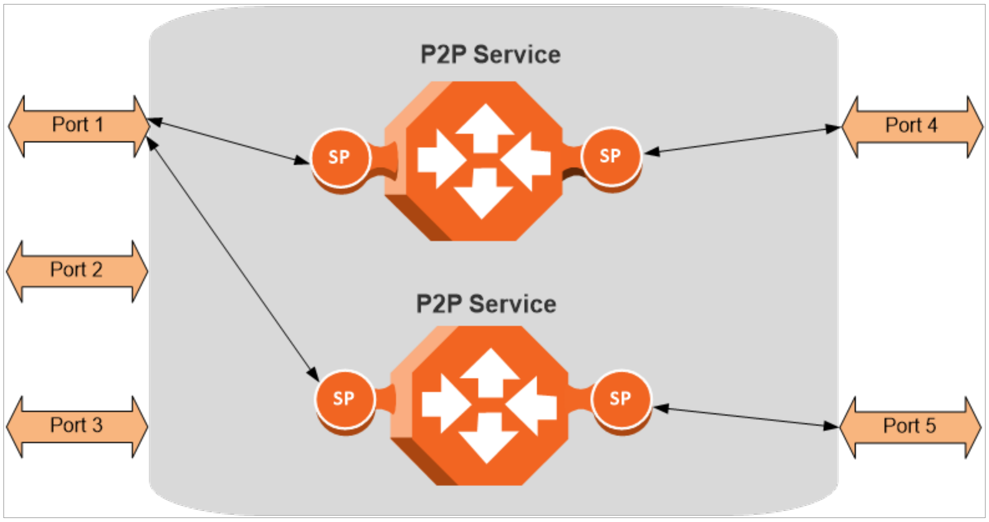
- Point-to-Point Service (P2P)
- MultiPoint Service (MP)
- Management Service

Point to Point Service (P2P)

Point-to-point services are used to provide connectivity between two interfaces of the network element. When traffic ingresses via one side of the service, it is immediately directed to the other side according to ingress and egress tunneling rules. This type of service contains exactly two service points and does not require MAC address-based learning or forwarding. Since the route is clear, the traffic is tunneled from one side of the service to the other and vice versa.

The following figure illustrates a P2P service.

Figure 71: *Point-to-Point Service*



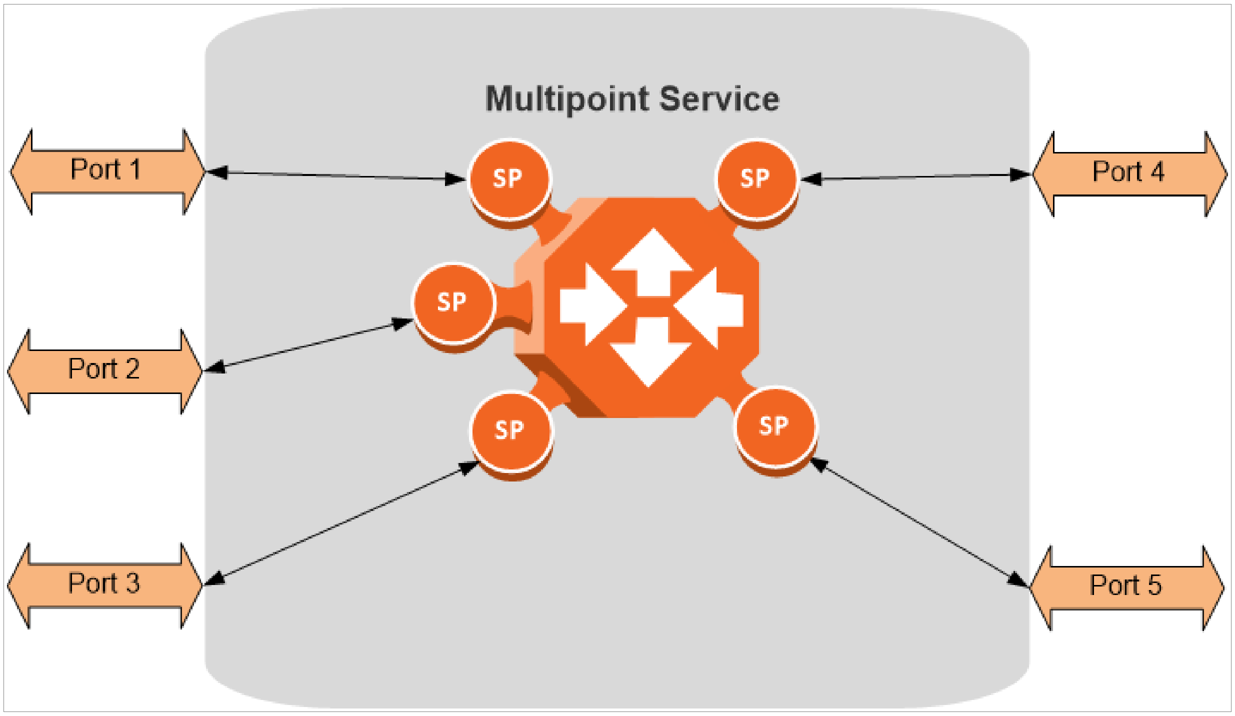
P2P services provide the building blocks for network services such as E-Line EVC (EPL and EVPL EVCs) and port-based services.

Multipoint Service (MP)

Multipoint services are used to provide connectivity between two or more service points. When traffic ingresses via one service point, it is directed to one of the service points in the service, other than the ingress service point, according to ingress and egress tunneling rules, and based on the learning and forwarding mechanism. If the destination MAC address is not known by the learning and forwarding mechanism, the arriving frame is flooded to all the other service points in the service except the ingress service point.

The following figure illustrates a Multipoint service.

Figure 72: *Multipoint Service*



Multipoint services provide the building blocks for network services such as E-LAN EVCs (EP-LAN and EVP-LAN EVCs), and for E-Line EVCs (EPL and EVPL EVCs) in which only two service points are active. In such a case, the user can disable MAC address learning in the service points to conserve system resources.

Learning and Forwarding Mechanism

PTP 850C can learn up to 65,536 Ethernet source MAC addresses. PTP 850C performs learning per service in order to enable the use of 1024 virtual bridges in the network element. If necessary due to security issues or resource limitations, users can limit the size of the MAC forwarding table. The maximum size of the MAC forwarding table is configurable per service in granularity of 16 entries.

When a frame arrives via a specific service point, the learning mechanism checks the MAC forwarding table for the service to which the service point belongs to determine whether that frame's source MAC address is known to the service. If the MAC address is not found, the learning mechanism adds it to the table under the specific service point.

In parallel with the learning process, the forwarding mechanism searches the service's MAC forwarding table for the frame's destination MAC address. If a match is found, the frame is forwarded to the service point associated with the MAC address. If not, the frame is flooded to all service points in the service.

The following table illustrates the operation of the learning and forwarding mechanism.

Table 9 *Ethernet Services Learning and Forwarding*

MAC Forwarding Table		
Input Key for learning / forwarding (search) operation	Result	Entry type

MAC Forwarding Table			
Service ID	MAC address	Service Point	
13	00:34:67:3a:aa:10	15	dynamic
13	00:0a:25:33:22:12	31	dynamic
28	00:0a:25:11:12:55	31	static
55	00:0a:25:33:22:12	15	dynamic
55	00:c3:20:57:14:89	31	dynamic
55	00:0a:25:11:12:55	31	dynamic

In addition to the dynamic learning mechanism, users can add static MAC addresses for static routing in each service. These user entries are not considered when determining the maximum size of the MAC forwarding table.

Users can manually clear all the dynamic entries from the MAC forwarding table. Users can also delete static entries per service.

The system also provides an automatic flush process. An entry is erased from the table as a result of:

- The global aging time expires for the entry.
- Loss of carrier occurs on the interface with which the entry is associated.
- Resiliency protocols, such as MSTP or G.8032.

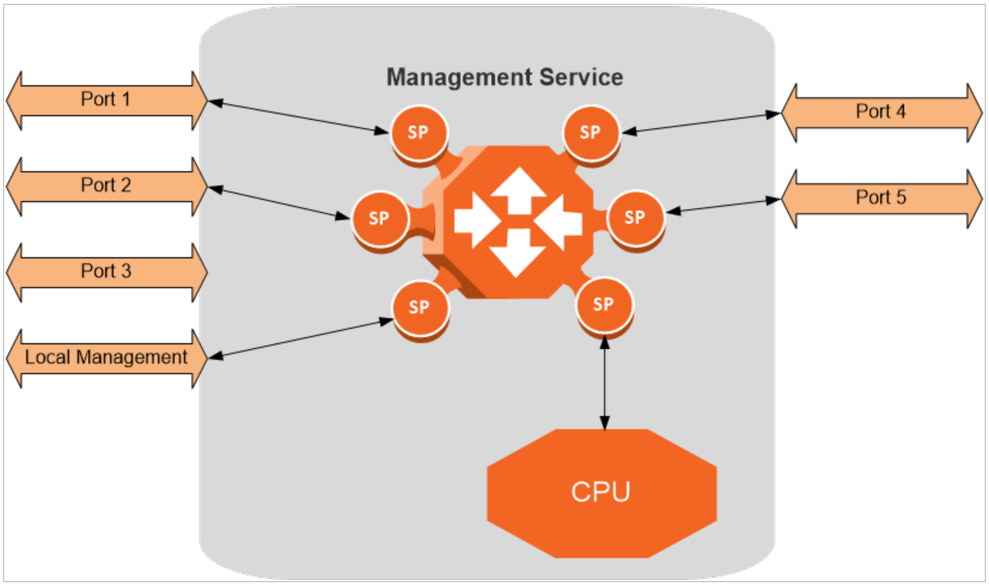
Management Service (MNG)

The management service connects the local management port, the network element host CPU, and the traffic ports into a single service. The management service is pre-defined in the system, with Service ID 1025. The pre-defined management service has a single service point that connects the service to the network element host CPU and the management port. To configure in-band management over multiple network elements, the user must connect the management service to the network by adding a service point on an interface that provides the required network connectivity.

Users can modify the attributes of the management service, but cannot delete it. The CPU service point is read-only and cannot be modified. The local management port is also connected to the service, but its service point is not visible to users. The management port is enabled by default and cannot be disabled.

The following figure illustrates a management service.

Figure 73: *Management Service*



Management services can provide building blocks for network services such as E-LAN EVCs (EP-LAN and EVP-LAN), as well as E-Line EVCs (EPL and EVPL EVCs) in which only two service points are active.

Service Attributes

PTP 850C services have the following attributes:

- **Service ID** – A unique ID that identifies the service. The user must select the Service ID upon creating the service. The Service ID cannot be edited after the service has been created. Service ID 1025 is reserved for the pre-defined Management service.
- **Service Type** – Determines the specific functionality that will be provided for Ethernet traffic using the service. For example, a Point-to-Point service provides traffic forwarding between two service points, with no need to learn a service topology based on source and destination MAC addresses. A Multipoint service enables operators to create an E-LAN service that includes several service points.
- **Service Admin Mode** – Defines whether or not the service is functional, i.e., able to receive and transmit traffic. When the Service Admin Mode is set to Operational, the service is fully functional. When the Service Admin Mode is set to Reserved, the service occupies system resources but is unable to transmit and receive data.
- **EVC-ID** – The Ethernet Virtual Connection ID (end-to-end). This parameter does not affect the network element's behavior, but is used by the NMS for topology management.
- **EVC Description** – The Ethernet Virtual Connection description. This parameter does not affect the network element's behavior, but is used by the NMS for topology management.
- **Maximum Dynamic MAC Address Learning per Service** – Defines the maximum number of dynamic Ethernet MAC address that the service can learn. This parameter is configured with a granularity of 16, and only applies to dynamic, not static, MAC addresses.
- **Static MAC Address Configuration** – Users can add static entries to the MAC forwarding table. The global aging time does not apply to static entries, and they are not counted with respect to the

Maximum Dynamic MAC Address Learning. It is the responsibility of the user not to use all the 65,536 entries in the table if the user also wants to utilize dynamic MAC address learning.

- **CoS Mode** – Defines whether the service inherits ingress classification decisions made at previous stages or overwrites previous decisions and uses the default CoS defined for the service. For more details on PTP 850C's hierarchical classification mechanism, refer to Classification on page QoS on the Ingress Path.
- **Default CoS** – The default CoS value at the service level. If the CoS Mode is set to overwrite previous classification decisions, this is the CoS value used for frames entering the service.
- **xSTP Instance** (0-46, 4095) – The spanning tree instance ID to which the service belongs. The service can be a traffic engineering service (instance ID 4095) or can be managed by the xSTP engines of the network element.

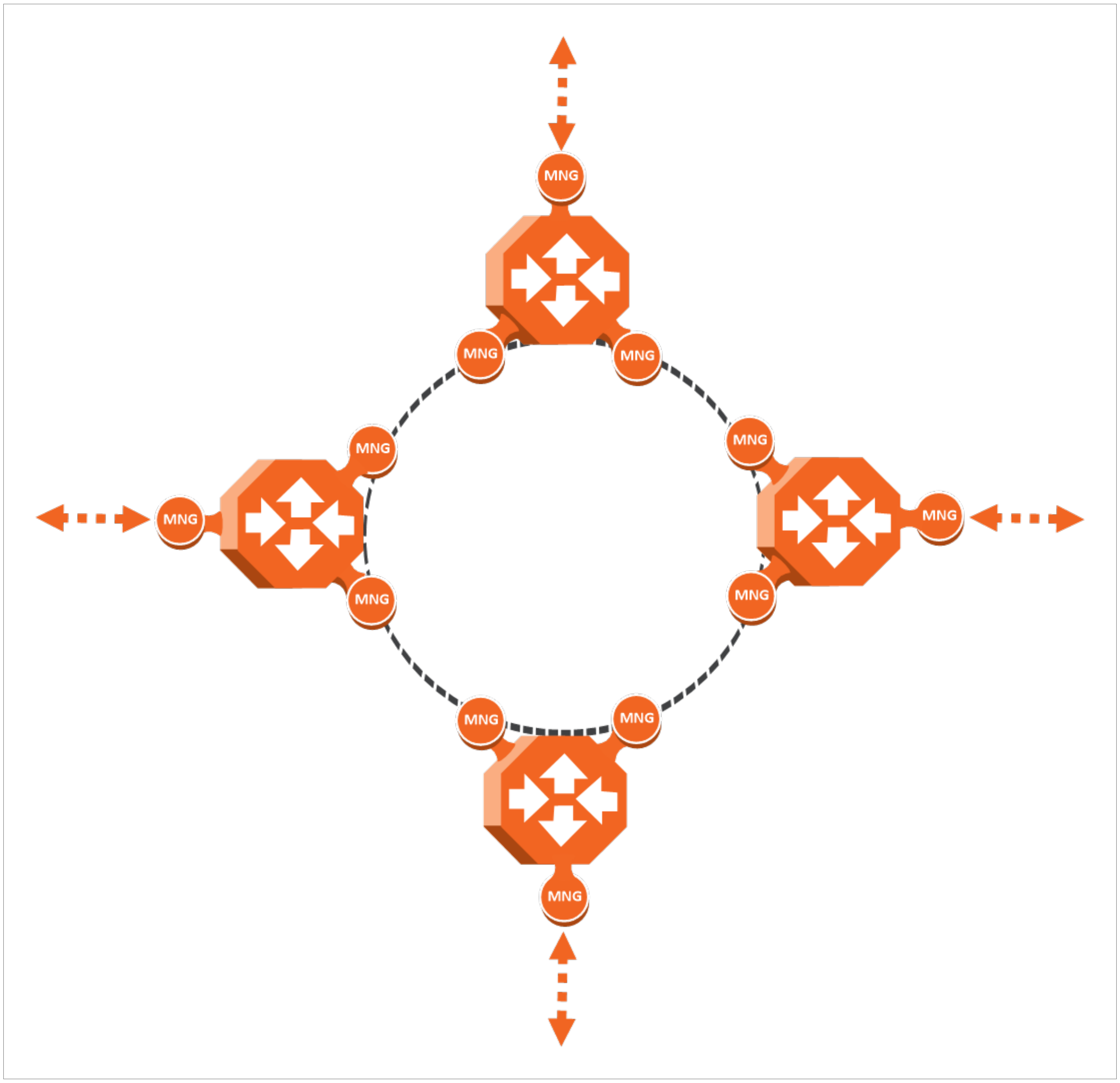
Service Points

Service points are logical entities attached to the interfaces that make up the service. Service points define the movement of frames through the service. Without service points, a service is simply a virtual bridge with no ingress or egress interfaces.

PTP 850C supports several types of service points:

- **Management (MNG) Service Point** – Only used for management services. The following figure shows a management service used for in-band management among four network elements in a ring. In this example, each service contains three MNG service points, two for East-West management connectivity in the ring, and one serving as the network gateway.

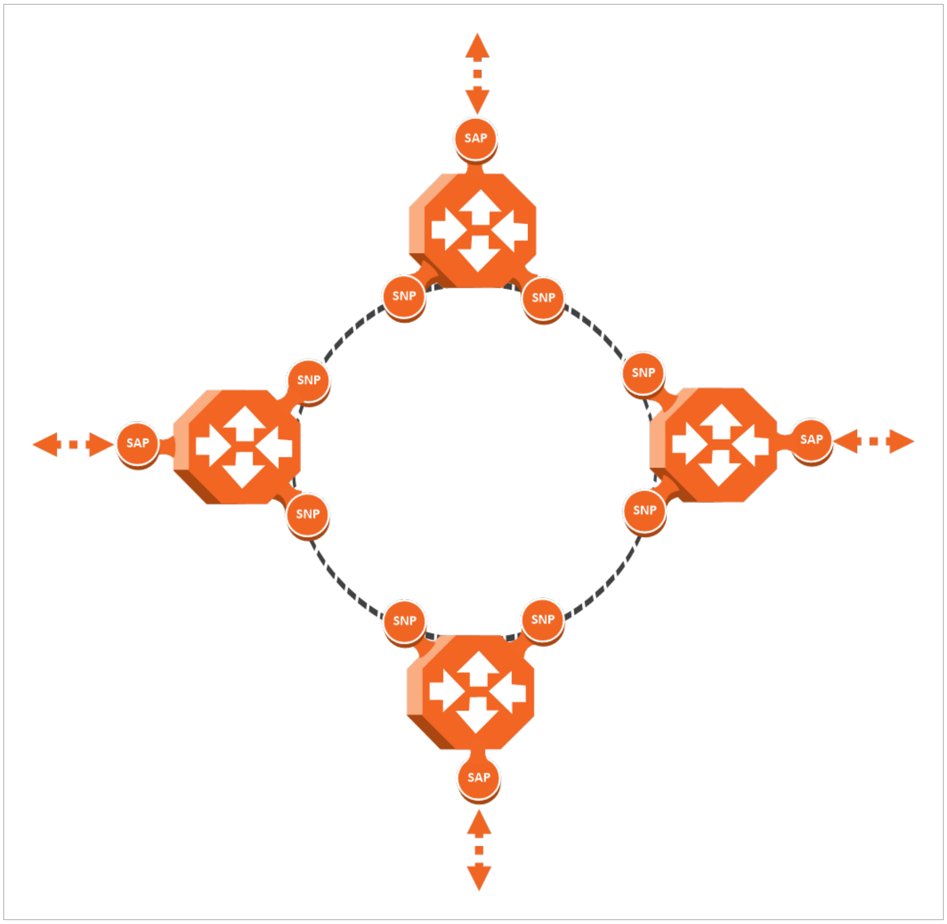
Figure 74: *Management Service and its Service Points*



- **Service Access Point (SAP) Service Point** – An SAP is equivalent to a UNI in MEF terminology and defines the connection of the user network with its access points. SAPs are used for Point-to-Point and Multipoint traffic services.
- **Service Network Point (SNP) Service Point** – An SNP is equivalent to an NNI or E-NNI in MEF terminology and defines the connection between the network elements in the user network. SNPs are used for Point-to-Point and Multipoint traffic services.

  The following figure shows four network elements in ring. An MP Service with three service points provides the connectivity over the network. The SNPs provide the connectivity among the network elements in the user network while the SAPs provide the access points for the network.

Figure 75: *SAPs and SNPs*



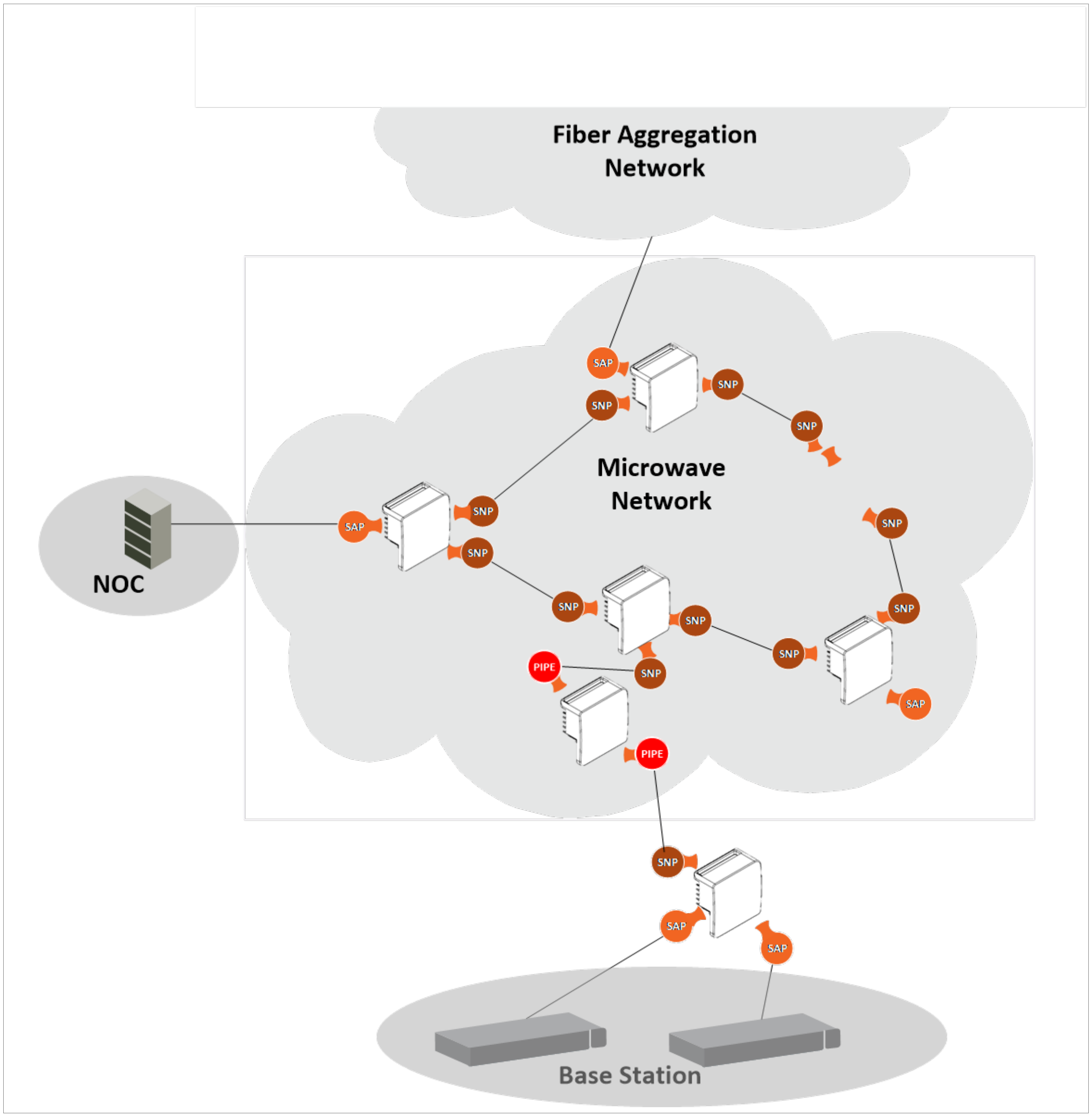
- **Pipe Service Point** – Used to create traffic connectivity between two points in a port-based manner. In other words, all the traffic from one port passes to the other port. Pipe service points are used in Point-to-Point and Multipoint services.

  The following figure shows a Point-to-Point service with Pipe service points that create a service between Port 1 of the network element on the left and Port 2 of the network element on the right.

Figure 76: *Pipe Service Points*

The following figure shows the usage of SAP, SNP and Pipe service points in a microwave network. The SNPs are used for interconnection between the network elements while the SAPs provide the access points for the network. Pipe service points are also used, to provide connectivity between elements that require port-based connectivity.

Figure 77: *SAP, SNP and Pipe Service Points in a Microwave Network*



The following table summarizes the service point types available per service type.

Table 10 *Service Point Types per Service Type*

		Service point type			
		MNG	**SAP**	**SNP**	**Pipe**
Service Type	Management	Yes	No	No	No
	Point-to-Point	No	Yes	Yes	Yes
	Multipoint	No	Yes	Yes	Yes

Service Point Classification

As explained above, service points connect the service to the network element interfaces. It is crucial that the network element have a means to classify incoming frames to the proper service point. This classification process is implemented by means of a parsing encapsulation rule for the interface associated with the service point. This rule is called the Attached Interface Type, and is based on a three-part key consisting of:

- The Interface ID of the interface through which the frame entered.
- The frame's C-VLAN and/or S-VLAN tags.

The Attached Interface Type provides a definitive mapping of each arriving frame to a specific service point in a specific service. Since more than one service point may be associated with a single interface, frames are assigned to the earliest defined service point in case of conflict.

SAP Classification

SAPs the following Attached Interface Types:

- **All to one** – All C-VLANs and untagged frames that enter the interface are classified to the same service point.
- **Dot1q** – A single C-VLAN is classified to the service point.
- **QinQ** – A single S-VLAN and C-VLAN combination is classified to the service point.
- **Bundle C-Tag**– A set of multiple C-VLANs are classified to the service point.
- **Bundle S-Tag** – A single S-VLAN and a set of multiple C-VLANs are classified to the service point.

SNP classification

SNPs can be used with the following Attached Interface Types:

- **Dot1q** – A single C VLAN is classified to the service point.
- **S-Tag** – A single S- VLAN is classified to the service point.

PIPE classification

Pipe service points can be used with the following Attached Interface Types:

- **Dot1q** – All C-VLANs and untagged frames that enter the interface are classified to the same service point.
- **S-Tag** – All S-VLANs and untagged frames that enter the interface are classified to the same service point.

MNG classification

Management service points can be used with the following Attached Interface Types:

- **Dot1q** – A single C-VLAN is classified to the service point.
- **S-Tag** – A single S-VLAN is classified to the service point.
- **QinQ** – A single S-VLAN and C-VLAN combination is classified into the service point.

The following table shows which service point – Attached Interface Type combinations can co-exist on the same interface.

Table 11 *Service Point Type-Attached Interface Type Combinations that can Co-Exist on the Same Interface*

	SP Type	**SAP**					**SNP**		**Pipe**		**MNG**		
SP Type	Attached Interface Type	802.1q	Bundle C-Tag	Bundle S-Tag	All to One	QinQ	802.1q	S-Tag	802.1q	S-Tag	802.1q	QinQ	S-Tag
SAP	802.1q	Yes	Yes	No	No	No	No	No	Only for P2P Service	No	Yes	No	No
	Bundle C-Tag	Yes	Yes	No	No	No	No	No	Only for P2P Service	No	Yes	No	No
	Bundle S-Tag	No	No	Yes	No	Yes	No	No	No	No	No	Yes	No
	All to One	No	No	No	Only 1 All to One SP Per Interface	No	No	No	No	No	No	No	No
	QinQ	No	No	Yes	No	Yes	No	No	No	No	No	Yes	No
SNP	802.1q	No	No	No	No	No	Yes	No	Only for P2P Service	No	Yes	No	No
	S-Tag	No	No	No	No	No	No	Yes	No	Only for P2P Service	No	No	Yes
Pipe	802.1q	Only for	Only for	No	No	No	Only for	No	Only one	No	Yes	No	No

	SP Type	SAP					SNP		Pipe		MNG		
		P2P Service	P2P Service				P2P Service		Pipe SP Per Interface				
	S-Tag	No	No	No	No	No	No	Only for P2P Service	No	Only one Pipe SP Per Interface	No	No	Yes
MNG	802.1q	Yes	Yes	No	No	No	Yes	No	Yes	No	No	No	No
	QinQ	No	No	Yes	No	Yes	No	No	No	No	No	No	No
	S-Tag	No	No	No	No	No	No	Yes	No	Yes	No	No	No

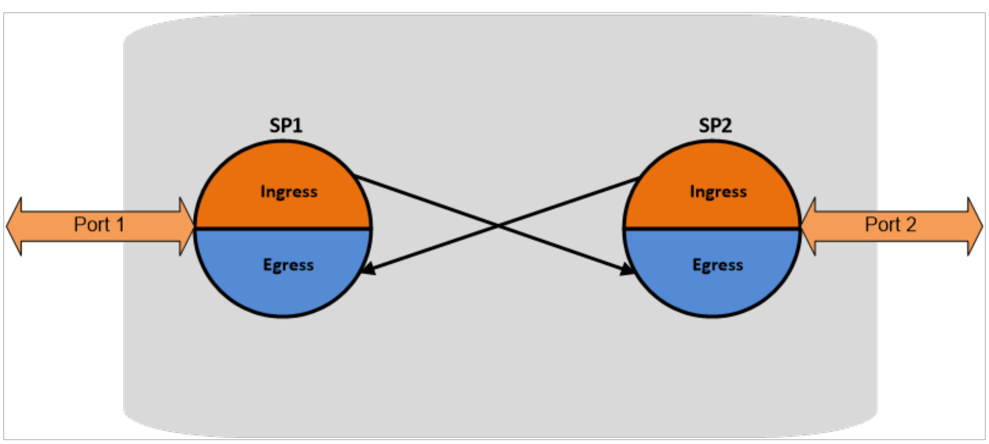
Service Point Attributes

As described above, traffic ingresses and egresses the service via service points. The service point attributes are divided into two types:

- **Ingress Attributes** – Define how frames are handled upon ingress, e.g., policing and MAC address learning.
- **Egress Attributes** – Define how frames are handled upon egress, e.g., preservation of the ingress CoS value upon egress, VLAN swapping.

The following figure shows the ingress and egress path relationship on a point-to-point service path. When traffic arrives via port 1, the system handles it using service point 1 ingress attributes then forwards it to service point 2 and handles it using the SP2 egress attributes:

Figure 78: *Service Path Relationship on Point-to-Point Service Path*



Service points have the following attributes:

General Service Point Attributes

- **Service Point ID** – Users can define up to 32 service points per service, except for management services which are limited to 30 service points in addition to the pre-defined management system service point.
- **Service Point Name** – A descriptive name, which can be up to 20 characters.
- **Service Point Type** – The type of service point, as described above.
- **S-VLAN Encapsulation** – The S-VLAN ID associated with the service point.
- **C-VLAN Encapsulation** – The C-VLAN ID associated with the service point.
- **Attached C VLAN** – For service points with an Attached Interface Type of Bundle C-Tag, this attribute is used to create a list of C-VLANs associated with the service point.
- **Attached S-VLAN** – For service points with an Attached Interface Type of Bundle S-Tag, this attribute is used to create a list of S-VLANs associated with the service point.

Ingress Service Point Attributes

The ingress attributes are attributes that operate upon frames when they ingress via the service point.

- **Attached Interface Type** – The interface type to which the service point is attached, as described above. Permitted values depend on the service point type.
- **Learning Administration** – Enables or disables MAC address learning for traffic that ingresses via the service point. This option enables users to enable or disable MAC address learning for specific service points.
- **Allow Broadcast** – Determines whether to allow frames to ingress the service via the service point when the frame has a broadcast destination MAC address.
- **Allow Flooding** – Determines whether incoming frames with unknown MAC addresses are forwarded to other service points via flooding.
- **CoS Mode** – Determines whether the service point preserves the CoS decision made at the interface level, overwrites the CoS with the default CoS for the service point.
- **Default CoS** – The service point CoS. If the CoS Mode is set to overwrite the CoS decision made at the interface level, this is the CoS value assigned to frames that ingress the service point.

Egress Service Point Attributes

The egress attributes are attributes that operate upon frames egressing via the service point.

- **C-VLAN ID Egress Preservation** – If enabled, C-VLAN frames egressing the service point retain the same C-VLAN ID they had when they entered the service.
- **C-VLAN CoS Egress Preservation** – If enabled, the C-VLAN CoS value of frames egressing the service point is the same as the value when the frame entered the service.
- **S-VLAN CoS Egress Preservation** – If enabled, the S-VLAN CoS value of frames egressing the service point is the same as the value when the frame entered the service.

- **Marking** – Marking refers to the ability to overwrite the outgoing priority bits and Color of the outer VLAN of the egress frame, either the C-VLAN or the S-VLAN. If marking is enabled, the service point overwrites the outgoing priority bits and Color of the outer VLAN of the egress frame. Marking mode is only relevant if either the outer frame is S-VLAN and S-VLAN CoS preservation is disabled, or the outer frame is C-VLAN and C-VLAN CoS preservation is disabled. When marking is enabled and active, marking is performed according to global mapping tables that map the 802.1p-UP bits and the DEI or CFI bit to a defined CoS and Color value.
- **Service Bundle ID** – This attribute can be used to assign one of the available service bundles from the H-QoS hierarchy queues to the service point. This enables users to personalize the QoS egress path. For details, refer to Standard QoS and Hierarchical QoS (H-QoS).

Ethernet Interfaces

The PTP 850C switching fabric distinguishes between physical interfaces and logical interfaces. Physical and logical interfaces serve different purposes in the switching fabric.

The concept of a physical interface refers to the physical characteristics of the interface, such as speed, duplex, auto-negotiation, master/slave, and standard RMON statistics.

A logical interface can consist of a single physical interface or a group of physical interfaces that share the same function. Examples of the latter are protection groups and link aggregation groups. Switching and QoS functionality are implemented on the logical interface level.

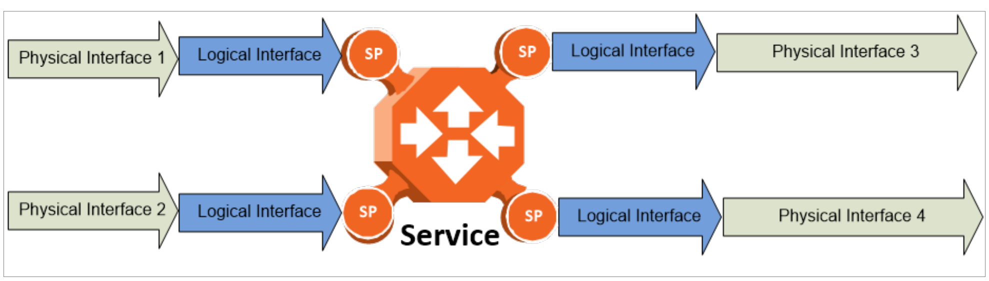
It is important to understand that the PTP 850C switching fabric regards all traffic interfaces as regular physical interfaces, distinguished only by the media type the interface uses, e.g., RJ-45, SFP, or Radio.

From the user's point of view, the creation of the logical interface is simultaneous with the creation of the physical interface. For example, when the user enables a radio interface, both the physical and the logical radio interface come into being at the same time.

Once the interface is created, the user configures both the physical and the logical interface. In other words, the user configures the same interface on two levels, the physical level and the logical level.

The following figure shows physical and logical interfaces in a one-to-one relationship in which each physical interface is connected to a single logical interface, without grouping.

Figure 79: *Physical and Logical Interfaces*



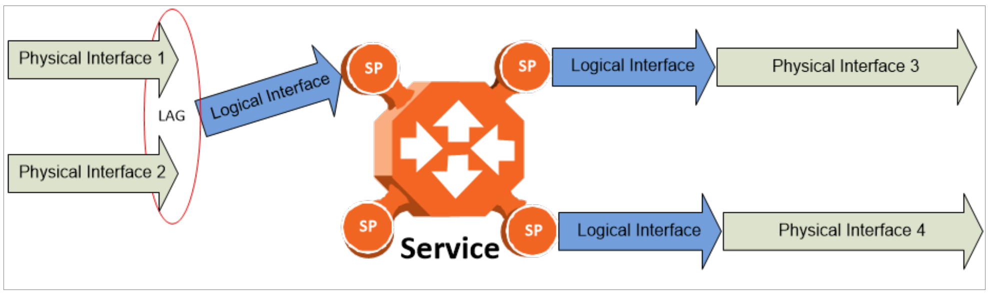
Note:

For simplicity only, this figure represents a uni-directional rather than a bi-directional traffic flow.

The next figure illustrates the grouping of two or more physical interfaces into a logical interface, a link aggregation group (LAG) in this example. The two physical interfaces on the ingress side send traffic into a single logical interface. The user configures each physical interface separately, and configures the logical interface as a single logical entity. For example, the user might configure each physical interface to 100 Mbps, full duplex, with auto-negotiation off. On the group level, the user might limit the group to a rate of 200 Mbps by configuring the rate meter on the logical interface level.

When physical interfaces are grouped into a logical interface, PTP 850C also shows standard RMON statistics for the logical interface, i.e., for the group. This information enables users to determine the cumulative statistics for the group, rather than having to examine the statistics for each interface individually.

Figure 80: *Grouped Interfaces as a Single Logical Interface on Ingress Side*

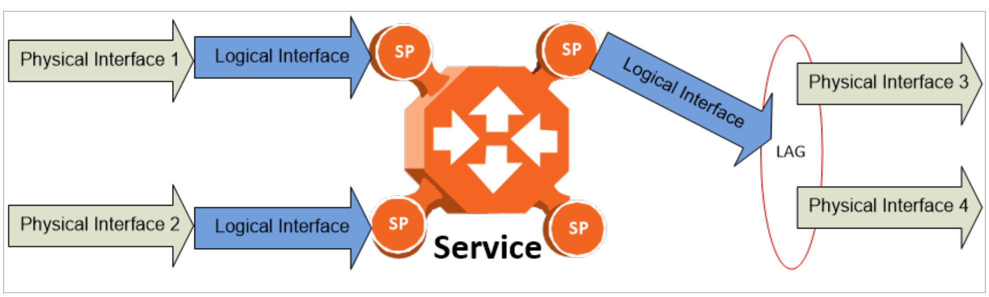


Note:

For simplicity only, this figure represents a uni-directional rather than a bi-directional traffic flow.

The following figure shows the logical interface at the egress side. In this case, the user can configure the egress traffic characteristics, such as scheduling, for the group as a whole as part of the logical interface attributes.

Figure 81: *Grouped Interfaces as a Single Logical Interface on Egress Side*



Note:

For simplicity only, this figure represents a uni-directional rather than a bi-directional traffic flow.

Physical Interfaces

The physical interfaces refer to the real traffic ports (layer 1) that are connected to the network. The Media Type attribute defines the Layer 1 physical traffic interface type, which can be:

- Radio interface
- RJ-45 or SFP Ethernet interface.

Physical Interface Attributes

The following physical interface parameters can be configured by users:

- **Admin** – Enables or disables the physical interface. This attribute is set via the Interface Manager section of the Web EMS.
- **Auto Negotiation** – Enables or disables auto-negotiation on the physical interface. Auto Negotiation is always off for radio and SFP interfaces.
- **Speed and Duplex** – The physical interface speed and duplex mode.
- **Flow Control** – The physical port flow control capability. Permitted values are: Symmetrical Pause and/or Asymmetrical Pause. This parameter is only relevant in Full Duplex mode.
- **IFG** – The physical port Inter-frame gap. Although users can modify the IFG field length, it is strongly recommended not to modify the default value of 12 bytes without a thorough understanding of how the modification will impact traffic. Permitted values are 6 to 15 bytes.
- **Preamble** – The physical port preamble value. Although users can modify the preamble field length, it is strongly recommended not to modify the default values of 8 bytes without a thorough understanding of how the modification will impact traffic. Permitted values are 6 to 15 bytes.
- **Interface description** – A text description of the interface, up to 40 characters.

The following read-only physical interface status parameters can be viewed by users:

- **Operational State** – The operational state of the physical interface (Up or Down).
- **Actual Speed and Duplex** – The actual speed and duplex value for the Ethernet link as agreed by the two sides of the link after the auto negotiation process.
- **Actual Flow Control State** – The actual flow control state values for the Ethernet link as agreed by the two sides after the auto negotiation process.
- **Actual Physical Mode** (only relevant for RJ-45 interfaces) – The actual physical mode (master or slave) for the Ethernet link, as agreed by the two sides after the auto negotiation process.

Ethernet Statistics

The PTP 850C platform stores and displays statistics in accordance with RMON and RMON2 standards.

Users can display various peak TX and RX rates (in seconds) and average TX and RX rates (in seconds), both in bytes and in packets, for each measured time interval. Users can also display the number of seconds in the interval during which TX and RX rates exceeded the configured threshold.

The following transmit statistic counters are available:

- Transmitted bytes (not including preamble) in good or bad frames. Low 32 bits.
- Transmitted bytes (not including preamble) in good or bad frames. High 32 bits.
- Transmitted frames (good or bad)
- Multicast frames (good only)

- Broadcast frames (good only)
- Pause control frame transmitted
- FCS error frames
- Oversized frames – frames with length > 1518 bytes (1522 bytes for VLAN-tagged frames) without errors
- Undersized frames (good only)
- Fragments frames (undersized bad)
- Jabber frames – frames with length > 1518 bytes (1522 for VLAN-tagged frames) with errors
- Frames with length 64 bytes, good or bad
- Frames with length 65-127 bytes, good or bad
- Frames with length 128-255 bytes, good or bad
- Frames with length 256-511 bytes, good or bad
- Frames with length 512-1023 bytes, good or bad.
- Frames with length 1024-1518 bytes, good or bad
- Frames with length 1519-1522 bytes, good or bad

The following receive statistic counters are available:

- Received bytes (not including preamble) in good or bad frames. Low 32 bits.
- Received bytes (not including preamble) in good or bad frames. High 32 bits.
- Received frames (good or bad)
- Multicast frames (good only)
- Broadcast frames (good only)
- Pause control frame received
- FCS error frames
- Counts oversized frames – frames with length > 1518 bytes (1522 bytes for VLAN-tagged frames) without errors *and* frames with length > MAX_LEN without errors
- Undersized frames (good only)
- Fragments frames (undersized bad)
- Counts jabber frames – frames with length > 1518 bytes (1522 for VLAN-tagged frames) with errors
- Frames with length 64 bytes, good or bad
- Frames with length 65-127 bytes, good or bad
- Frames with length 128-255 bytes, good or bad
- Frames with length 256-511 bytes, good or bad
- Frames with length 512-1023 bytes, good or bad

- Frames with length 1024-1518 bytes, good or bad
- VLAN-tagged frames with length 1519-1522 bytes, good or bad

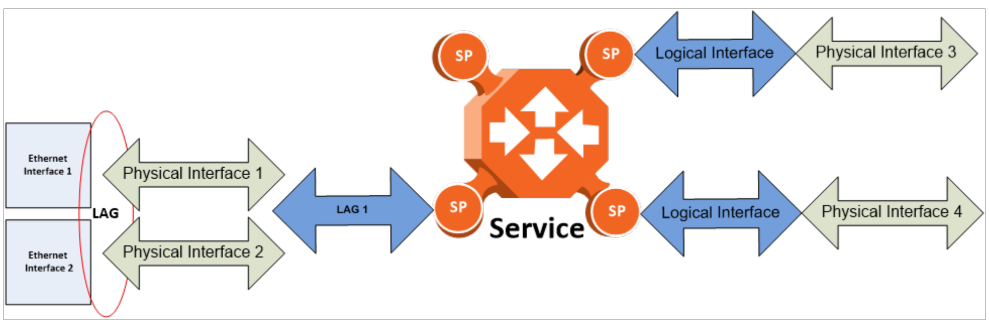
Logical Interfaces

A logical interface consists of one or more physical interfaces that share the same traffic ingress and egress characteristics. From the user's point of view, it is more convenient to define interface behavior for the group as a whole than for each individual physical interface that makes up the group. Therefore, classification, QoS, and resiliency attributes are configured and implemented on the logical interface level, in contrast to attributes such as interface speed and duplex mode, which are configured on the physical interface level.

It is important to understand that the user relates to logical interfaces in the same way in both a one-to-one scenario in which a single physical interface corresponds to a single logical interface, and a grouping scenario such as a link aggregation group or a radio protection group, in which several physical interfaces correspond to a single logical interface.

The following figure illustrates the relationship of a LAG group to the switching fabric. From the point of view of the user configuring the logical interface attributes, the fact that there are two Ethernet interfaces is not relevant. The user configures and manages the logical interface just as if it represented a single Ethernet interface.

Figure 82: *Relationship of Logical Interfaces to the Switching Fabric*



Logical Interface Attributes

The following logical interface attributes can be configured by users:

General Attributes

- **Traffic Flow Administration** – Enables traffic via the logical interface. This attribute is useful when the user groups several physical interfaces into a single logical interface. The user can enable or disable traffic to the group using this parameter.

Ingress Path Classification at Logical Interface Level

These attributes represent part of the hierarchical classification mechanism, in which the logical interface is the lowest point in the hierarchy.

- **MPLS Trust Mode** – When this attribute is set to Trust mode and the arriving packet has MPLS EXP priority bits, the interface performs CoS and Color classification according to a user-configurable

MPLS EXP bit to CoS and Color classification table.

- **DSCP Trust Mode** –When this attribute is set to Trust mode and the arriving packet has DSCP priority bits, the interface performs CoS and Color classification according to a user-configurable DSCP bit to CoS and Color classification table. If MPLS EXP priority bits are present, DSCP is not considered regardless of the Trust mode setting and regardless of whether an MPLS match was found.
- **802.1p Trust Mode** – When this attribute is set to Trust mode and the arriving packet is 802.1Q or 802.1AD, the interface performs CoS and Color classification according to user-configurable tables for 802.1q UP bit (C-VLAN frames) or 802.1AD UP bit (S-VLAN frames) to CoS and Color classification. MPLS and DSCP classification have priority over 802.1p Trust Mode, so that if a match is found on the MPLS or DSCP level, 802.1p bits are not considered.
- **Default CoS** – The default CoS value for frames passing through the interface. This value can be overwritten on the service point and service level. The Color is assumed to be Green.

For more information about classification at the logical interface level, refer to Logical Interface-Level Classification.

Ingress Path Rate Meters at Logical Interface Level

- **Unicast or Unknown-Unicast Traffic Rate Meter Admin** – Enables or disables the unicast rate meter (policer) on the logical interface.
- **Unicast or Unknown-Unicast Traffic Rate Meter Profile** – Associates the rate meter (policer) with a specific rate meter (policer) profile.
- **Multicast or Unknown-Multicast Traffic Rate Meter Admin** – Enables or disables the multicast rate meter (policer) on the logical interface.
- **Multicast or Unknown-Multicast Traffic Rate Meter Profile** – Associates the rate meter (policer) with a specific rate meter (policer) profile.
- **Broadcast Traffic Rate Meter Admin** – Enables or disables the broadcast rate meter (policer) on the logical interface.
- **Broadcast Traffic Rate Meter Profile** – Associates the rate meter (policer) with a specific rate meter (policer) profile.
- **Ethertype 1 Rate Meter Admin** – Enables or disables the Ethertype 1 rate meter (policer) on the logical interface.
- **Ethertype 1 Rate Meter Profile** – Associates the rate meter (policer) with a specific rate meter (policer) profile.
- **Ethertype 1 Value** – The Ethertype value to which the user wants to apply this rate meter (policer). The field length is 4 nibbles (for example, 0x0806 - ARP).
- **Ethertype 2 Rate Meter Admin** – Enables or disables the Ethertype 2 rate meter (policer) on the logical interface.
- **Ethertype 2 Rate Meter Profile** – Associates the rate meter (policer) with a specific rate meter (policer) profile.
- **Ethertype 2 Value** – The Ethertype value to which the user wants to apply the rate meter (policer). The field length is 4 nibbles (for example, 0x0806 - ARP).

- **Ethertype 3 Rate Meter Admin** – Enables or disables the Ethertype 3 rate meter (policer) on the logical interface.
- **Ethertype 3 Rate Meter Profile** – Associates the rate meter (policer) with a specific rate meter (policer) profile.
- **Ethertype 3 Value** – The Ethertype value to which the user wants to apply the rate meter (policer). The field length is 4 nibbles (for example, 0x0806 - ARP).
- **Inline Compensation** – The logical interface's ingress compensation value. The rate meter (policer) attached to the logical interface uses this value to compensate for Layer 1 non-effective traffic bytes.

The following read-only logical interface status parameters can be viewed by users:

- **Traffic Flow Operational Status** – Indicates whether or not the logical interface is currently functional.

Logical Interface Statistics

RMON Statistics at Logical Interface Level

As discussed in Ethernet Statistics, if the logical interface represents a group, such as a LAG, the PTP 850C platform stores and displays RMON and RMON2 statistics for the logical interface.

Ingress Frame and Byte per Color Statistics at Logical Interface Level

Users can display the number of frames and bytes ingressing the logical interface per color, in granularity of 64 bits:

- Green Frames
- Green Bytes
- Yellow Frames
- Yellow Bytes
- Red Frames
- Red Bytes

Link Aggregation Groups (LAG) and LACP

Link aggregation (LAG) enables users to group several physical interfaces into a single logical interface bound to a single MAC address. This logical interface is known as a LAG group.

PTP 850 uses an automated distribution function to generate the most efficient distribution among the LAG physical ports. The LAG distribution function uses the following parameters:

- Ethernet
  - MAC – DA and SA
- MPLS
  - For multiple MPLS labels, only the first is considered
- IPv4

- DA and SA, if up to three MPLS labels are defined

- IPv6
  - DA Bytes 5-16 and SA Bytes 9-16 if there is no MPLS label
  - DA Bytes 8-16 and SA Bytes 9-16 if up to three MLPS labels are defined

LAG can be used to provide redundancy for Ethernet interfaces, both on the same PTP 850C unit (line protection) and on separate units (line protection and equipment protection).

LAG can also be used to aggregate several interfaces in order to create a wider (aggregate) Ethernet link. For example, LAG can be used to create a 3 Gbps channel by grouping the three Ethernet interfaces to a single LAG.

A LAG group can be configured to be automatically closed in the event of LAG degradation. This option is used if the customer wants traffic from the switch to be re-routed during such time as the link is providing less than a certain capacity. When enabled, the LAG is automatically closed in the event that any one or more ports in the LAG fail. When all ports in the LAG are again operational, the LAG is automatically re-opened.

Up to four LAG groups can be created.

Link Aggregation Control Protocol (LACP) expands the capabilities of static LAG, and provides interoperability with third-party equipment that uses LACP. LACP improves the communication between LAG members. This improves error detection capabilities in situations such as improper LAG configuration or improper cabling. It also enables the LAG to detect uni-directional failure and remove the link from the LAG, preventing packet loss.

PTP 850C's LACP implementation does not include write parameters or churn detection.

Note:

LACP can only be used with Ethernet interfaces.

LACP cannot be used with Enhanced LAG Distribution or with the LAG Group Shutdown in Case of Degradation Event feature.

Optionally, Multi-Homing can be enabled on a LAG group. When Multi-Homing is enabled:

- If ETH-BN (Ethernet Bandwidth Notification) is enabled on one of the interfaces in the LAG, BNM messages with current radio bandwidth are sent simultaneously on all of the LAG members.
- If ASP Management Safe Mode is enabled on one of the interfaces in the LAG, CSF messages are sent simultaneously on all of the LAG members.

An additional option to support Multi-Homing is Multi-Active. This option is only available when Multi-Homing is configured, and is primarily used when the LAG is a Control interface for ETH-BN in configurations where the device is receiving traffic from devices in a static MLAG active-active multi-homing configuration. Multi-Active enables the device to support load balancing when the LAG is receiving traffic from two active routers.

When Multi-Active is enabled , the radio bandwidth reported in the BNM packets is divided by the number of active LAG members.

LAG groups can include interfaces with the following constraints:

- Only physical interfaces, not logical interfaces, can belong to a LAG group.
- It is recommended not to include radio interfaces in a LAG group.
- Interfaces can only be added to the LAG group if no services or service points are attached to the interface.
- Any classification rules defined for the interface are overridden by the classification rules defined for the LAG group.
- When removing an interface from a LAG group, the removed interface is assigned the default interface values.

PTP 850C enables users to select the LAG members without limitations, such as interface speed and interface type. Proper configuration of a LAG group is the responsibility of the user.

Quality of Service (QoS)

Related topics:

- Ethernet Service Model
- In-Band Management

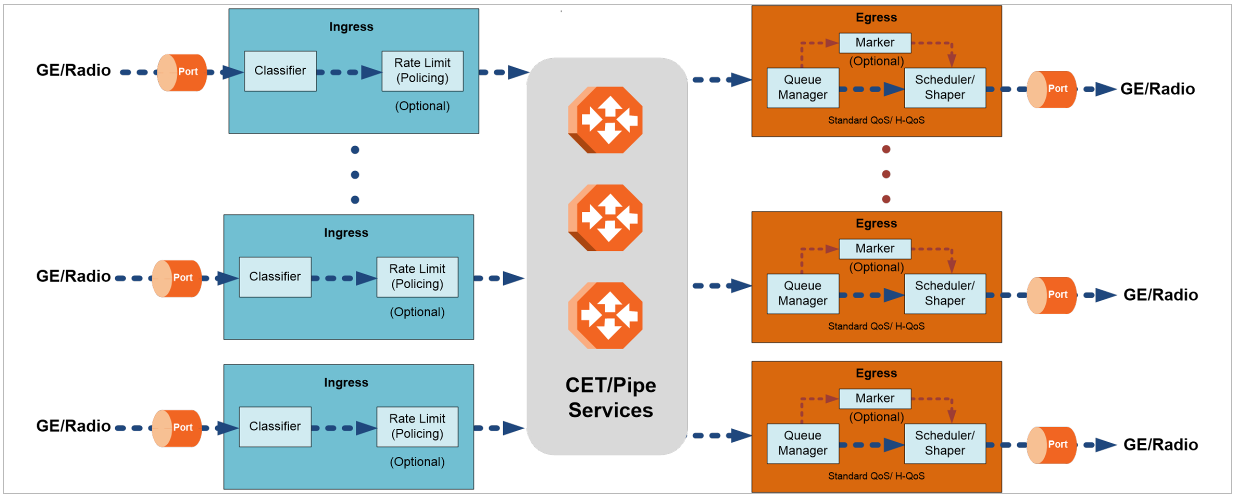
Quality of Service (QoS) deals with the way frames are handled within the switching fabric. QoS is required in order to deal with many different network scenarios, such as traffic congestion, packet availability, and delay restrictions.

PTP 850C's personalized QoS enables operators to handle a wide and diverse range of scenarios. PTP 850C's smart QoS mechanism operates from the frame's ingress into the switching fabric until the moment the frame egresses via the destination port.

QoS capability is very important due to the diverse topologies that exist in today's network scenarios. These can include, for example, streams from two different ports that egress via single port, or a port-to-port connection that holds hundreds of services. In each topology, a customized approach to handling QoS will provide the best results.

The figure below shows the basic flow of PTP 850C's QoS mechanism. Traffic ingresses (left to right) via the Ethernet or radio interfaces, on the "ingress path." Based on the services model, the system determines how to route the traffic. Traffic is then directed to the most appropriate output queue via the "egress path."

Figure 83: *QoS Block Diagram*



The ingress path consists of the following QoS building blocks:

- **Ingress Classifier** – A hierarchical mechanism that deals with ingress traffic on three different levels: interface, service point, and service. The classifier determines the exact traffic stream and associates it with the appropriate service. It also calculates an ingress frame CoS and Color. CoS and Color classification can be performed on three levels, according to the user's configuration.
- **Ingress Rate Metering** – A hierarchical mechanism that deals with ingress traffic on three different levels: interface, service point, and service point CoS. The rate metering mechanism enables the system to measure the incoming frame rate on different levels using a TrTCM standard MEF rate meter, and to determine whether to modify the color calculated during the classification stage.

The egress path consists of the following QoS building blocks:

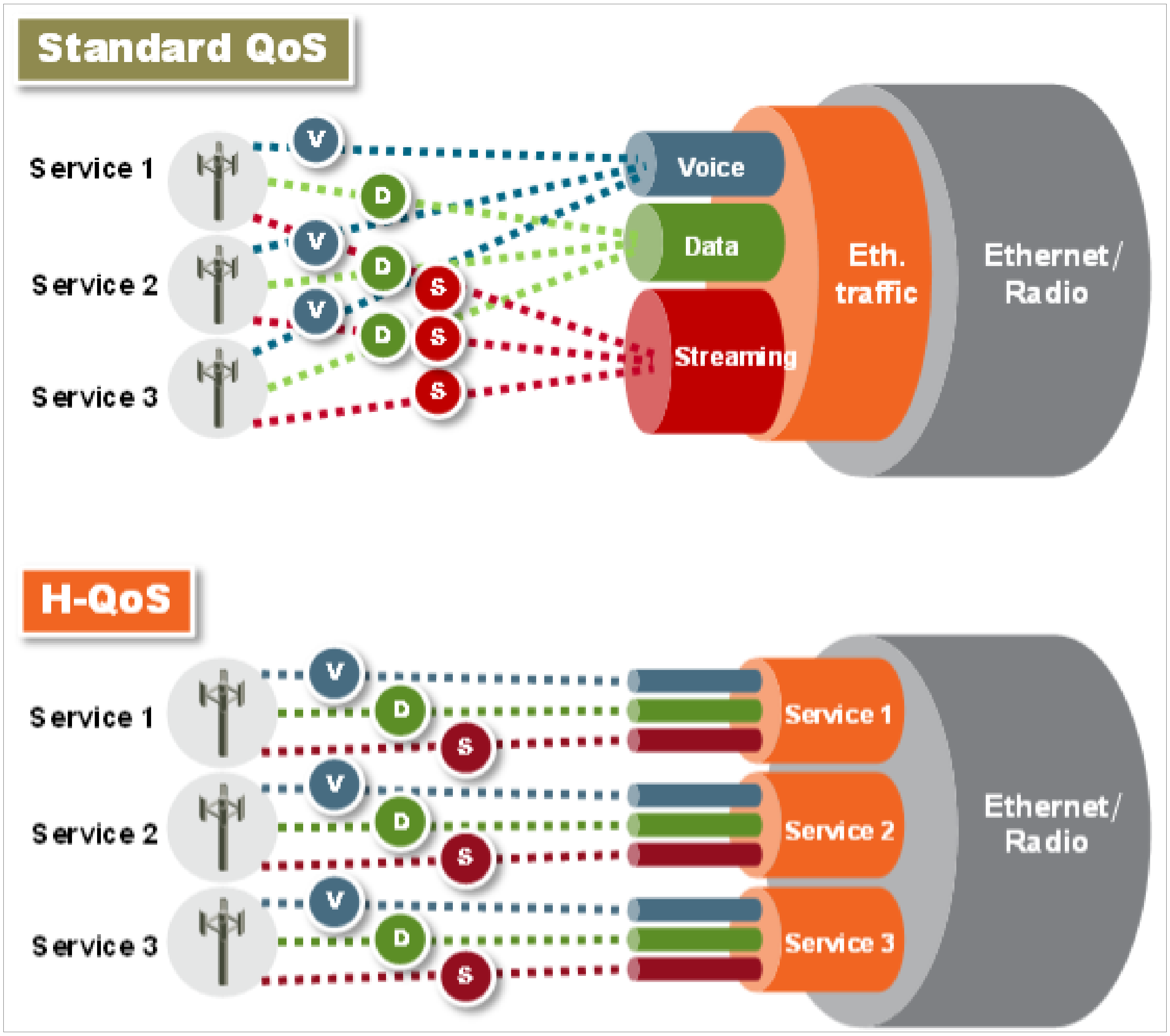
- **Queue Manager** – This is the mechanism responsible for managing the transmission queues, utilizing smart WRED per queue and per packet color (Green or Yellow).
- **Scheduling and Shaping** – A hierarchical mechanism that is responsible for scheduling the transmission of frames from the transmission queues, based on priority among queues, Weighted Fair Queuing (WFQ) in bytes per each transmission queue, and eligibility to transmit based on required shaping on several different levels (per queue, per service bundle, and per port).
- **Marker** – This mechanism provides the ability to modify priority bits in frames based on the calculated CoS and Color.

The following two modes of operation are available on the egress path:

- **Standard QoS** – This mode provides eight transmission queues per port.
- **Hierarchical QoS (H-QoS)** – In this mode, users can associate services from the service model to configurable groups of eight transmission queues (service bundles). In H-QoS mode, PTP 850C performs QoS in a hierarchical manner in which the egress path is managed on three levels: logical interfaces, service bundles, and specific queues. This enables users to fully distinguish between streams, therefore providing a true SLA to customers.

The following figure illustrates the difference between how standard QoS and H-QoS handle traffic:

Figure 84: *Standard QoS and H-QoS Comparison*



QoS on the Ingress Path

Classification

PTP 850C supports a hierarchical classification mechanism. The classification mechanism examines incoming frames and determines their CoS and Color. The benefit of hierarchical classification is that it provides the ability to “zoom in” or “zoom out”, enabling classification at higher or lower levels of the hierarchy. The nature of each traffic stream defines which level of the hierarchical classifier to apply, or whether to use several levels of the classification hierarchy in parallel.

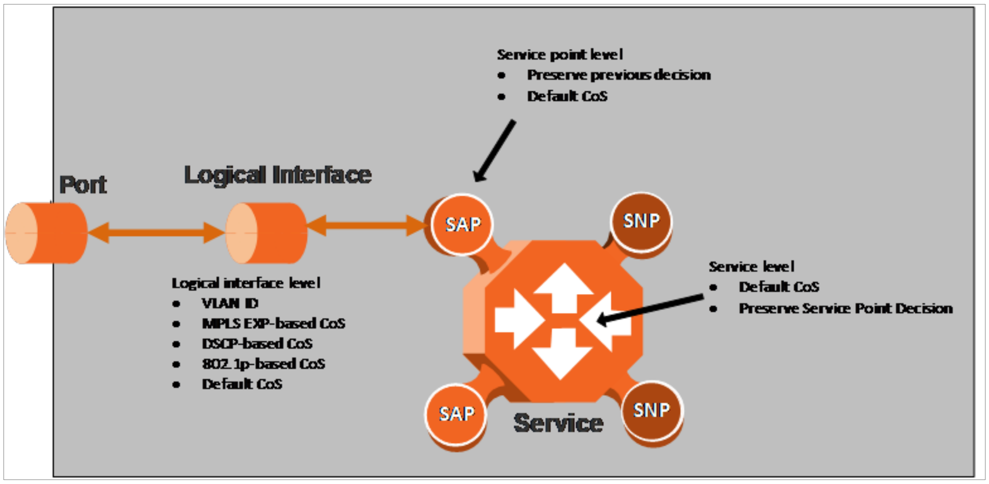
The hierarchical classifier consists of the following levels:

- Logical interface-level classification
- Service point-level classification

- Service level classification

The following figure illustrates the hierarchical classification model. In this figure, traffic enters the system via the port depicted on the left and enters the service via the SAP depicted on the upper left of the service. The classification can take place at the logical interface level, the service point level, and/or the service level.

Figure 85: *Hierarchical Classification*



Logical Interface-Level Classification

Logical interface-level classification enables users to configure classification on a single interface or on a number of interfaces grouped tougher, such as a LAG group.

The classifier at the logical interface level supports the following classification methods, listed from highest to lowest priority. A higher level classification method supersedes a lower level classification method:

- VLAN ID
- MPLS EXP field.
- DSCP bits (only considered if MPLS is not present, regardless of trust setting)
- 802.1p bits
- Default CoS

PTP 850C performs the classification on each frame ingressing the system via the logical interface. Classification is performed step by step from the highest priority to the lowest priority classification method. Once a match is found, the classifier determines the CoS and Color decision for the frame for the logical interface-level.

Users can disable some of these classification methods by configuring them as un-trusted. For example, if MPLS classification is configured as un-trusted for a specific interface, the classification mechanism does not perform classification according to the MPLS EXP bits. This is useful, for example, if the required classification is based on 802.1p bits.

If no match is found at the logical interface level, the default CoS is applied to incoming frames at this level. In this case, the Color of the frame is assumed to be Green.

Interface-level classification is configured as part of the logical interface configuration. For details, refer to Ingress Path Classification at Logical Interface Level.

The following tables show the default values for logical interface-level classification. The key values for these tables are the priority bits of the respective frame encapsulation layers (VLAN, IP, and MPLS), while the key results are the CoS and Colors calculated for incoming frames. These results are user-configurable, but it is recommended that only advanced users should modify the default values.

Table 12 *MPLS EXP Default Mapping to CoS and Color*

MPLS EXP bits	CoS (configurable)	Color (configurable)
0	0	Yellow
1	1	Green
2	2	Yellow
3	3	Green
4	4	Yellow
5	5	Green
6	6	Green
7	7	Green

Figure 86: *DSCP Default Mapping to CoS and Color*

DSCP	DSCP (bin)	Description	CoS (Configurable)	Color (Configurable)
0 (default)	000000	BE (CS0)	0	Green
10	001010	AF11	1	Green
12	001100	AF12	1	Yellow
14	001110	AF13	1	Yellow
18	010010	AF21	2	Green
20	010100	AF22	2	Yellow
22	010110	AF23	2	Yellow
26	011010	AF31	3	Green
28	011100	AF32	3	Yellow
30	011110	AF33	3	Yellow
34	100010	AF41	4	Green
36	100100	AF42	4	Yellow
38	100110	AF43	4	Yellow

DSCP	DSCP (bin)	Description	CoS (Configurable)	Color (Configurable)
46	101110	EF	7	Green
8	001000	CS1	1	Green
16	010000	CS2	2	Green
24	011000	CS3	3	Green
32	100000	CS4	4	Green
40	101000	CS5	5	Green
48	110000	CS6	6	Green
51	110011	DSCP_51	6	Green
52	110100	DSCP_52	6	Green
54	110110	DSCP_54	6	Green
56	111000	CS7	7	Green

Default value is CoS equal best effort and Color equal Green.

Figure 87: *C-VLAN 802.1 UP and CFI Default Mapping to CoS and Color*

802.1 UP	CFI	CoS (configurable)	Color (configurable)
0	0	0	Green
0	1	0	Yellow
1	0	1	Green
1	1	1	Yellow
2	0	2	Green
2	1	2	Yellow
3	0	3	Green
3	1	3	Yellow
4	0	4	Green
4	1	4	Yellow
5	0	5	Green
5	1	5	Yellow
6	0	6	Green
6	1	6	Yellow
7	0	7	Green

802.1 UP	CFI	CoS (configurable)	Color (configurable)
7	1	7	Yellow

Figure 88: *S-VLAN 802.1 UP and DEI Default Mapping to CoS and Color*

802.1 UP	DEI	CoS (Configurable)	Color (Configurable)
0	0	0	Green
0	1	0	Yellow
1	0	1	Green
1	1	1	Yellow
2	0	2	Green
2	1	2	Yellow
3	0	3	Green
3	1	3	Yellow
4	0	4	Green
4	1	4	Yellow
5	0	5	Green
5	1	5	Yellow
6	0	6	Green
6	1	6	Yellow
7	0	7	Green
7	1	7	Yellow

Service Point-Level Classification

Classification at the service point level enables users to give special treatment, in higher resolution, to specific traffic flows using a single interface to which the service point is attached. The following classification modes are supported at the service point level. Users can configure these modes by means of the service point CoS mode.

- Preserve previous CoS decision (logical interface level)
- Default service point CoS

If the service point CoS mode is configured to preserve previous CoS decision, the CoS and Color are taken from the classification decision at the logical interface level. If the service point CoS mode is configured to default service point CoS mode, the CoS is taken from the service point's default CoS, and the Color is Green.

Service-Level Classification

Classification at the service level enables users to provide special treatment to an entire service. For example, the user might decide that all frames in a management service should be assigned a specific CoS regardless of the ingress port. The following classification modes are supported at the service level:

- Preserve previous CoS decision (service point level)
- Default CoS

If the service CoS mode is configured to preserve previous CoS decision, frames passing through the service are given the CoS and Color that was assigned at the service point level. If the service CoS mode is configured to default CoS mode, the CoS is taken from the service's default CoS, and the Color is Green.

Rate Meter (Policing)

PTP 850C's TrTCM rate meter mechanism complies with MEF 10.2, and is based on a dual leaky bucket mechanism. The TrTCM rate meter can change a frame's CoS settings based on CIR/EIR+CBS/EBS, which makes the rate meter mechanism a key tool for implementing bandwidth profiles and enabling operators to meet strict SLA requirements.

The PTP 850C hierarchical rate metering mechanism is part of the QoS performed on the ingress path, and consists of the following levels:

- Logical interface-level rate meter
- Service point-level rate meter
- Service point CoS-level rate meter

MEF 10.2 is the de-facto standard for SLA definitions, and PTP 850C's QoS implementation provides the granularity necessary to implement service-oriented solutions.

Hierarchical rate metering enables users to define rate meter policing for incoming traffic at any resolution point, from the interface level to the service point level, and even at the level of a specific CoS within a specific service point. This option enables users to customize a set of eight policers for a variety of traffic flows within a single service point in a service.

Another important function of rate metering is to protect resources in the network element from malicious users sending traffic at an unexpectedly high rate. To prevent this, the rate meter can cut off traffic from a user that passes the expected ingress rate.

TrTCM rate meters use a leaky bucket mechanism to determine whether frames are marked Green, Yellow, or Red. Frames within the Committed Information Rate (CIR) or Committed Burst Size (CBS) are marked Green. Frames within the Excess Information Rate (EIR) or Excess Burst Size (EBS) are marked Yellow. Frames that do not fall within the CIR/CBS+EIR/EBS are marked Red and dropped, without being sent any further.

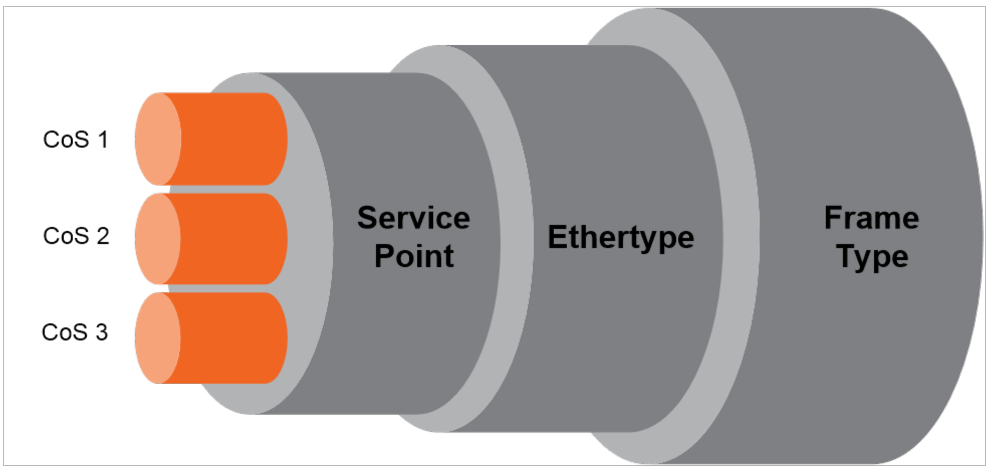
PTP 850C provides up to 1024 user-defined TrTCM rate meters. The rate meters implement a bandwidth profile, based on CIR/EIR, CBS/EBS, Color Mode (CM), and Coupling flag (CF). Up to 250 different profiles can be configured.

Ingress rate meters operate at three levels:

- Logical Interface:
  - Per frame type (unicast, multicast, and broadcast)
  - Per frame ethertype
- Per Service Point
- Per Service Point CoS

> **Note**:
>
> Ingress rate meters can be configure per service point or per service point CoS, but not on both.

Figure 89: *Ingress Policing Model*



Users can attach and activate a rate meter profile at the logical interface level, and on a service point or service point + CoS level. Users must create the profile first, then attach it to the interface, service point, or service point + CoS.

Global Rate Meter Profiles

Users can define up to 250 rate meter user profiles. The following parameters can be defined for each profile:

- **Committed Information Rate (CIR)** – Frames within the defined CIR are marked Green and passed through the QoS module. Frames that exceed the CIR rate are marked Yellow. The CIR defines the average rate in bits/s of Service Frames up to which the network delivers service frames and meets the performance objectives. Permitted values are 0 to 10 Gbps, with a minimum granularity of 32Kbps.
- **Committed Burst Size (CBS)** – Frames within the defined CBS are marked Green and passed through the QoS module. This limits the maximum number of bytes available for a burst of service frames in order to ensure that traffic conforms to the CIR. Permitted values are 0 to 4096 Kbytes, with a minimum granularity of 2 Kbytes.
- **Excess Information Rate (EIR)** – Frames within the defined EIR are marked Yellow and processed according to network availability. Frames beyond the combined CIR and EIR are marked Red and dropped by the policer. Permitted values are 0 to 10 Gbps, with a minimum granularity of 32 Kbps.

- **Excess Burst Size (EBS)** – Frames within the defined EBS are marked Yellow and processed according to network availability. Frames beyond the combined CBS and EBS are marked Red and dropped by the policer. Permitted values are 0 to 4096 Kbytes, with a minimum granularity of 2 Kbytes.

> **Note**:
>
> EIR and EBS are only relevant for rate meters assigned to logical interfaces.

- **Color Mode** – Color mode can be enabled (Color aware) or disabled (Color blind). In Color aware mode, all frames that ingress with a CFI/DEI field set to 1 (Yellow) are treated as EIR frames, even if credits remain in the CIR bucket. In Color blind mode, all ingress frames are treated first as Green frames regardless of CFI/DEI value, then as Yellow frames (when there is no credit in the Green bucket). A Color-blind policer discards any previous Color decisions.
- **Coupling Flag** – If the coupling flag between the Green and Yellow buckets is enabled, then if the Green bucket reaches the maximum CBS value the remaining credits are sent to the Yellow bucket up to the maximum value of the Yellow bucket.

The following parameter is neither a profile parameter, nor specifically a rate meter parameter, but rather, is a logical interface parameter. For more information about logical interfaces, refer to Logical Interfaces.

- **Line Compensation** – A rate meter can measure CIR and EIR at Layer 1 or Layer 2 rates. Layer 1 capacity is equal to Layer 2 capacity plus 20 additional bytes for each frame due to the preamble and Inter Frame Gap (IFG). In most cases, the preamble and IFG equals 20 bytes, but other values are also possible. Line compensation defines the number of bytes to be added to each frame for purposes of CIR and EIR calculation. When Line Compensation is 20, the rate meter operates as Layer 1. When Line Compensation is 0, the rate meter operates as Layer 2. This parameter is very important to users that want to distinguish between Layer 1 and Layer 2 traffic. For example, 1 Gbps of traffic at Layer 1 is equal to ~760 Mbps if the frame size is 64 bytes, but ~986 Mbps if the frame size is 1500 bytes. This demonstrates that counting at Layer 2 is not always fair in comparison to counting at Layer 1, that is, the physical level.

Ingress Statistics

Users can display the following statistics counters for ingress frames and bytes per interface and per service point:

- Green Frames (64 bits)
- Green Bytes (64 bits)
- Yellow Frames (64 bits)
- Yellow Bytes (64 bits)
- Red Frames (64 bits)
- Red Bytes (64 bits)

Service point statistics can be displayed for the service point in general or for specific CoS queues on the service point.

QoS on the Egress Path

Queue Manager

The queue manager (QM) is responsible for managing the output transmission queues. PTP 850C supports up to 64 transmission queues per interface (with H-QoS) , with configurable buffer size. Users can specify the buffer size of each queue independently. The total amount of memory dedicated to the queue buffers is 2 Gigabits.

The following considerations should be taken into account in determining the proper buffer size:

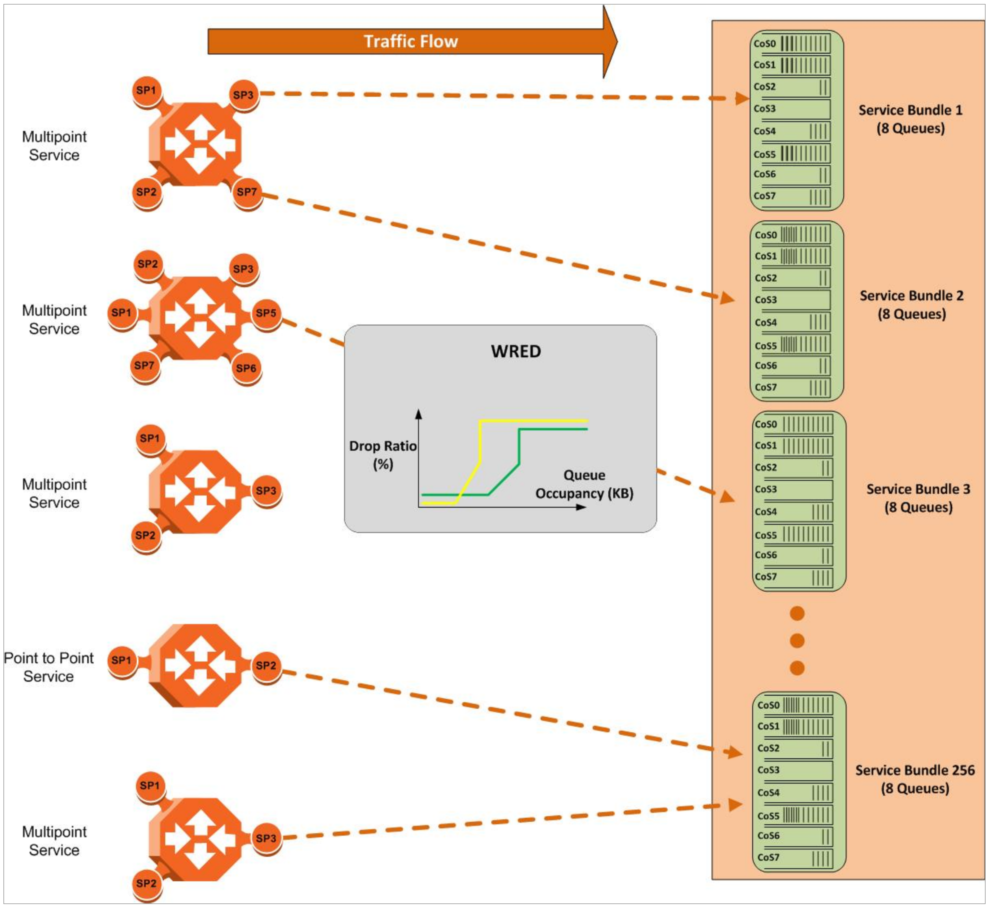
- **Latency considerations** – If low latency is required (users would rather drop frames in the queue than increase latency) small buffer sizes are preferable.
- **Throughput immunity to fast bursts** – When traffic is characterized by fast bursts, it is recommended to increase the buffer sizes to prevent packet loss. Of course, this comes at the cost of a possible increase in latency.

Users can configure burst size as a tradeoff between latency and immunity to bursts, according the application requirements.

The queues are ordered in groups of eight queues. These eight queues correspond to CoS values, from 0 to 7; in other words, eight priority queues.

The following figure depicts the queue manager. Physically, the queue manager is located between the ingress path and the egress path.

Figure 90: *PTP 850C Queue Manager*



In the figure above, traffic is passing from left to right. The traffic passing from the ingress path is routed to the correct egress destination interfaces via the egress service points. As part of the assignment of the service points to the interfaces, users define the group of eight queues through which traffic is to be transmitted out of the service point. This is part of the service point egress configuration.

After the traffic is tunneled from the ingress service points to the egress service points, it is aggregated into one of the eight queues associated with the specific service point. The exact queue is determined by the CoS calculated by the ingress path. For example, if the calculated CoS is 6, the traffic is sent to queue 6, and so on.

Before assigning traffic to the appropriate queue, the system makes a determination whether to forward or drop the traffic using a WRED algorithm with a predefined green and yellow curve for the desired queue. This operation is integrated with the queue occupancy level.

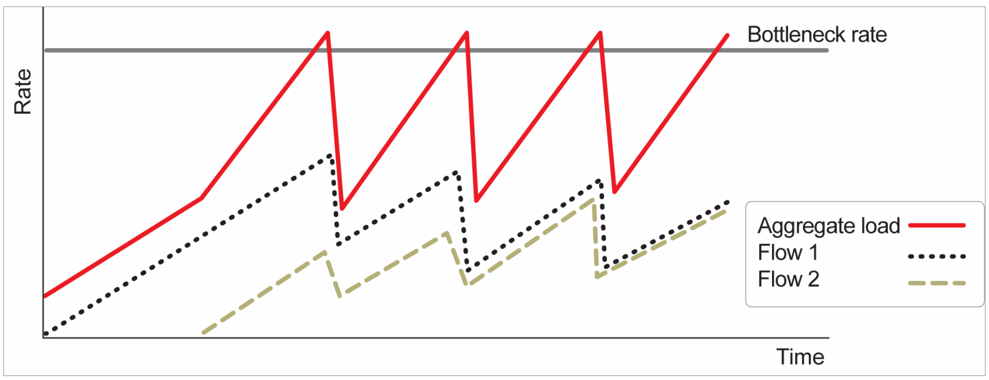
The queues share a single memory of 2 Gbits. PTP 850C enables users to define a specific size for each queue which is different from the default size. Moreover, users can create an over-subscription scenario among the queues for when the buffer size of the aggregate queues is lower than the total memory allocated to all the queues. In doing this, the user must understand both the benefits and the potential hazards, namely, that if a lack of buffer space occurs, the queue manager will drop incoming frames without applying the usual priority rules among frames.

The queue size is defined by the WRED profile that is associated with the queue. For more details, refer to WRED on page WRED.

WRED

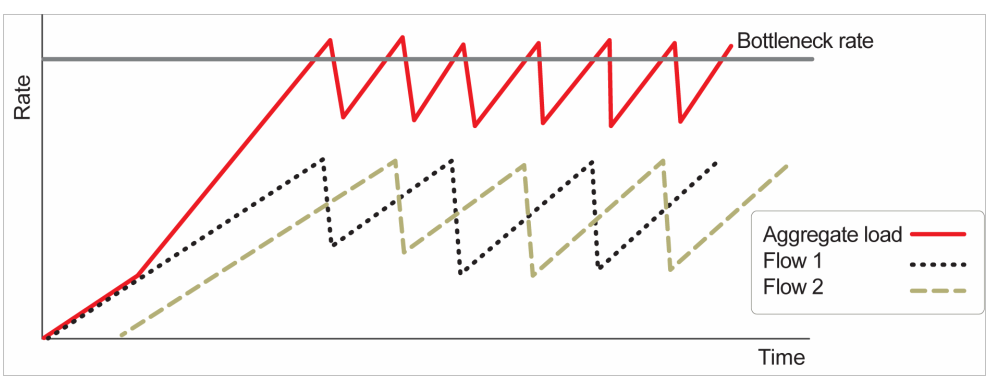
The Weighted Random Early Detection (WRED) mechanism can increase capacity utilization of TCP traffic by eliminating the phenomenon of global synchronization. Global synchronization occurs when TCP flows sharing bottleneck conditions receive loss indications at around the same time. This can result in periods during which link bandwidth utilization drops significantly as a consequence of simultaneous falling to a “slow start” of all the TCP flows. The following figure demonstrates the behavior of two TCP flows over time without WRED.

Figure 91: *Synchronized Packet Loss*



WRED eliminates the occurrence of traffic congestion peaks by restraining the transmission rate of the TCP flows. Each queue occupancy level is monitored by the WRED mechanism and randomly selected frames are dropped before the queue becomes overcrowded. Each TCP flow recognizes a frame loss and restrains its transmission rate (basically by reducing the window size). Since the frames are dropped randomly, statistically each time another flow has to restrain its transmission rate as a result of frame loss (before the real congestion occurs). In this way, the overall aggregated load on the radio link remains stable while the transmission rate of each individual flow continues to fluctuate similarly. The following figure demonstrates the transmission rate of two TCP flows and the aggregated load over time when WRED is enabled.

Figure 92: *Random Packet Loss with Increased Capacity Utilization Using WRED*



When queue occupancy goes up, this means that the ingress path rate (the TCP stream that is ingressing the switch) is higher than the egress path rate. This difference in rates should be fixed in order to reduce packet drops and to reach the maximal media utilization, since PTP 850C will not egress packets to the media at a rate which is higher than the media is able to transmit.

To deal with this, PTP 850C enables users to define up to 30 WRED profiles. Each profile contains a Green traffic curve and a Yellow traffic curve. These curves describe the probability of randomly dropping frames as a function of queue occupancy. In addition, using different curves for Yellow packets and Green packets enables users to enforce the rule that Yellow packets be dropped before Green packets when there is congestion.

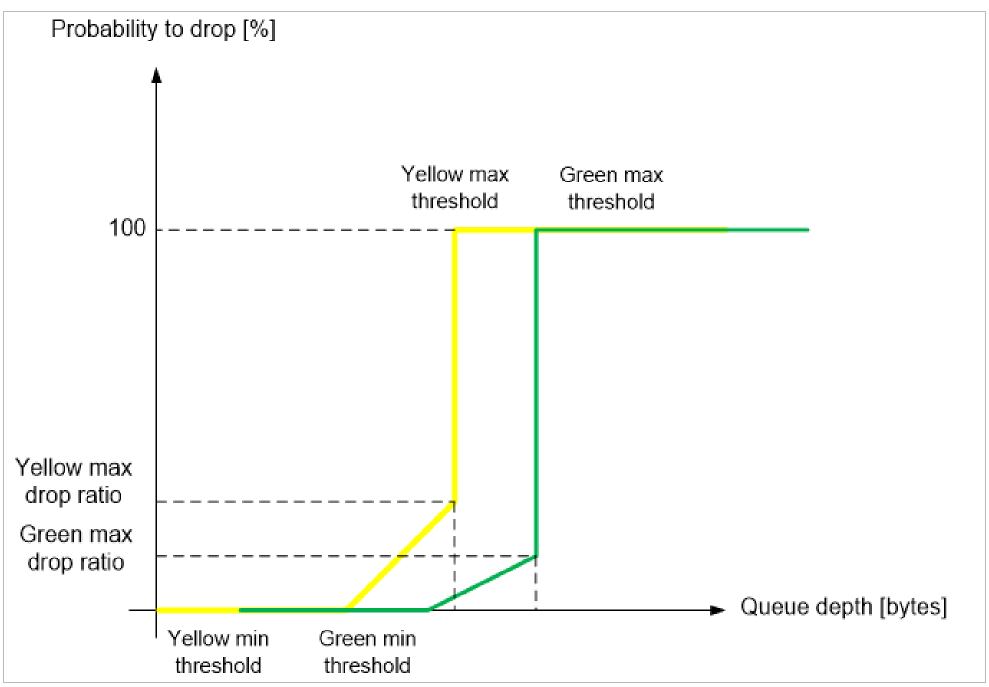
PTP 850C also includes two pre-defined read-only WRED profiles:

- Profile number 31 defines a tail-drop curve and is configured with the following values:
  - 100% Yellow traffic drop after 64kbytes occupancy.
  - 100% Green traffic drop after 128kbytes occupancy.
  - Yellow maximum drop is 100%
  - Green maximum drop is 100%
- Profile number 32 defines a profile in which all will be dropped. It is for internal use and should not be applied to traffic.

A WRED profile can be assigned to each queue. The WRED profile assigned to the queue determines whether or not to drop incoming packets according to the occupancy of the queue. Basically, as queue occupancy grows, the probability of dropping each incoming frame increases as well. As a consequence, statistically more TCP flows will be restrained before traffic congestion occurs.

The following figure provides an example of a WRED profile.

Figure 93: *WRED Profile Curve*



> **Note**:
>
> The tail-drop profile, Profile 31, is the default profile for each queue. A tail drop curve is useful for reducing the effective queue size, such as when low latency must be guaranteed.

Global WRED Profile Configuration

PTP 850C supports 30 user-configurable WRED profiles and one pre-defined (default) profile. The following are the WRED profile attributes:

- **Green Minimum Threshold** – Permitted values are 24 Kbytes to 8 Mbytes, with granularity of 8 Kbytes.
- **Green Maximum Threshold** – Permitted values are 24 Kbytes to 8 Mbytes, with granularity of 8 Kbytes.
- **Green-Maximum Drop** – Permitted values are 1% to 100%, with 1% drop granularity.
- **Yellow Minimum Threshold** – Permitted values are 24 Kbytes to 8 Mbytes, with granularity of 8 Kbytes.
- **Yellow Maximum Threshold** – Permitted values are 24 Kbytes to 8 Mbytes, with granularity of 8 Kbytes.
- **Yellow Maximum Drop** – Permitted values are 1% to 100%, with 1% drop granularity.

> **Note**:
>
> K is equal to 1024.

Users can enter any value within the permitted range. Based on the value entered by the user, the software automatically rounds off the setting according to the granularity. If the user enters a value below the lowest granular value (except 0), the software adjusts the setting to the minimum.

For each curve, frames are passed on and not dropped up to the minimum Green and Yellow thresholds. From this point, WRED performs a pseudo-random drop with a ratio based on the curve up to the maximum Green and Yellow thresholds. Beyond this point, 100% of frames with the applicable Color are dropped.

The system automatically assigns the default “tail drop” WRED profile (Profile ID 31) to every queue. Users can change the WRED profile per queue based on the application served by the queue.

Standard QoS and Hierarchical QoS (H-QoS)

In a standard QoS mechanism, egress data is mapped to a single service bundle on the egress interface. This single service bundle supports up to eight priority queues, which correspond to the CoS of the data. Since all traffic for the interface egresses via these queues, there is no way to distinguish between different services and traffic streams within the same priority.

Figure 84 shows three services, each with three distinct types of traffic streams:

- Voice – high priority
- Data – medium priority
- Streaming – lower priority

While the benefits of QoS on the egress path can be applied to the aggregate streams, without H-QoS they will not be able to distinguish between the various services included in these aggregate streams.

Moreover, different behavior among the different traffic streams that constitute the aggregate stream can cause unpredictable behavior between the streams. For example, in a situation in which one traffic stream can transmit 50 Mbps in a shaped manner while another can transmit 50 Mbits in a burst, frames may be dropped in an unexpected way due to a lack of space in the queue resulting from a long burst.

Hierarchical QoS (H-QoS) solves this problem by enabling users to create a real egress tunnel for each stream, or for a group of streams that are bundled together. This enables the system to fully perform H-QoS with a top-down resolution, and to fully control the required SLA for each stream.

H-QoS Hierarchy

The egress path hierarchy is based on the following levels:

- Queue level
- Service bundle level
- Logical interface level

The queue level represents the physical priority queues. Each eight queues are bundled and represent eight CoS priority levels. One or more service points can be attached to a specific bundle, and the traffic from the service point to one of the eight queues is based on the CoS that was calculated on the ingress path.

> **Note**:
>
> With standard QoS, all services are assigned to a single default service bundle.

The service bundle level represents the groups of eight priority queues. Every eight queues are managed as a single service bundle.

The interface level represents the physical port through which traffic from the specified service point egresses.

The following summarizes the egress path hierarchy:

- One service bundle per interface in standard QoS / 8 service bundles per interface in H-QoS.
- Eight queues per service bundle

H-QoS on the Interface Level

Users can assign a single leaky bucket shaper to each interface. The shaper on the interface level stops traffic from the interface if a specific user-defined peak information rate (PIR) has been exceeded.

For both H-QoS and standard QoS, users can configure scheduling rules for the priority queues, as follows:

- Scheduling (serve) priorities among the eight priority queues.
- Weighted Fair Queuing (WFQ) among queues with the same priority.

> **Note**:
>
> The system assigns the rules for all service bundles under the interface.

RMON counters are valid on the interface level.

H-QoS on the Service Bundle Level

Users can assign a dual leaky bucket shaper to each service bundle. On the service bundle level, the shaper changes the scheduling priority if traffic via the service bundle is above the user-defined CIR and below the PIR. If traffic is above the PIR, the scheduler stops transmission for the service bundle.

Service bundle traffic counters are valid on this level.

Note:

With standard QoS, users assign the egress traffic to a single service bundle (Service Bundle ID 1).

H-QoS on the Queue Level

The egress service point points to a specific service bundle. Depending on the user application, the user can connect either a single service point or multiple service points to a service bundle. Usually, if multiple service points are connected to a service bundle, the service points will share the same traffic type and characteristics. Mapping to the eight priority queues is based on the CoS calculated on the ingress path, before any marking operation, which only changes the egress CoS and Color.

Users can assign a dual leaky bucket to each queue. The shaper on the queue level stops traffic from leaving the queue if a specific user-defined PIR or CIR has been exceeded.

Traffic counters are valid on this level.

H- QoS Mode

As discussed above, users can select whether to work in Standard QoS mode or H-QoS mode. H-QoS is enabled and disabled on the logical interface level. For an interface on which H-QoS is enabled, users can configure the egress service points to transmit traffic via multiple service bundles. This enables users to fully distinguish among the streams and to achieve SLA per service.

Shaping on the Egress Path

Egress shaping determines the traffic profile for each queue. PTP 850C performs dual leaky bucket egress shaping on the queue level.

Queue Shapers

Users can configure up to 31 dual leaky bucket shaper profiles. Frames within the Committed Information Rate (CIR) or Committed Burst Size (CBS) are marked Green. Frames within the Excess Information Rate (EIR) or Excess Burst Size (EBS) are marked Yellow. Frames that do not fall within the CIR/CBS+EIR/EBS are marked Red and dropped, without being sent any further.

The CIR value can be set to the following values:

- 0 - 40 Gbps – granularity of 81 Kbps

The CBS value can be set to the following values:

- 1-63 KB. The default value is 16 KB.

The EIR value can be set to the following values:

- 0 - 40 Gbps – granularity of 81 Kbps

The CBS value can be set to the following values:

- 1-63 KB. The default value is 16 KB.

> **Note**:
>
> Users can enter any values within the permitted range. Based on the value entered by the user, the software automatically rounds off the setting according to the granularity. If the user enters a value below the lowest granular value (except 0), the software adjusts the setting to the minimum.

Users can attach one of the configured queue shaper profiles to each priority queue. If no profile is attached to the queue, no egress shaping is performed on that queue.

Service Bundle Shapers

Users can configure up to 255 dual leaky bucket shaper profiles. The profiles can be configured as follows:

- Valid CIR values are:
  - 0 - 40 Gbps – granularity of 81 Kbps
- Valid PIR values are:
  - 0 - 40 Gbps – granularity of 81 Kbps

> **Note**:
>
> Users can enter any value within the permitted range. Based on the value entered by the user, the software automatically rounds off the setting according to the granularity. If the user enters a value below the lowest granular value (except 0), the software adjusts the setting to the minimum.

Users can attach one of the configured service bundle shaper profiles to each service bundle. If no profile is attached to the service bundle, no egress shaping is performed on that service bundle.

Line Compensation for Shaping

Users can configure a line compensation value for all the shapers under a specific logical interface. For more information, refer to Global Rate Meter Profiles.

Egress Scheduling

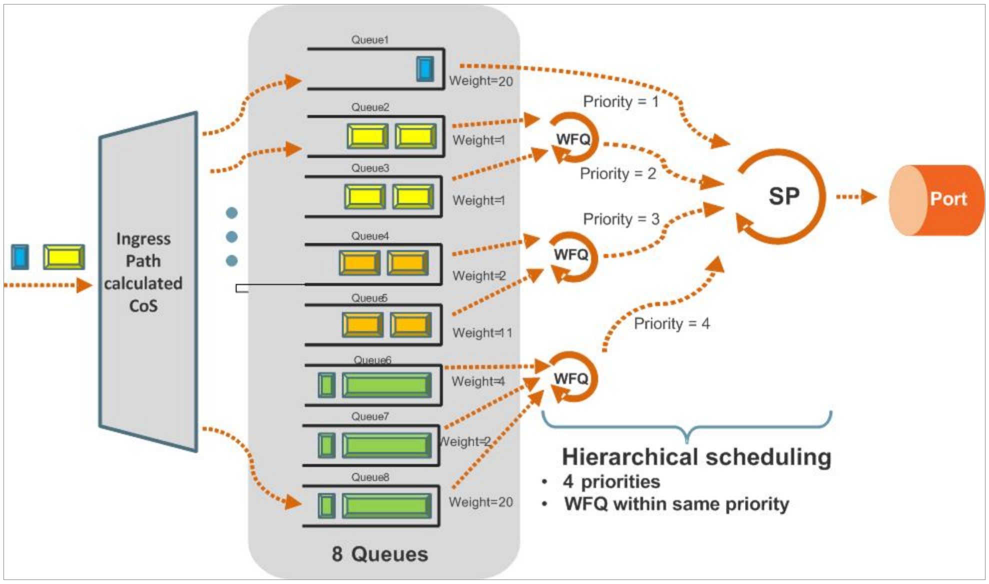
Egress scheduling is responsible for transmission from the priority queues. PTP 850C uses a unique algorithm with a hierarchical scheduling model over the three levels of the egress path that enables compliance with SLA requirements.

The scheduler scans all the queues, per interface, and determines which queue is ready to transmit. If more than one queue is ready to transmit, the scheduler determines which queue transmits first based on:

- **Queue Priority** – A queue with higher priority is served before lower-priority queues.
- **Weighted Fair Queuing (WFQ) –** If two or more queues have the same priority and are ready to transmit, the scheduler transmits frames from the queues based on a WFQ algorithm that determines the ratio of frames per queue based on a predefined weight assigned to each queue.

The following figure shows the scheduling mechanism for a single service bundle (equivalent to Standard QoS). When a user assigns traffic to more than single service bundle (H-QoS mode), multiple instances of this model (up to 32 per port) are valid.

Figure 94: *Scheduling Mechanism for a Single Service Bundle*



Interface Priority

The profile defines the exact order for serving the eight priority queues in a single service bundle.

The priority mechanism distinguishes between two states of the service bundle:

- Green State – Committed state
- Yellow state – Best effort state

Green State refers to any time when the *service bundle total rate* is below the user-defined CIR. Yellow State refers to any time when the *service bundle total rate* is above the user-defined CIR but below the PIR.

User can define up to four Green priority profiles, from 4 (highest) to 1 (lowest). An additional four Yellow priority profiles are defined automatically.

The following table provides a sample of an interface priority profile. This profile is also used as the default interface priority profile.

Table 13 *QoS Priority Profile Example*

Profile ID (1-9)			
CoS	**Green Priority (user defined)**	**Yellow Priority (read only)**	**Description**
CoS	Green Priority (user defined)	Yellow Priority (read only)	Description
0	1	1	Best Effort
1	2	2	Data Service 4

Profile ID (1-9)			
CoS	**Green Priority (user defined)**	**Yellow Priority (read only)**	**Description**
2	2	2	Data Service 3
3	2	2	Data Service 2
4	2	2	Data Service 1
5	3	3	Real Time 2 (Video with large buffer)
6	3	3	Real Time 1 (Video with small buffer)
7	4	4	Management (Sync, PDUs, etc.)

When the service bundle state is Green (committed state), the service bundle priorities are as defined in the Green Priority column. When the service bundle state is Yellow (best effort state), the service bundle priorities are system-defined priorities shown in the Yellow Priority column.

Note:

CoS 7 is always marked with the highest priority, no matter what the service bundle state is, since it is assumed that only high priority traffic will be tunneled via CoS 7.

The system supports up to nine interface priority profiles. Profiles 1 to 8 are defined by the user, while profile 9 is the pre-defined read-only default interface priority profile.

The following interface priority profile parameters can be configured by users:

- **Profile ID** – Profile ID number. Permitted values are 1 to 8.
- **CoS 0 Priority** – CoS 0 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 0 Description** – CoS 0 user description field, up to 20 characters.
- **CoS 1 Priority** – CoS 1 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 1 Description** – CoS 1 user description field, up to 20 characters.
- **CoS 2 Priority** – CoS 2 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 2 Description** – CoS 2 user description field, up to 20 characters.
- **CoS 3 Priority** – CoS 3 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 3 Description** – CoS 3 user description field, up to 20 characters.
- **CoS 4 Priority** – CoS 4 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 4 Description** – CoS 4 user description field, up to 20 characters.
- **CoS 5 Priority** – CoS 5 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 5 Description** – CoS 5 user description field, up to 20 characters.
- **CoS 6 Priority** – CoS 6 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 6 Description** – CoS 6 user description field, up to 20 characters.

- **CoS 7 Priority** – CoS 7 queue priority, from 4 (highest) to 1 (lowest).
- **CoS 7 Description** – CoS 7 user description field, up to 20 characters.

Users can attach one of the configured interface priority profiles to each interface. By default, the interface is assigned Profile ID 9, the pre-defined system profile.

Weighted Fair Queuing (WFQ)

As described above, the scheduler serves the queues based on their priority, but when two or more queues have data to transmit and their priority is the same, the scheduler uses Weighted Fair Queuing (WFQ) to determine the weight within each priority. WFQ defines the transmission ratio between the queues.

The system supports up to six WFQ profiles. Profile ID 1 is a pre-defined read-only profile, and is used as the default profile. Profiles 2 to 6 are user-defined profiles.

The following table provides an example of a WFQ profile.

Table 14 *WFQ Profile Example*

Profile ID (1-7)		
CoS	**CIR Queue Weight**	**EIR Queue Weight**
0	20	20
1	20	20
2	20	20
3	20	20
4	20	20
5	20	20
6	20	20
7	20	20

For each CoS, the user can define;

- **Profile ID** – Profile ID number. Permitted values are 2 to 6.
- **CIR Weight** – Transmission quota for CIR traffic. Permitted values are 1 to 20.
- **EIR Weight** – Transmission quota for EIR traffic. Permitted values are 1 to 20.

Users can attach one of the configured WFQ profiles to each interface. By default, the interface is assigned Profile ID 1, the pre-defined system profile.

Egress PMs and Statistics

Queue-Level Statistics

PTP 850C supports the following counters per queue at the queue level:

- Transmitted Green Packet (64 bits counter)
- Transmitted Green Bytes (64 bits counter)
- Transmitted Green Bits per Second (32 bits counter)
- Dropped Green Packets (64 bits counter)
- Dropped Green Bytes (64 bits counter)
- Transmitted Yellow Packets (64 bits counter)
- Transmitted Yellow Bytes (64 bits counter)
- Transmitted Yellow Bits per Second (32 bits counter)
- Dropped Yellow Packets (64 bits counter)
- Dropped Yellow Bytes (64 bits counter)
- Service Bundle-Level Statistics

PTP 850C supports the following counters per service bundle at the service bundle level:

- Transmitted Green Packets (64 bits counter)
- Transmitted Green Bytes (64 bits counter)
- Transmitted Green Bits per Second (32 bits counter)
- Dropped Green Packets (64 bits counter)
- Dropped Green Bytes (64 bits counter)
- Transmitted Yellow Packets (64 bits counter)
- Transmitted Yellow Bytes (64 bits counter)
- Transmitted Yellow Bits per Second (32 bits counter)
- Dropped Yellow Packets (64 bits counter)
- Dropped Yellow Bytes (64 bits counter)
- Advanced Queue and Service Bundle-Level PMs

For each logical interface, users can configure thresholds for Green and Yellow traffic per queue. Users can then display the following PMs for 15-minute and 24-hour intervals, per queue and color:

- Maximum bytes passed per second
- Minimum bytes passed per second
- Average bytes passed per second
- Maximum bytes dropped per second
- Minimum bytes dropped per second
- Average bytes dropped per second
- Maximum packets passed per second
- Minimum packets passed per second

- Average packets passed per second
- Maximum packets dropped per second
- Minimum packets dropped per second
- Average packets dropped per second
- Seconds bytes per second were over the configured threshold per interval

Interface-Level Statistics

For information on statistics at the interface level, refer to Ethernet Statistics.

Marker

Marking refers to the ability to overwrite the outgoing priority bits and Color of the outer VLAN of the egress frame. Marking mode is only applied if the outer frame is S-VLAN and S-VLAN CoS preservation is disabled, or if the outer frame is C-VLAN and C-VLAN CoS preservation is disabled. If outer VLAN preservation is enabled for the relevant outer VLAN, the egress CoS and Color are the same as the CoS and Color of the frame when it ingressed into the switching fabric.

Marking is performed according to a global table that maps CoS and Color values to the 802.1p-UP bits and the DEI or CFI bits. If Marking is enabled on a service point, the CoS and Color of frames egressing the service via that service point are overwritten according to this global mapping table.

If marking and CoS preservation for the relevant outer VLAN are both disabled, marking is applied according to the Green frame values in the global marking table.

When marking is performed, the following global tables are used by the marker to decide which CoS and Color to use as the egress CoS and Color bits.

Table 15 *802.1q UP Marking Table (C-VLAN)*

CoS	Color	802.1q UP (Configurable)	CFI Color (Configurable)
0	Green	0	0
0	Yellow	0	1
1	Green	1	0
1	Yellow	1	1
2	Green	2	0
2	Yellow	2	1
3	Green	3	0
3	Yellow	3	1
4	Green	4	0
4	Yellow	4	1
5	Green	5	0
5	Yellow	5	1

CoS	Color	802.1q UP (Configurable)	CFI Color (Configurable)
6	Green	6	0
6	Yellow	6	1
7	Green	7	0
7	Yellow	7	1

Table 16 *802.1ad UP Marking Table (S-VLAN)*

CoS	Color	802.1ad UP (configurable)	DEI Color (configurable)
0	Green	0	0
0	Yellow	0	1
1	Green	1	0
1	Yellow	1	1
2	Green	2	0
2	Yellow	2	1
3	Green	3	0
3	Yellow	3	1
4	Green	4	0
4	Yellow	4	1
5	Green	5	0
5	Yellow	5	1
6	Green	6	0
6	Yellow	6	1
7	Green	7	0
7	Yellow	7	1

The keys for these tables are the CoS and Color. The results are the 802.1q/802.1ad UP and CFI/DEI bits, which are user-configurable. It is strongly recommended that the default values not be changed except by advanced users.

Standard QoS and Hierarchical QoS (H-QoS) Summary

The following table summarizes and compares the capabilities of standard QoS and H-QoS.

Table 17 *Summary and Comparison of Standard QoS and H-QoS*

Capability	Standard QoS	Hierarchical QoS
Number of transmission queues per port	8	64
Number of service bundles	1 (always service bundle id equal 1)	8
WRED	Per queue (two curves – for green traffic and for yellow traffic via the queue)	Per queue (two curves – for green traffic and for yellow traffic via the queue)
Shaping at queue level	Single leaky bucket	Dual leaky bucket
Shaping at service bundle level	None	Dual leaky bucket
Shaping at port level	Single leaky bucket	Single leaky bucket
Transmission queues priority	Per queue priority (4 priorities).	Per queue priority (4 priorities). All service bundles for a specific port inherit the 8-queues priority settings.
Weighted fair Queue (WFQ)	Queue level (between queues)	Queue level (between queues) Service Bundle level (between service bundles)
Marker	Supported	Supported
Statistics	Queue level (8 queues) Service bundle level (1 service bundle) Port level	Queue level (64 queues) Service bundle level (8 service bundles) Port level

Global Switch Configuration

The following parameters are configured globally for the PTP 850C switch:

- **S- VLAN Ethertype** –Defines the ethertype recognized by the system as the S-VLAN ethertype. PTP 850C supports the following S-VLAN ethertypes:
  - 0x8100
  - 0x88A8 (default)

- 0x9100
- 0x9200

- **C-VLAN Ethertype** – Defines the ethertype recognized by the system as the C-VLAN ethertype. PTP 850C supports 0x8100 as the C-VLAN ethertype.
- **MRU** – The maximum segment size defines the maximum receive unit (MRU) capability and the maximum transmit capability (MTU) of the system. Users can configure a global MRU for the system. Permitted values are 64 bytes to 9612 bytes.

Automatic State Propagation and Link Loss Forwarding

Related topics:

- Network Resiliency
- Unit Redundancy
- Link Aggregation Groups (LAG) and LACP

Automatic State Propagation (ASP) enables propagation of radio failures back to the Ethernet port. You can also configure ASP to close the Ethernet port based on a radio failure at the remote carrier. ASP improves the recovery performance of resiliency protocols.

Note:

It is recommended to configure both ends of the link to the same ASP configuration.

Automatic State Propagation Operation

Automatic state propagation is configured as pairs of interfaces. Each interface pair includes one Monitored Interface and one Controlled Interface. Multiple pairs can be configured using the same Monitored Interface and multiple Controlled Interfaces.

The Monitored Interface is a radio interface. The Controlled Interface is an Ethernet interface or LAG. An Ethernet interface can only be assigned to one Monitored interface.

Each Controlled Interface is assigned an LLF ID. If ASP trigger by remote fault is enabled on the remote side of the link, the ASP state of the Controlled Interface is propagated to the Controlled Interface with the same LLF ID at the remote side of the link. This means if ASP is triggered locally, it is propagated to the remote side of the link, but only to Controlled Interfaces with LLF IDs that match the LLF IDs of the affected Controlled Interfaces on the local side of the link.

The following events in the Monitored Interface trigger ASP:

- Radio LOF
- Radio Excessive BER
- Remote Radio LOF
- Remote Excessive BER
- Remote LOC

The user can also configure the ASP pair so that Radio LOF, Radio Excessive BER, or loss of the Ethernet connection at the remote side of the link will also trigger ASP.

When a triggering event takes place:

- If the Controlled Interface is an electrical GbE port, the port is closed.
- If the Controlled Interface is an optical GbE port, the port is muted.

The Controlled Interface remains closed or muted until all triggering events are cleared.

In addition, when a local triggering event takes place, the ASP mechanism sends an indication to the remote side of the link. Even when no triggering event has taken place, the ASP mechanism sends periodic update messages indicating that no triggering event has taken place.

Users can configure a trigger delay time, so that when a triggering event takes place, the ASP mechanism does not propagate the event until this delay time has elapsed.

Automatic State Propagation and Protection

When the Controlled Interface is part of a 1+1 protection pair, such as a 1+1 HSB protection configuration, a port shutdown message is only sent to the remote side of the link if both of the protected interfaces are shut down.

Note:

HSB protection is planned for future release.

In a 1+1 HSB configuration using Multi-Unit LAG mode, in which two Ethernet interfaces on each unit belong to a static LAG, an ASP triggering event only shuts down the external user port.

When the Monitored interface is part of a 1+1 HSB configuration, ASP is only triggered if both interfaces fail.

Closing an Ethernet port because of ASP does not trigger a protection switchover.

Preventing Loss of In-Band Management

If the link uses in-band management, shutting down the Ethernet port can cause loss of management access to the unit. To prevent this, users can configure ASP to operate in Client Signal Failure (CSF) mode. In CSF mode, the ASP mechanism does not physically shut down the Controlled Interface when ASP is triggered. Instead, the ASP mechanism sends a failure indication message (a CSF message). The CSF message is used to propagate the failure indication to external equipment.

CSF mode is particularly useful when the PTP 850C unit is an element in the following network topologies:

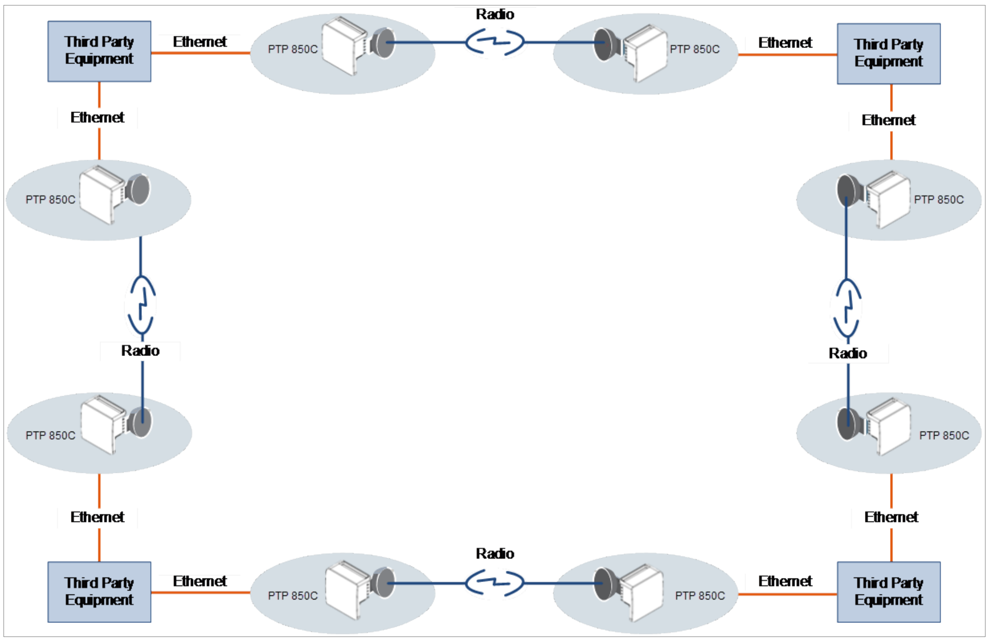
- Ring or mesh network topology.
- An PTP 820N connected to an PTP 850C unit being utilized as a pipe via an Ethernet interface (back-to-back on the same site).
- Payload traffic is spanned by G.8032 in the network.
- In-band management is spanned by MSTP in the network.

- An PTP 850C unit being utilized as a pipe is running one MSTP instance for spanning in-band management.

Adaptive Bandwidth Notification (EOAM)

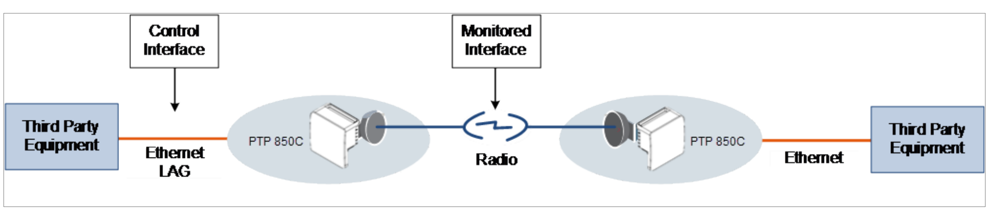
Adaptive Bandwidth Notification (ABN, also known as EOAM) enables third party applications to learn about bandwidth changes in a radio link when ACM is active. Once ABN is enabled, the radio unit reports bandwidth information to third-party switches.

Figure 95: *Network Topology with PTP 850C Units and Third-Party Equipment*



The ABN entity creates a logical relationship between a radio interface, called the Monitored Interface, and an Ethernet interface or a logical group of Ethernet interfaces, called the Control Interface. When bandwidth degrades from the nominal bandwidth value in the Monitored Interface, messages relaying the actual bandwidth values are periodically sent over the Control Interface. A termination message is sent once the bandwidth returns to its nominal level.

Figure 96: *ABN Entity*



The nominal bandwidth is calculated by the system based on the maximum bandwidth profile. The ABN entity measures the bandwidth in samples once a change in profile takes place. A weighted average is calculated based on the samples at regular, user-defined intervals to determine whether a bandwidth degradation event has occurred. Bandwidth degradation is reported only if the measured bandwidth remains below the nominal bandwidth at the end of a user-defined holdoff period. This prevents the PTP 850C from reporting bandwidth degradation due to short fading events.

Network Resiliency

PTP 850C provides carrier-grade service resiliency using the following protocols:

- G.8032 Ethernet Ring Protection Switching (ERPS)
- Multiple Spanning Tree Protocol (MSTP)

These protocols are designed to prevent loops in ring/mesh topologies.

G.8032 Ethernet Ring Protection Switching (ERPS)

ERPS, as defined in the G.8032 ITU standard, is currently the most advanced ring protection protocol, providing convergence times of sub-50ms. ERPS prevents loops in an Ethernet ring by guaranteeing that at any time, traffic can flow on all except one link in the ring. This link is called the Ring Protection Link (RPL). Under normal conditions, the RPL is blocked, i.e., not used for traffic. One designated Ethernet Ring Node, the RPL Owner Node, is responsible for blocking traffic at one end of the RPL. When an Ethernet ring failure occurs, the RPL Owner unblocks its end of the RPL, allowing the RPL to be used for traffic. The other Ethernet Ring Node adjacent to the RPL, the RPL Neighbor Node, may also participate in blocking or unblocking its end of the RPL. A number of ERP instances (ERPIs) can be created on the same ring.

G.8032 ERPS Benefits

ERPS, as the most advanced ring protection protocol, provides the following benefits:

- Provides sub-50ms convergence times.
- Provides service-based granularity for load balancing, based on the ability to configure multiple ERPIs on a single physical ring.
- Provides configurable timers to control switching and convergence parameters per ERPI.

G.8032 ERPS Operation

The ring protection mechanism utilizes an APS protocol to implement the protection switching actions. Forced and manual protection switches can also be initiated by the user, provided the user-initiated switch has a higher priority than any other local or far-end request.

Ring protection switching is based on the detection of defects in the transport entity of each link in the ring. For purposes of the protection switching process, each transport entity within the protected domain has a state of either Signal Fail (SF) or Non-Failed (OK). R-APS control messages are forwarded by each node in the ring to update the other nodes about the status of the links.

Note:

An additional state, Signal Degrade (SD), is planned for future release. The SD state is similar to SF, but with lower priority.

Users can configure up to 16 ERPIs. Each ERPI is associated with an Ethernet service defined in the system. This enables operators to define a specific set of G.8032 characteristics for individual services or groups of services within the same physical ring. This includes a set of timers that enables operators to optimize protection switching behavior per ERPI:

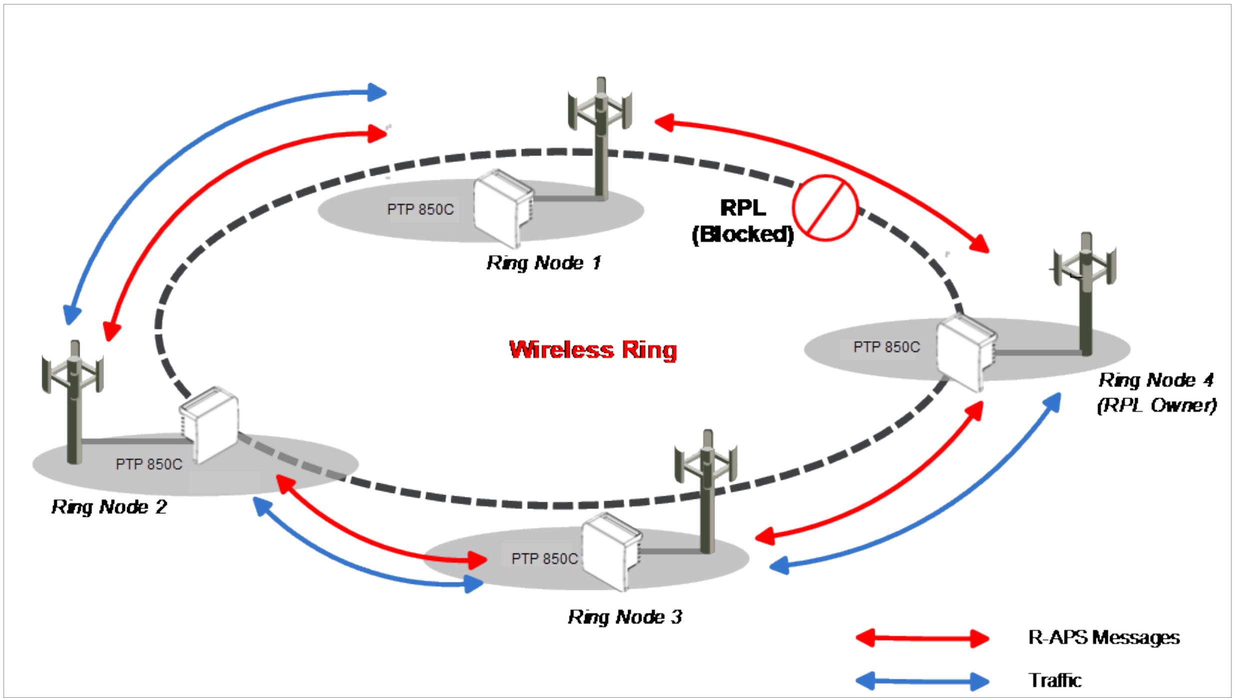
- **Wait to Restore (WTR) Timer** – Defines a minimum time the system waits after signal failure is recovered before reverting to idle state.
- **Guard Time** – Prevents unnecessary state changes and loops.
- **Hold-off Time** – Determines the time period from failure detection to response.

Each ERPI maintains a state machine that defines the node's state for purposes of switching and convergence. The state is determined according to events that occur in the ring, such as signal failure and forced or manual switch requests, and their priority. Possible states are:

- Idle
- Protecting
- Forced Switch (FS)
- Manual Switch (MS)
- Pending

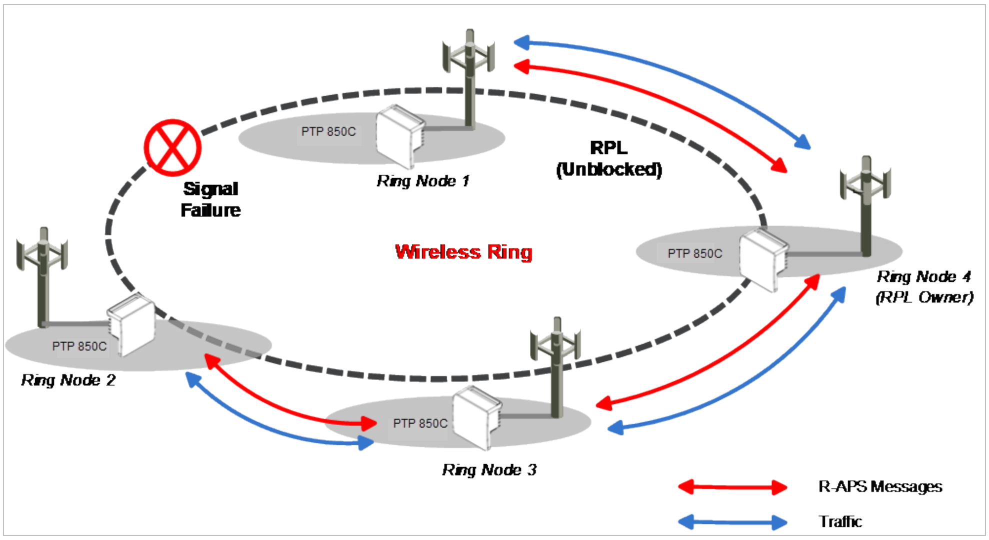
As shown in the following figure, in idle (normal) state, R-APS messages pass through all links in the ring, while the RPL is blocked for traffic. The RPL can be on either edge of the ring. R-APS messages are sent every five seconds.

Figure 97: *G.8032 Ring in Idle (Normal) State*



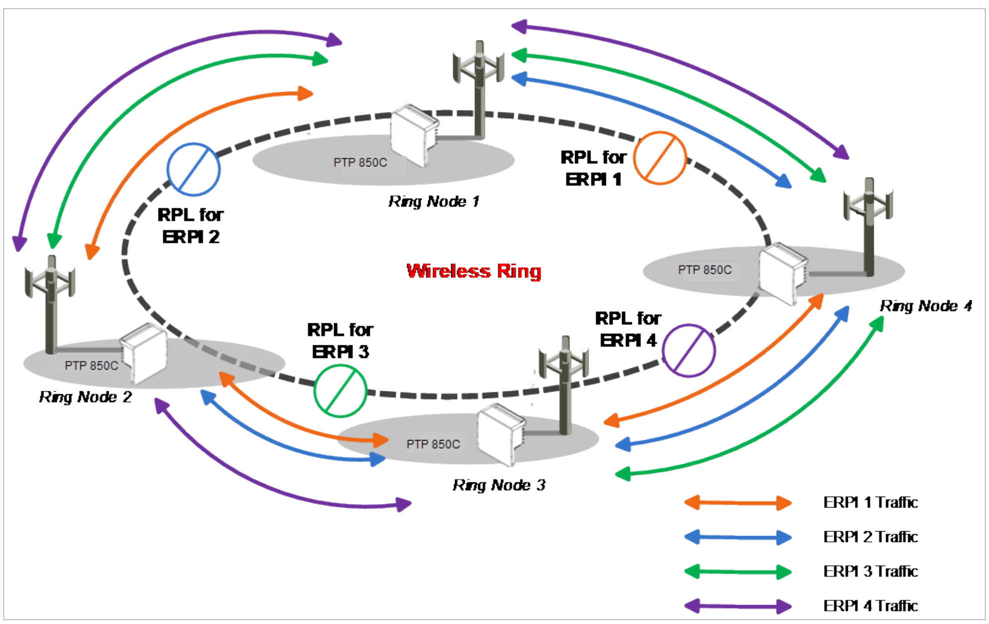
Once a signal failure is detected, the RPL is unblocked for each ERPI. As shown in the following figure, the ring switches to protecting state. The nodes that detect the failure send periodic SF messages to alert the other nodes in the link of the failure and initiate the protecting state.

Figure 98: *G.8032 Ring in Protecting State*



The ability to define multiple ERPIs and assign them to different Ethernet services or groups of services enables operators to perform load balancing by configuring a different RPL for each ERPI. The following figure illustrates a ring in which four ERPIs each carry services with 33% capacity in idle state, since each link is designated the RPL, and is therefore idle, for a different ERPI.

Figure 99: *Load Balancing Example in G.8032 Ring*



Multiple Spanning Tree Protocol (MSTP)

MSTP, as defined in IEEE 802.1q, provides full connectivity for frames assigned to any given VLAN throughout a bridged LAN consisting of arbitrarily interconnected bridges.

With MSTP, an independent multiple spanning tree instance (MSTI) is configured for each group of services, and only one path is made available (unblocked) per spanning tree instance. This prevents network loops and provides load balancing capability. It also enables operators to differentiate among Ethernet services by mapping them to different, specific MSTIs. The maximum number of MSTIs is configurable, from 2 to 16.

MSTP is an extension of, and is backwards compatible with, Rapid Spanning Tree Protocol (RSTP).

PTP 850C supports MSTP according to the following IEEE standards:

- 802.1q
- 802.1ad amendment (Q-in-Q)
- 802.1ah (TE instance)

MSTP Benefits

MSTP significantly improves network resiliency in the following ways:

- Prevents data loops by configuring the active topology for each MSTI such that there is never more than a single route between any two points in the network.
- Provides for fault tolerance by automatically reconfiguring the spanning tree topology whenever there is a bridge failure or breakdown in a data path.
- Automatically reconfigures the spanning tree to accommodate addition of bridges and bridge ports to the network, without the formation of transient data loops.
- Enables frames assigned to different services or service groups to follow different data routes within administratively established regions of the network.
- Provides for predictable and reproducible active topology based on management of the MSTP parameters.
- Operates transparently to the end stations.
- Consumes very little bandwidth to establish and maintain MSTIs, constituting a small percentage of the total available bandwidth which is independent of both the total traffic supported by the network and the total number of bridges or LANs in the network.
- Does not require bridges to be individually configured before being added to the network.

MSTP Operation

MSTP includes the following elements:

- **MST Region** – A set of physically connected bridges that can be portioned into a set of logical topologies.
- **Internal Spanning Tree (IST)** – Every MST Region runs an IST, which is a special spanning tree instance that disseminates STP topology information for all other MSTIs.
- **CIST Root** – The bridge that has the lowest Bridge ID among all the MST Regions.
- **Common Spanning Tree (CST)** – The single spanning tree calculated by STP, RSTP, and MSTP to connect MST Regions. All bridges and LANs are connected into a single CST.

- **Common Internal Spanning Tree (CIST)** – A collection of the ISTs in each MST Region, and the CST that interconnects the MST regions and individual spanning trees. MSTP connects all bridges and LANs with a single CIST.

MSTP specifies:

- An MST Configuration Identifier that enables each bridge to advertise its configuration for allocating frames with given VIDs to any of a number of MSTIs.
- A priority vector that consists of a bridge identifier and path cost information for the CIST.
- An MSTI priority vector for any given MSTI within each MST Region.

Each bridge selects a CIST priority vector for each port based on the priority vectors and MST Configuration Identifiers received from the other bridges and on an incremental path cost associated with each receiving port. The resulting priority vectors are such that in a stable network:

- One bridge is selected to be the CIST Root.
- A minimum cost path to the CIST Root is selected for each bridge.
- The CIST Regional Root is identified as the one root per MST Region whose minimum cost path to the root is not through another bridge using the same MST Configuration Identifier.

Based on priority vector comparisons and calculations performed by each bridge for each MSTI, one bridge is independently selected for each MSTI to be the MSTI Regional Root, and a minimum cost path is defined from each bridge or LAN in each MST Region to the MSTI Regional Root.

The following events trigger MSTP re-convergence:

- Addition or removal of a bridge or port.
- A change in the operational state of a port or group (LAG or protection).
- A change in the service to instance mapping.
- A change in the maximum number of MSTIs.
- A change in an MSTI bridge priority, port priority, or port cost.

> Note:
>
> All except the last of these triggers can cause the entire MSTP to re-converge. The last trigger only affects the modified MSTI.

MSTP Interoperability

MSTP in PTP 850C units is interoperable with:

- IP-10 units running RSTP.
- PTP 820 AND PTP 850 units running MSTP.
- Third-party bridges running MSTP.
- Third-party bridges running RSTP

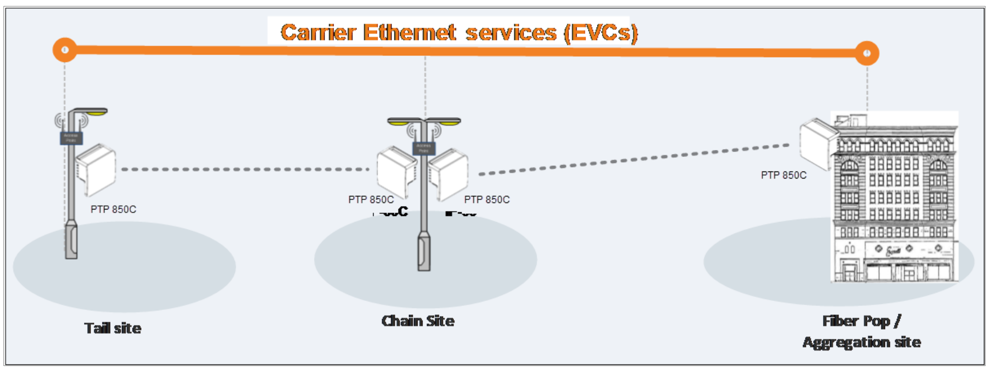
OAM

PTP 850C provides complete Service Operations Administration and Maintenance (SOAM) functionality at multiple layers, including:

- Fault management status and alarms.
- Maintenance signals, such as AIS, and RDI.
- Maintenance commands, such as loopbacks and Linktrace commands.
- Ethernet Bandwidth Notification (ETH-BN)

PTP 850C is fully compliant with 802.1ag, G.8013/Y.1731, MEF-17, MEF-20, MEF-30, and MEF-31.

Figure 100: *PTP 850C End-to-End Service Management*



Connectivity Fault Management (FM)

The IEEE 802.1ag and G.8013/Y.1731 standards and the MEF-17, MEF-20, MEF-30, and MEF-31 specifications define SOAM. SOAM is concerned with detecting, isolating, and reporting connectivity faults spanning networks comprising multiple LANs, including LANs other than IEEE 802.3 media.

IEEE 802.1ag Ethernet FM (Connectivity Fault Management) consists of three protocols that operate together to aid in fault management:

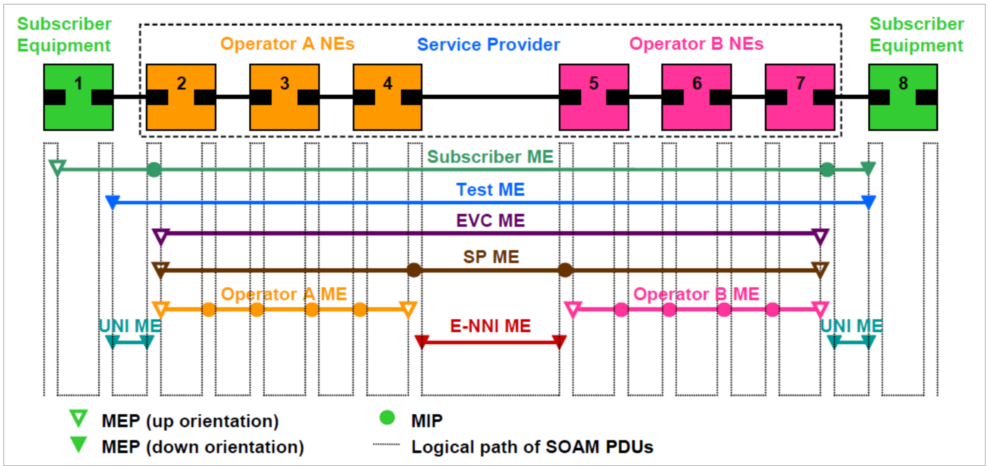
- Continuity check
- Link trace
- Loopback.

PTP 850C utilizes these protocols to maintain smooth system operation and non-stop data flow.

The following are the basic building blocks of FM:

- Maintenance domains, their constituent maintenance points, and the managed objects required to create and administer them.

Figure 101: *SOAM Maintenance Entities (Example)*



- Protocols and procedures used by maintenance points to maintain and diagnose connectivity faults within a maintenance domain.
  - CCM (Continuity Check Message): CCM can detect Connectivity Faults (loss of connectivity or failure in the remote MEP).
  - Loopback: LBM/LBR mechanism is an on-demand mechanism. It is used to verify connectivity from any MEP to any certain Maintenance Point in the MA/MEG. A session of loopback messages can include up to 1024 messages with varying intervals ranging from 1 to 60 seconds. Message size can reach jumbo frame size.
  - Linktrace: The LTM/LTR mechanism is an on-demand mechanism. It can detect the route of the data from any MEP to any other MEP in the MA/MEG. It can be used for the following purposes:
    - Adjacent relation retrieval – The ETH-LT function can be used to retrieve the adjacency relationship between an MEP and a remote MEP or MIP. The result of running ETH-LT function is a sequence of MIPs from the source MEP until the target MIP or MEP.
    - Fault localization – The ETH-LT function can be used for fault localization. When a fault occurs, the sequence of MIPs and/or MEP will probably be different from the expected sequence. The difference between the sequences provides information about the fault location.
    - AIS: AIS (defined in G.8013/Y.1731) is the Ethernet alarm indication signal function used to suppress alarms following detection of defect conditions at the server (sub) layer.

SFP DDM and Inventory Monitoring

PTP 850C supports static and dynamic monitoring for all SFP transceivers, including all SFP and SFP+ transceivers used in Ethernet ports. Dynamic monitoring PMs are also available.

DDM (Digital Diagnostic Monitoring) enables users to display dynamic information about the SFP state, including:

- RX Power (in dBm)
- TX Power (in dBm)

- Bias current (mA)
- Temperature (both Celsius and Fahrenheit)
- Supply Voltage (VCC)

Inventory monitoring enables users to display the following information about each SFP transceiver installed in the PTP 850C unit:

- Connector Type
- Transceiver Type (e.g., 10G BASE-LR)
- Vendor Name
- Vendor Part Number
- Vendor Serial Number
- Vendor Revision
- Wavelength
- Maximum length of link per fiber optic cable type

DDM PMs can be displayed for 15-minute and 24-hour intervals. For each interval, the following PMs are displayed:

- Minimum RX power during the interval (dBm)
- Average RX power during the interval (dBm)
- Maximum RX power during the interval (dBm)
- Minimum TX power during the interval (dBm)
- Average TX power during the interval (dBm)
- Maximum TX power during the interval (dBm)
- Minimum voltage (VCC) received by the SFP transceiver during the interval
- Average voltage (VCC) received by the SFP transceiver during the interval
- Maximum voltage (VCC) received by the SFP transceiver during the interval

Note:

DDM parameters are not relevant for electrical SFPs.

Thresholds for these alarms are programmed into the SFP transceivers by the manufacturer.

Ethernet Bandwidth Notification (ETH-BN)

Ethernet Bandwidth Notification (ETH-BN) is defined by the Y.1731 OAM standard. The purpose of ETH-BN is to inform the L2 or L3 customer switch of the capacity of the radio link in transmit direction. This enables the switch to respond to fluctuations in the radio link by, for example, reconfiguring the shaper on the egress port facing the radio link or rerouting traffic to other egress ports.

Once ETH-BN is enabled, the radio unit reports bandwidth information to upstream third-party switches. The ETH-BN entity creates a logical relationship between a radio interface, called the Monitored Interface, and an Ethernet interface, called the Control Interface. When bandwidth degrades from the nominal value in the Monitored Interface, messages relaying the actual bandwidth values (BNM frames) are periodically sent over the Control Interface. Once the bandwidth returns to its nominal level, BNM messages are no longer sent. Optionally, the device can be configured to send BNM frames even when bandwidth is at its nominal level.

The Monitored Interface can be a single radio interface, a Link Bonding Group, a Multi-Carrier ABC group, a Multiband group, or a radio LAG. To be used as a Monitored Interface, the LAG must consist of radio interfaces only.

The same radio interface can be configured as a Monitored Interface for multiple EBN instances. However, an Ethernet interface can only be configured as a Control Interface for a single EBN instance.

The following limitations:

- If CFM MEPs are being used, the MEL for ETH-BN must be set to a value greater than the MEG level of the MEP. Otherwise, the BNM frames will be dropped. – this is correct.
- If CFM MEPs are not being used, the MEL for ETH-BN must be set to a value greater than 0. Otherwise, the BNM frames will be dropped.

Synchronization

This section describes PTP 850C's flexible synchronization solution that enables operators to configure a combination of synchronization techniques, based on the operator's network and migration strategy, including:

- PTP optimized transport, supporting IEEE 1588 and NTP, with guaranteed ultra-low PDV and support for ACM and narrow channels.
- Native Sync Distribution, for end-to-end distribution using GbE.

This section includes:

- PTP 850C Synchronization Solution
- Available Synchronization Interfaces
- Synchronous Ethernet (SyncE)
- IEEE-1588v2 PTP Optimized Transport
- SSM Support and Loop Prevention

Related topics:

- NTP Support

PTP 850C Synchronization Solution

Cambium's synchronization solution ensures maximum flexibility by enabling the operator to select any combination of techniques suitable for the operator's network and migration strategy.

- PTP optimized transport
  - Supports a variety of protocols, such as IEEE-1588 and NTP
  - Supports IEEE-1588 Transparent Clock
  - Guaranteed ultra-low PDV (<0.015 ms per hop)
  - Unique support for ACM and narrow channels
- SyncE node
- IEEE-1588v2 PTP Optimized Transport
  - Transparent Clock – Resides between master and slave nodes, and measurers and adjusts for delay variation to guarantee ultra-low PDV.
  - Boundary Clock – Regenerates frequency and phase synchronization, providing, increasing the scalability of the synchronization network while rigorously maintaining timing accuracy.

Available Synchronization Interfaces

Frequency signals can be taken by the system from a number of different interfaces (one reference at a time). The reference frequency may also be conveyed to external equipment through different interfaces.

Table 18 *Synchronization Interface Options*

Available interfaces as frequency input (reference sync source)	Available interfaces as frequency output
• Radio carrier • GbE Ethernet interfaces	• Radio carrier • GbE Ethernet interfaces

It is possible to configure up to eight synchronization sources in the system. At any given moment, only one of these sources is active; the clock is taken from the active source onto all other appropriately configured interfaces.

Users can configure a revertive timer for the PTP 850 unit. When the revertive timer is configured, the unit will not switch to another synchronization source unless that source has been stable for at least the number of seconds defined in the revertive timer. This helps to prevent a situation in which numerous switchovers occur when a synchronization source reports a higher quality for a brief time interval, followed by a degradation of the source's quality. By default, the revertive timer is set to 0, which means that it is disabled.

Synchronous Ethernet (SyncE)

SyncE is standardized in ITU-T G.8261 and G.8262, and refers to a method whereby the frequency is delivered on the physical layer.

> **Note**:
>
> SyncE is not supported with electrical SFP transceivers.

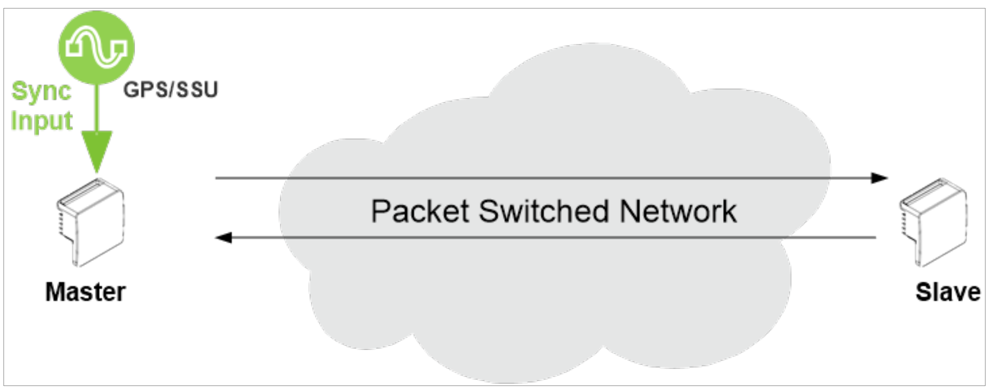
IEEE-1588v2 PTP Optimized Transport

Precision Timing Protocol (PTP) refers to the distribution of frequency and phase, information across a packet-switched network.

PTP 850C supports PTP optimized transport, a message-based protocol that can be implemented across packet-based networks. To ensure minimal packet delay variation (PDV), PTP 850C's synchronization solution includes 1588v2-compliant Transparent Clock. Transparent Clock provides the means to measure and adjust for delay variation, thereby ensuring low PDV.

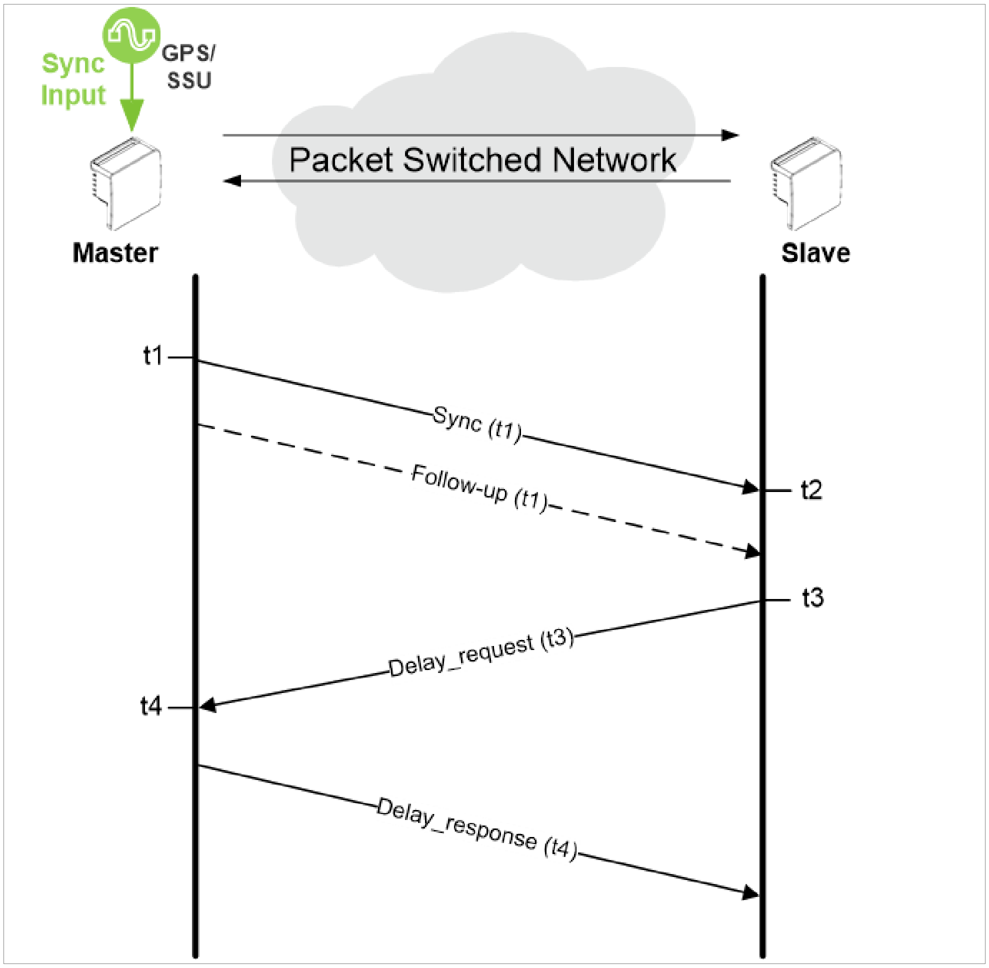
IEEE-1588v2 PTP synchronization is based on a master-slave architecture in which the master and slave exchange PTP packets carrying clock information. The master is connected to a reference clock, and the slave synchronizes itself to the master.

Figure 102: *IEEE-1588v2 PTP Optimized Transport – General Architecture*



Accurate synchronization requires a determination of the propagation delay for PTP packets. Propagation delay is determined by a series of messages between the master and slave.

Figure 103: *Calculating the Propagation Delay for PTP Packets*



In this information exchange:

1. The master sends a Sync message to the slave and notes the time (t1) the message was sent.
2. The slave receives the Sync message and notes the time the message was received (t2).
3. The master conveys the t1 timestamp to the slave, in one of the following ways:
    - One-Step – Embedding the t1 timestamp in the Sync message.
    - Two-Step – Embedding the t1 timestamp in a Follow-up message.
4. The slave sends a Delay_request message to the master and notes the time the message was sent (t3).
5. The master receives the Delay_request message and notes the time the message was received (t4).
6. The master conveys the t4 timestamp to the slave by embedding the t4 timestamp in a Delay_ response message.

Based on this message exchange, the protocol calculates both the clock offset between the master and slave and the propagation delay, based on the following formulas:

Offset = [(t2 – t1) – (t4 – t3)]/2

Propagation Delay = [(t2 – t1) + (t4 – t3)]/2

The calculation is based on the assumption that packet delay is constant and that delays are the same in each direction. For information on the factors that may undermine these assumptions and how PTP 850C's IEEE-1588v2 implementations mitigate these factors, see Mitigating PDV.

IEEE-1588v2 Characteristics

IEEE-1588v2 provides packet-based synchronization that can transmit both frequency accuracy and phase information. This is essential for LTE applications, and adds the ability to transmit phase information to SyncE.

Other IEEE-1588v2 benefits include:

- Nanosecond precession.
- Meets strict 5G requirements for rigorous frequency and phase timing.
- Hardware time stamping of PTP packets.
- Standard protocol compatible with third-party equipment.
- Short frame and higher message rates.
- Supports unicast as well as multicast.
- Enables smooth transition from unsupported networks.
- Mitigates PDV issues by using Transparent Clock and Boundary Clock (see Mitigating PDV).
- Minimal consumption of bandwidth and processing power.
- Simple configuration.

Mitigating PDV

To get the most out of PTP and minimize PDV, PTP 850C supports Transparent Clock and Boundary Clock.

PTP calculates path delay based on the assumption that packet delay is constant and that delays are the same in each direction. Delay variation invalidates this assumption. High PDV in wireless transport for synchronization over packet protocols, such as IEEE-1588, can dramatically affect the quality of the recovered clock. Slow variations are the most harmful, since in most cases it is more difficult for the receiver to average out such variations.

PDV can arise from both packet processing delay variation and radio link delay variation.

Packet processing delay variation can be caused by:

- Queuing Delay – Delay associated with incoming and outgoing packet buffer queuing.
- Head of Line Blocking – Occurs when a high priority frame, such as a frame that contains IEEE-1588 information, is forced to wait until a lower-priority frame that has already started to be transmitted completes its transmission.
- Store and Forward – Used to determine where to send individual packets. Incoming packets are stored in local memory while the MAC address table is searched and the packet's cyclic redundancy field is checked before the packet is sent out on the appropriate port. This process introduces

variations in the time latency of packet forwarding due to packet size, flow control, MAC address table searches, and CRC calculations.

Radio link delay variation is caused by the effect of ACM, which enables dynamic modulation changes to accommodate radio path fading, typically due to weather changes. Lowering modulation reduces link capacity, causing traffic to accumulate in the buffers and producing transmission delay.

Note:

When bandwidth is reduced due to lowering of the ACM modulation point, it is essential that high priority traffic carrying IEEE-1588 packets be given the highest priority using PTP 850C's enhanced QoS mechanism, so that this traffic will not be subject to delays or discards.

These factors can combine to produce a minimum and maximum delay, as follows:

- Minimum frame delay can occur when the link operates at a high modulation and no other frame has started transmission when the IEEE-1588 frame is ready for transmission.
- Maximum frame delay can occur when the link is operating at QPSK modulation and a large (e.g., 1518 bytes) frame has just started transmission when the IEEE-1588 frame is ready for transmission.

The worst case PDV is defined as the greatest difference between the minimum and maximum frame delays. The worst case can occur not just in the radio equipment itself but in every switch across the network.

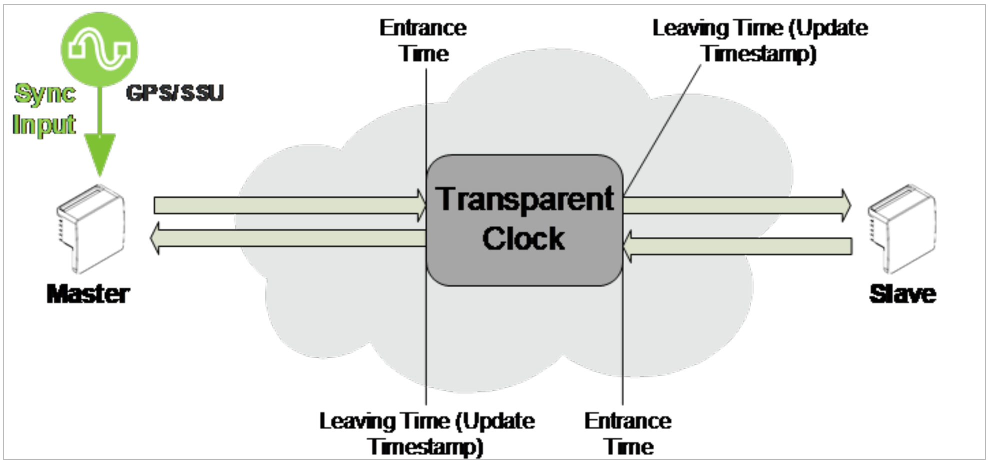
To ensure minimal packet delay variation (PDV), PTP 850C's synchronization solution includes 1588v2-compliant Transparent Clock and Boundary Clock synchronization protocols. The following section describes Transparent Clock and how it counters PDV.

Transparent Clock

PTP 850C supports End-to-End Transparent Clock, which updates the correction field for the delay associated with individual packet transfers. End-to-End Transparent Clock is the most appropriate option for microwave radio links.

A Transparent Clock node resides between a master and a slave node, and updates the packets passing between the master and slave to compensate for delay, enabling the terminating clock in the slave node to remove the delay accrued in the Transparent Clock node. The Transparent Clock node is itself neither a master nor a slave node, but rather, serves as a bridge between master and slave nodes.

Figure 104: *Transparent Clock – General Architecture*

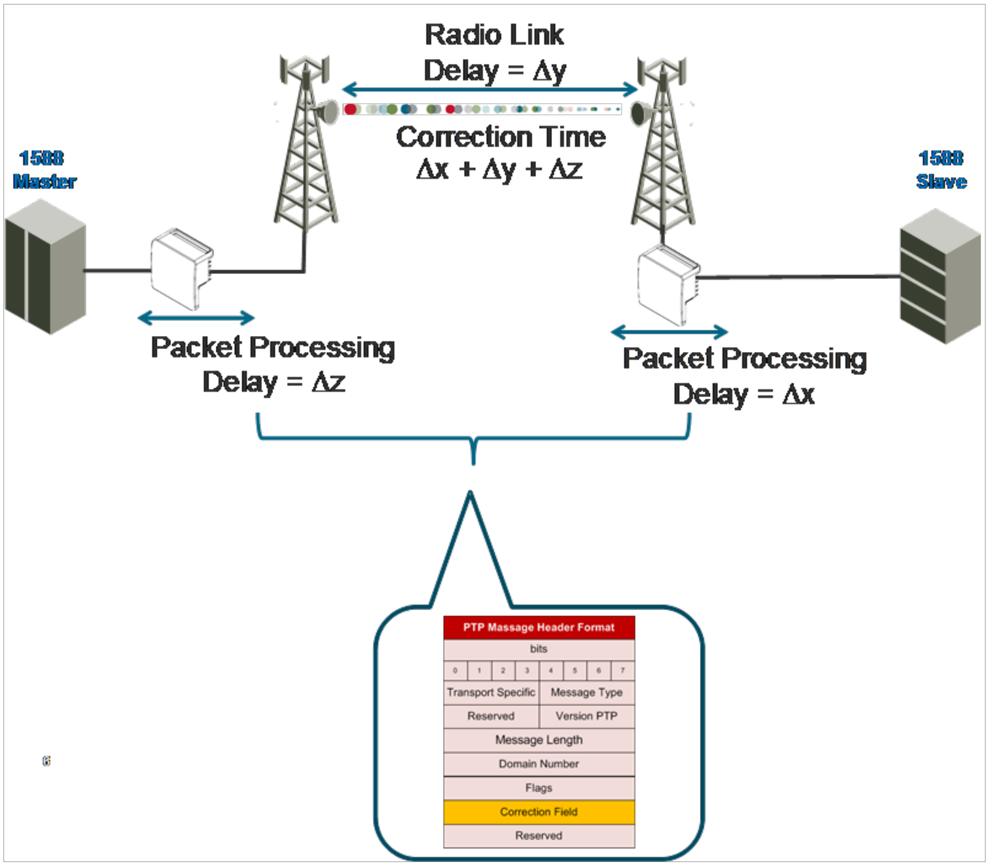


PTP 850C uses 1588v2-compliant Transparent Clock to counter the effects of asymmetrical delay and delay variation. Transparent Clock measures and adjusts for delay variation, enabling the PTP 850C to guarantee ultra-low PDV.

The Transparent Clock algorithm forwards and adjusts the messages to reflect the residency time associated with the Sync and Delay_Request messages as they pass through the device. The delays are inserted in the 64-bit time-interval correction field.

As shown in the figure below, PTP 850C measures and updates PTP messages based on both the radio link delay, and the packet processing delay that results from the network processor (switch operation).

Figure 105: *Transparent Clock Delay Compensation*

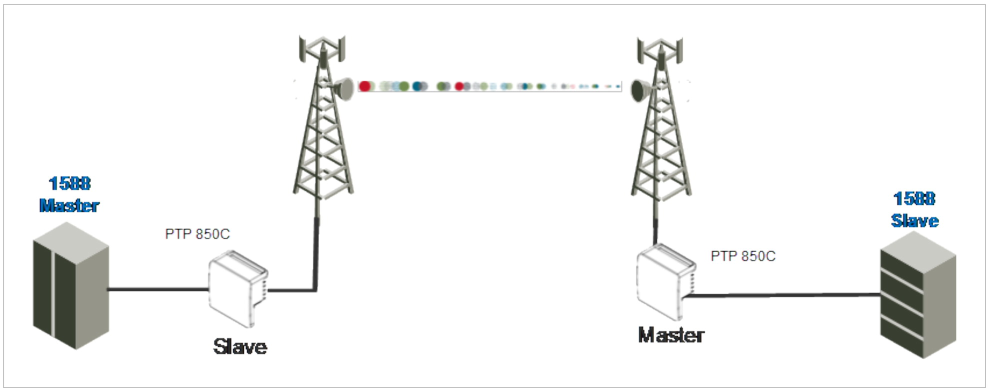


Boundary Clock

IEEE-1588v2 Boundary Clock enables the PTP 850C to regenerate phase synchronization via standard Ethernet. Boundary Clock provides better performance than other synchronization methods, enabling compliance with ITU-T Telecom Profile G.8275.1. This enables PTP 850C, with Boundary Clock, to meet the rigorous synchronization requirements of 5G networks.

In Boundary Clock, a single node can serve in both master and slave roles. The Boundary Clock node terminates the PTP flow, recovers the clock and timestamp, and regenerates the PTP flow. The Boundary Clock node selects the best synchronization source from a higher domain and regenerates PTP towards lower domains. This reduces the processing load from master clocks and increases the scalability of the synchronization network, while rigorously maintaining timing accuracy.

Figure 106: *Boundary Clock – General Architecture*



Boundary Clock uses the Best Master Clock (BMC) algorithm to determine which of the clocks in the network has the highest quality. This clock is designated the Grand Master clock, and it synchronizes all other clocks (slave clocks) in the network. If the Grand Master clock is removed from the network, or the BMC algorithm determines that another clock has superior quality, the BMC algorithm defines a new Grand Master clock and adjusts all other clocks accordingly. This process is fault tolerant, and no user input is required.

A node running as master clock can use the following inputs and outputs.

Figure 107: *Boundary Clock Input Options*

Synchronization Input	Frequency/Phase
Ethernet packets from PTP 1588 Remote Master via radio or Ethernet interface	Phase
SyncE (including ESMC) via radio or Ethernet interface	Frequency

Table 19 *Boundary Clock Output Options*

Synchronization Input	Frequency/Phase
Ethernet packets from PTP 1588 master via radio or Ethernet interface	Phase
SyncE (including ESMC) via radio or Ethernet interface	Frequency

Users can configure the following parameters for the sending of PTP messages:

- UDP/IPv4, per IEEE 1588 Annex D, or IEEE 802.3 Ethernet, per IEEE 1588 Annex F.
- Unicast or multicast mode.

SSM Support and Loop Prevention

In order to provide topological resiliency for synchronization transfer, PTP 850C implements the passing of SSM messages over the radio interfaces. SSM timing in PTP 850C complies with ITU-T G.781.

In addition, the SSM mechanism provides reference source resiliency, since a network may have more than one source clock.

The following are the principles of operation:

- At all times, each source interface has a "quality status" which is determined as follows:
  - If quality is configured as fixed, then the quality status becomes "failure" upon interface failure (such as LOS, LOC, LOF, etc.).
  - If quality is automatic, then the quality is determined by the received SSMs or becomes "failure" upon interface failure (such as LOS, LOC, LOF, etc.).
- Each unit holds a parameter which indicates the quality of its reference clock. This is the quality of the current synchronization source interface.
- The reference source quality is transmitted through SSM messages to all relevant radio interfaces.
- Each unit determines the current active clock reference source interface:
  - The interface with the highest available quality is selected.
  - From among interfaces with identical quality, the interface with the highest priority is selected.
- In order to prevent loops, an SSM with quality "Do Not Use" is sent towards the active source interface

At any given moment, the system enables users to display:

- The current source interface quality.
- The current received SSM status for every source interface.
- The current node reference source quality.

As a reference, the following are the possible quality values (from highest to lowest):

- AUTOMATIC (available only in interfaces for which SSM support is implemented)
- G.811 (ETSI systems)
- SSU-A (ETSI systems)
- SSU-B (ETSI systems)
- G.813/8262 – default
- PRS (ANSI systems)
- Stratum 2 (ANSI systems)
- Transit Node (ANSI systems)
- Stratum 3E (ANSI systems)
- Stratum 3 (ANSI systems)
- SMC (ANSI systems)
- Unknown (ANSI systems)
- DO NOT USE
- Failure (cannot be configured by user)

Note:

Normally, when an interface is in holdover state, it uses stored data to determine its outgoing clock. However, customers can set the unit to apply a default quality of DNU (Do Not Use) to any interface in holdover state.

Radio Payload Encryption and FIPS

AES-256 Payload Encryption

PTP 850C supports AES-256 payload encryption. On an PTP 850C device, AES-256 payload encryption can be enabled on radio interface 1 or on a Multi-Carrier ABC group.

The Advanced Encryption Standard (AES) is defined in Federal Information Processing Standard Publication 197 (FIPS 197) for symmetric encryption. AES-256 is widely considered to be secure and efficient and is therefore broadly accepted as the standard for both government and industry applications.

Figure 108: *AES-256 Encrypted Link*

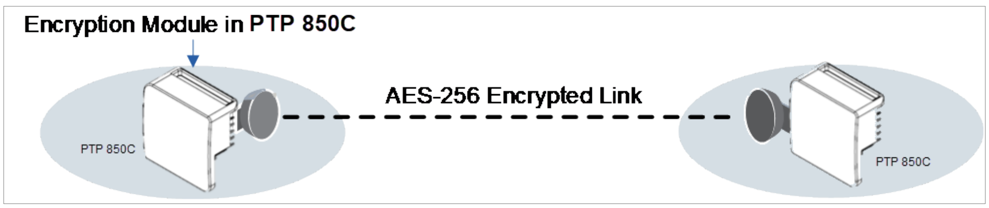


Figure 100

> **Note**:
>
> The AES-256 payload encryption feature is a controlled item under applicable Export Laws. Please contact your Cambium representative to confirm that the encryption feature can be delivered.

AES Benefits

1. Provides protection against eavesdropping and man-in-the-middle attacks on the radio
2. Full encryption for all radio traffic
3. Wire-speed, lowest latency encryption
4. Eliminates the need for external encryption devices:
   - Cost effective encryption solution
   - Low Capex and operational costs; fast and simple deployment

PTP 850C AES Implementation

In PTP 850C, AES provides full payload encryption for all L1 radio traffic. AES encryption operates on a point-to-point radio link level. It also encrypts control data passing through the radio link, such as the Link ID, ATPC data, and SSM messages. AES encryption operates on a point-to-point radio link level.

PTP 850C uses a dual-key encryption mechanism for AES.

1. The user provides a master key. The master key can also be generated by the system upon user command. The master key is a 32-byte symmetric encryption key. The same master key must be

manually configured on both ends of the encrypted link.

2. The session key is a 32-byte symmetric encryption key used to encrypt the actual data. Each link uses two session keys, one for each direction. For each direction, the session key is generated by the transmit side unit and propagated automatically to the other side of the link via a Key Exchange Protocol. The Key Exchange Protocol exchanges session keys by encrypting them with the master key, using the AES-256 encryption algorithm. For PTP 850C, session keys are regenerated at two-minute intervals.

The first KEP exchange that takes place after a new master key is configured causes traffic to be blocked for up to one minute, until the Crypto Validation State becomes Valid. Subsequent KEP exchanges that take place when a session key expires do not affect traffic. KEP exchanges have no effect upon ACM, RSL, and MSE.

Once AES encryption has been enabled on both sides of the link, the Key Exchange Protocol periodically verifies that both ends of the link have the same master key. If a mismatch is detected, an alarm is raised and traffic transmission is stopped for the mismatched carrier at both sides of the link. The link becomes non-valid and traffic stops being forwarded.

The unit must be reset after changing the AES-256 Admin mode, whether it is to enable or disable AES-256. When the user applies the change, an alarm is raised and the alarm is not cleared until the reset has been performed.

Note:

When AES-256 is enabled, the maximum ACM profile may be reduced by one in certain cases. For more details, see Supported Modulations per Frequency and Channel Bandwidth.

FIPS 140-3 Compliance

PTP 850C can be configured to be FIPS 140-3 level-2 compliant, in specific hardware and software configurations, as described in this section.

Note:

Only certain System Release versions support FIPS 140-3. For further information, check the Release Notes for the System Release version you are using or consult with your Cambium representative.

FIPS Overview

The objective of FIPS 140-3 is to provide a standard for secured communication devices, with an emphasis on encryption and cryptographic methods. The FIPS standards are promulgated by the National Institute of Standards and Technology (NIST), and provide an extensive set of requirements for both hardware and software. For a full list of FIPS requirements, refer to the *FIPS 140-3 Non-Proprietary Security Policy*, available upon request.

It is the responsibility of the customer to ensure that the above FIPS requirements are met.

Hardware Requirements

For an PTP 850C node to be FIPS-compliant, the unit must be FIPS-compliant hardware. A FIPS-compliant PTP 820C unit has a unique marketing model ending in the letters AF, in the following format: PTP 850C-***-AF

Three special labels, included with the PTP 850C radio kit, must be affixed to a FIPS-compliant PTP 850C unit once the diplexer unit has been attached to the radio unit. These labels are tamper-evident and must be applied in such a way that it is not possible to remove the diplexer unit from the radio unit without also removing a label and leaving evidence that the label was tampered with. The labels must be replaced if the radio or diplexer is replaced. Replacement labels can be ordered from Cambium Networks, part number BS-0341-2. Tamper-evident labels should be inspected for integrity at least once every six months.

For details, refer to the Installation Guide for PTP 850C.

Software Requirements

FIPS compliance requires the user to operate the PTP 850C in FIPS mode. FIPS mode must be enabled by the user. It can be enabled via the Web EMS, the CLI, or SNMPv3. Enabling FIPS mode requires a system reset.

PTP 850C Management

This chapter includes:

Management Overview

The Cambium management solution is built on several layers of management:

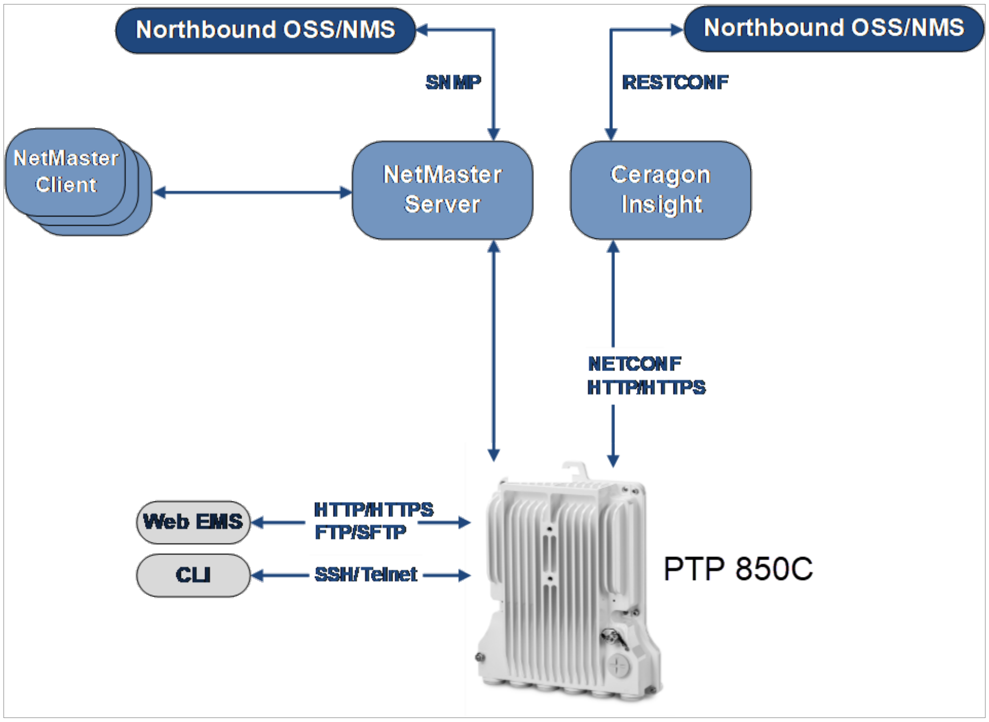
- Web-based EMS – HTTP web-based Element Management System (EMS)
- CLI – Command Line Interface
- SDN – Software-Defined Networking with NETCONF/YANG capabilities
- NMS – NetMaster Network Management System

Every PTP 850C includes an HTTP web-based EMS that enables the operator to perform device configuration, performance monitoring, remote diagnostics, alarm reports, and more. These same tasks can also be performed using the CLI.

PTP 850C supports NETCONF/YANG, enabling customers to manage, configure, and monitor network elements within the paradigm of SDN network architecture.

In addition, PTP 850C devices provide an SNMP v1/v2c/v3 northbound interface on the IDU for centralized network management. Cambium offers the NetMaster network management system (NMS), which provides centralized operation and maintenance capability for the complete range of PTP 850 devices. To facilitate automated network topology discovery via NMS, PTP 850C supports the Link Layer Discovery Protocol (LLDP).

Figure 109: *Integrated Management Tools*



Automatic Network Topology Discovery with LLDP Protocol

PTP 850C supports the Link Layer Discovery Protocol (LLDP), a vendor-neutral layer 2 protocol that can be used by a station attached to a specific LAN segment to advertise its identity and capabilities and to receive identity and capacity information from physically adjacent layer 2 peers. PTP 850C's LLDP implementation is based on the IEEE 802.1AB – 2009 standard.

LLDP provides automatic network connectivity discovery by means of a port identity information exchange between each port and its peer. The port exchanges information with its peer and advertises this information to the NMS managing the unit. This enables the NMS to quickly identify changes to the network topology.

Enabling LLDP on PTP 850C units enables the NMS to:

- Automatically detect the PTP 850C unit neighboring the managed PTP 850C unit, and determine the connectivity state between the two units.

- Automatically detect a third-party switch or router neighboring the managed PTP 850C unit, and determine the connectivity state between the PTP 850C unit and the switch or router.

Management Communication Channels and Protocols

Related Topics:

- Secure Communication Channels

Network Elements can be accessed locally via serial or Ethernet management interfaces, or remotely through the standard Ethernet LAN. The application layer is indifferent to the access channel used.

The NMS can be accessed through its GUI interface application, which may run locally or in a separate platform; it also has an SNMP-based northbound interface to communicate with other management systems.

Table 20 *Dedicated Management Ports*

Port number	Protocol	Frame structure	Details
161	SNMP	UDP	Sends SNMP Requests to the network elements
162 Configurable	SNMP (traps)	UDP	Sends SNMP traps forwarding (optional)
514	Syslog	UDP	Sends Syslog messages (optional)
80	HTTP	TCP	Manages devices **Note**: When HTTPS is used, users can configure Port 80 to be closed and traffic redirected to Port 443.
443	HTTPS	TCP	Manages devices (optional)
444	HTTPS	TCP	Used for Smart Activation Key
From port 21 (default) to any remote port (>1023). Initial port (21) is configurable.	FTP Control Port	TCP	Downloads software and configuration files, uploads security and configuration logs, and unit info files. (FTP Server responds to client's control port) (optional)
From Any port (>1023) to any remote port (>1023)	FTP Data Port	TCP	Downloads software and configuration files, uploads security and configuration logs, and unit info files. The FTP server sends ACKs (and data) to client's data port.
From port 22 (default) to any remote port (>1023).	SFTP Control Port	TCP	Downloads software and configuration files, and CSR certificates, uploads security and configuration logs, and unit info files.

Port number	Protocol	Frame structure	Details
Initial port (22) is configurable.			(SFTP Server responds to client's control port) (optional)
From Any port (>1023) to any remote port (>1023)	SFTP Data Port	TCP	Downloads software and configuration files, and CSR certificates, uploads security and configuration logs, and unit info files. The SFTP server sends ACKs (and data) to client's data port.
23	telnet	TCP	Remote CLI access (optional)
22	SSH	TCP	Secure remote CLI access (optional)

All remote system management is carried out through standard IP communications. Each NE behaves as a host with a single IP address.

The communications protocol used depends on the management channel being accessed.

As a baseline, these are the protocols in use:

- Standard HTTP for web-based management
- Standard telnet for CLI-based management

Web-Based Element Management System (Web EMS)

The Cambium Web Element Management System (Web EMS) is an HTTP web-based element manager that enables the operator to perform configuration operations and obtain statistical and performance information related to the system, including:

- **Configuration Management** – Enables you to view and define configuration data for the PTP 850C system.
- **Fault Monitoring** – Enables you to view active alarms.
- **Performance Monitoring** – Enables you to view and clear performance monitoring values and counters.
- **Diagnostics and Maintenance** – Enables you to define and perform loopback tests, and software updates.
- **Security Configuration** – Enables you to configure PTP 850C security features.
- **User Management** – Enables you to define users and user profiles.

A Web-Based EMS connection to the PTP 850C can be opened using an HTTP Browser (Explorer or Mozilla Firefox). The Web EMS uses a graphical interface. Most system configurations and statuses are available via the Web EMS. However, some advanced configuration options are only available via CLI.

The Web EMS shows the actual unit configuration and provides easy access to any interface on the unit. The Web EMS opens to a Unit Summary page that displays the key unit parameters and current alarms on a single page for quick viewing. The next page in the Web EMS, easily accessible from the root directory, is the Link Summary page, which provides a graphical representation of the link and enables to easily display and configure the radio parameters on both the local and the remote device.

Note:

For optimal Web EMS performance, it is recommended to ensure that the network speed is at least 100 Kbps for most operations, and at least 5 Mbps for software download operations.

The Web EMS includes a Quick Platform Setup page designed to simplify initial configuration and minimize the time it takes to configure a working link.

The Web EMS also includes quick link configuration wizards that guide the user, step-by-step, through the creation of 1+0 links with point-to-point services.

With respect to system security, the Web EMS includes two features to facilitate monitoring and configuring security-related parameters.

To configure security-related features, the Web EMS gathers several pages under the Quick Configuration portion of the Web EMS main menu. Users can configure the following parameters from these pages:

- FIPS Admin
- Import and export security settings
- Session timeout
- Login banner
- AES-256 payload encryption
- HTTP or HTTPS
- Telnet access
- SNMP parameters
- Users and user profiles
- Login and password parameters
- RSA public key configuration
- Certificate Signing Request (CSR) file download and install

The Web EMS also includes a Security Summary page that gathers a number of important security-related parameters in a single page for quick viewing. The Security Summary page can be displayed from the root of the Web EMS main menu.

The Security Summary page includes:

- FIPS Admin status
- Session Timeout
- Login Banner
- AES-256 payload encryption status

- HTTP/HTTPS configuration
- Telnet access status (enabled/disabled)
- SNMP parameters
- Login and password security parameters
- Users and their parameters
- Public RSA key currently configured on the device

Users can toggle between the following menu structure options:

- **Advanced** – Advanced mode includes all available Web EMS options, including both basic link and configuration and advanced configuration such as QoS and Ethernet protocols.
- **Basic** – Basic mode provides a condensed set of menu options that cover most or all of the configurations necessary to set up and maintain an PTP 850 unit, including link configuration wizards for most link types. The purpose of Basic mode is to provide the average user with a menu tree that is simple to navigate yet includes most or all options that most users need.

Users can toggle between Advanced or Basic mode by clicking Advanced and Basic in the upper left corner or any page in the Web EMS. The default mode is Advanced mode.

SDN Support

PTP 850C supports SDN, with NETCONF/YANG capabilities.

SDN (Software-Defined Networking) is a comprehensive, software-centric approach to networking that makes network planning and management more flexible, efficient, and effective in many ways

PTP 850C's SDN implementation is a key part of Cambium's vision for evolving wireless backhaul towards SDN via open architecture based on standard Northbound and Southbound interfaces. This vision includes innovative SDN solutions for dynamic network performance and resource optimization, and SDN-based backhaul network provisioning, monitoring, and self-healing.

SDN provides a full portfolio of network and network element management capabilities, including

- Topology auto discovery
- Performance monitoring
- Fault Management
- Alarms and events

PTP 850C's NETCONF and YANG implementation includes the following main standard interfaces, protocols, and data models:

- NETCONF RFC 6241
- Support for get/get-config/edit/copy/delete
- YANG RFC 6020
- YANG data models:

- ONF Core Model v1.4
- AirInterface v2.0 – openBackhaul.com proposal to Open Networking Foundation (ONF)
- WireInterface v2.0 – openBackhaul.com proposal to Open Networking Foundation (ONF)
- PureEthernetStructure v2.0 – openBackhaul.com proposal to Open Networking Foundation (ONF)
- EthernetContainer v2.0 – openBackhaul.com proposal to Open Networking Foundation (ONF)
- Adds support for alarms v1.0 – openBackhaul.com proposal to Open Networking Foundation (ONF)
- Adds support for firmware v1.0 – openBackhaul.com proposal to Open Networking Foundation (ONF)

SDN provides significant benefits to network operators, including:

- Improving time-to-market and increasing network planning flexibility by enabling easy connection and integration with legacy devices from multiple vendors.
- High performance and resiliency due to the availability of plug-in applications and SDN's intrinsic design for resiliency and availability.
- Lower CAPEX and OPEX resulting from self-defined scripts, quicker introduction of new services, and fast troubleshooting.

For additional information, refer to the *NETCONF Reference Guide for PTP 820 and PTP 850 Products*.

WiFi Management

Note:

WiFi management requires the addition of a plugin module.

The PTP 850C is equipped with a WiFi access point. The WiFi access point does not broadcast its SSID and enables a secure WiFi connection for technical personnel to be able to manage the PTP 850C system with no wired connection using a portable device.

Command Line Interface (CLI)

A CLI connection to the PTP 850C can be opened via SSH or telnet. All parameter configurations can be performed via CLI.

Note:

Telnet is disabled by default and must be enabled by user configuration. Therefore, if initial access to the device is via CLI, the user must use a terminal connection or SSH.

Configuration Management

The system configuration file consists of a set of all the configurable system parameters and their current values.

PTP 850C configuration files can be imported and exported. This enables you to copy the system configuration to multiple PTP 850C units.

System configuration files consist of a zip file that contains three components:

- A binary configuration file which is used by the system to restore the configuration.
- A text file which enables users to examine the system configuration in a readable format. The file includes the value of all system parameters at the time of creation of the backup file.
- An additional text file which enables users to write CLI scripts in order to make desired changes in the backed-up configuration. This file is executed by the system after restoring the configuration.

The system provides three restore points to manage different configuration files. Each restore point contains a single configuration file. Files can be added to restore points by creating backups of the current system state or by importing them from an external server.

Note:

In the Web EMS, these restore points are referred to as “file numbers.”

For example, a user may want to use one restore point to keep a last good configuration, another to import changes from an external server, and the third to store the current configuration.

Any of the restore points can be used to apply a configuration file to the system.

The user can determine whether or not to include security-related settings, such as users and user profiles, in the exported configuration file. By default, security settings are included.

Software Management

The PTP 850C software installation and upgrade process includes the following steps:

- **Download** – The files required for the installation or upgrade are downloaded from a remote server.
- **Installation** – The files are installed in the appropriate modules and components of the PTP 850C.
- **Reset** – The PTP 850C is restarted in order to boot the new software and firmware versions.

PTP 850C software and firmware releases are provided in a single bundle that includes software and firmware for all components supported by the system. When the user downloads a software bundle, the system verifies the validity of the bundle. The system also compares the files in the bundle to the files currently installed in the PTP 850C and its components, so that only files that differ between the new version bundle and the current version in the system are actually downloaded. A message is displayed to the user for each file that is actually downloaded.

Note: When downloading an older version, all files in the bundle may be downloaded, including files that are already installed.

Software bundles can be downloaded via FTP, SFTP, HTTP, or HTTPS. When downloading software via HTTP or HTTPS, the PTP 850C unit acts as an HTTP server, and the software can be downloaded directly to the unit. When downloading software via FTP or SFTP, the PTP 850C functions as an FTP or SFTP client, and FTP or SFTP server software must be installed on the PC or laptop being using to perform the upgrade.

After the software download is complete, the user initiates the installation. A timer can be used to perform the installation after a defined time interval. The system performs an automatic reset after the installation.

Using Pre-Defined Configuration Files

PTP 850C units can be configured from the Web EMS in a single step by applying a pre-defined configuration file. This drastically reduces the initial installation and setup time in the field.

Using pre-defined configuration files also reduces the risk of configuration errors and enables operators to invest less time and money training installation personnel. Installers can focus on hardware configuration, relying on the pre-defined configuration file to implement the proper software configuration on each device.

The pre-defined configuration file can be generated by Cambium Professional Services and provided as a service.

A pre-defined configuration file can be prepared for multiple PTP 850C units, with the relevant configuration details specified and differentiated per-unit. This simplifies administration, since a single file can be used with multiple devices.

Pre-defined configuration files can include all the parameters necessary to configure basic links, including:

- Activation Key (or Demo mode) configuration
- Radio Parameters
- Interface Groups (e.g., LAG)
- Management Service

All configurations that can be implemented via the Web EMS Quick Configuration wizards can also be configured using pre-defined configuration files.

Pre-defined configuration files can be created by Cambium Professional Services, according to customer specifications. For further information, consult your Cambium representative.

IPv6 Support

PTP 850C management communications can use both IPv4 and IPv6. The unit IP address for management can be configured in either or both formats.

Additionally, other management communications can utilize either IPv4 or IPv6. This includes:

- Software file downloads
- Configuration file import and export
- Trap forwarding
- Unit information file export (used primarily for maintenance and troubleshooting)

Dynamic IPv6 configuration is supported via DHCPv6. When enabled, devices can obtain their IPv6 address automatically via DHCPv6.

In-Band Management

PTP 850C can optionally be managed In-Band, via its radio and Ethernet interfaces. This method of management eliminates the need for a dedicated management interface. For more information, refer to Management Service (MNG).

Local Management

PTP 850C includes an electrical GbE management port.

Alarms

Configurable BER Threshold for Alarms and Traps

Users can configure alarm and trap generation in the event of Excessive BER and Signal Degrade BER above user-defined thresholds. Users have the option to configure whether or not excessive BER is propagated as a fault and considered a system event.

RSL Threshold Alarm

Users can configure an alarm that is raised if the RSL falls beneath a user-defined threshold. This feature can be enabled or disabled per radio carrier. By default, it is disabled. The RSL threshold alarm provides a preventative maintenance tool for monitoring the health of the link and ensuring that problems can be identified and corrected quickly.

Editing and Disabling Alarms and Events

Users can change the description text (by appending extra text to the existing description) or the severity of any alarm in the system. Users can also choose to disable specific alarms and events. Any alarm or event can be disabled, so that no indication of the alarm or event is displayed, and no traps are sent for the alarm or event.

This is performed as follows:

- Each alarm and event in the system is identified by a unique name (see separate list of system alarms and events).
- The user can perform the following operations on any alarm:
- View current description and severity
- Define the text to be appended to the description and/or severity
- Return the alarm to its default values
- Disable or re-enable the alarm (or event)
- The user can also return all alarms and events to their default values.

Timeout for Trap Generation

Users can configure a wait time of 0 to 120 seconds after an alarm is cleared in the system before the alarm is actually reported as being cleared. This prevents traps flooding the NMS in the event that some external condition causes the alarm to be raised and cleared continuously.

This means that when the alarm is cleared, the alarm continues to be displayed and no *clear alarm* trap is sent until the timeout period is finished.

The timeout for trap generation can be configured via CLI. By default, the timeout is 10 seconds.

NTP Support

Related topics:

- Synchronization

PTP 850C supports Network Time Protocol (NTP). NTP distributes Coordinated Universal Time (UTC) throughout the system, using a jitter buffer to neutralize the effects of variable latency.

Users can configure up to four NTP servers. Each server can be configured using IPv4 or IPv6. When multiple servers are configured, the unit chooses the best server according to the implementation of Version 4.2.6p1 of the NTPD (Network Time Protocol Daemon). The servers are continually polled. The polling interval is determined by the NTPD, to achieve maximum accuracy consistent with minimum network overhead.

PTP 850C supports NTPv3 and NTPv4. NTPv4 provides interoperability with NTPv3 and with SNTP.

Optionally, NTP authentication is available, as defined in the NTP specification (IETF RFC 5905). NTP authentication enables the client to verify the authenticity of the NTP server before synchronizing its clock with the server's time. This can help prevent man-in-the-middle attacks and other types of threats that could manipulate the client's clock by providing it with false time information.

UTC Support

PTP 850C uses the Coordinated Universal Time (UTC) standard for time and date configuration. UTC is a more updated and accurate method of date coordination than the earlier date standard, Greenwich Mean Time (GMT).

Every PTP 850C unit holds the UTC offset and daylight savings time information for the location of the unit. Each management unit presenting the information (CLI and Web EMS) uses its own UTC offset to present the information in the correct time.

Syslog Support

Syslog can be used to send Security Log, Event Log, and Configuration Log messages to up to two external Syslog servers. This can simplify network monitoring and maintenance for operators by enabling them to centralize troubleshooting and monitoring information for multiple network elements in a single location.

Syslog uses UDP protocol on port 514.

Optionally, for extra security you can enable TLS-based Secure Syslog. This enables server authentication, which means the client authenticates the Syslog server. This provides an extra layer of protection against various types of security threats, including masquerade, modification, and disclosure threats.

When Secure Syslog is enabled, the device uses the TCP port (6514) for Syslog messages.

Note:

Secure Syslog requires that the server support TLS 1.2 or higher.

System Security Features

To guarantee proper performance and availability of a network as well as the data integrity of the traffic, it is imperative to protect it from all potential threats, both internal (misuse by operators and administrators) and external (attacks originating outside the network).

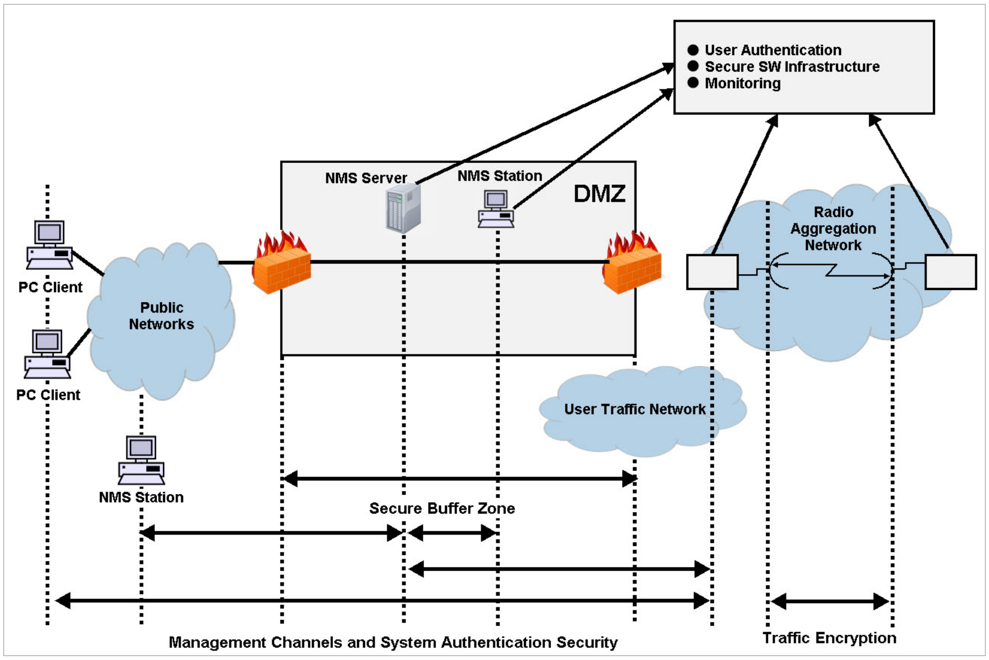
System security is based on making attacks difficult (in the sense that the effort required to carry them out is not worth the possible gain) by putting technical and operational barriers in every layer along the way, from the access outside the network, through the authentication process, up to every data link in the network.

Cambium’s Layered Security Concept

Each layer protects against one or more threats. However, it is the combination of them that provides adequate protection to the network. In most cases, no single layer protection provides a complete solution to threats.

The layered security concept is presented in the following figure. Each layer presents the security features and the threats addressed by it. Unless stated otherwise, requirements refer to both network elements and the NMS.

Figure 110: *Security Solution Architecture Concept*



Defenses in Management Communication Channels

Since network equipment can be managed from any location, it is necessary to protect the communication channels' contents end to end.

These defenses are based on existing and proven cryptographic techniques and libraries, thus providing standard secure means to manage the network, with minimal impact on usability.

They provide defense at any point (including public networks and radio aggregation networks) of communications.

While these features are implemented in Cambium equipment, it is the responsibility of the operator to have the proper capabilities in any external devices used to manage the network.

In addition, inside Cambium networking equipment it is possible to control physical channels used for management. This can greatly help deal with all sorts of DoS attacks.

Operators can use secure channels instead or in addition to the existing management channels:

- SNMPv3 for all SNMP-based protocols for both NEs and NMS
- HTTPS for access to the NE's web server
- SSH-2 for all CLI access SFTP for all software and configuration download between NMS and NEs

All protocols run with secure settings using strong encryption techniques. Unencrypted modes are not allowed, and algorithms used must meet modern and client standards.

Users are allowed to disable all insecure channels.

In the network elements, the bandwidth of physical channels transporting management communications is limited to the appropriate magnitude, in particular, channels carrying management frames to the CPU.

Attack types addressed.

- Tempering with management flows
- Management traffic analysis
- Unauthorized software installation
- Attacks on protocols (by providing secrecy and integrity to messages)
- Traffic interfaces eavesdropping (by making it harder to change configuration)
- DoS through flooding

Defenses in User and System Authentication Procedures

User Configuration and User Profiles

User configuration is based on the Role-Based Access Control (RBAC) model. According to the RBAC model, permissions to perform certain operations are assigned to specific roles. Users are assigned to particular roles, and through those role assignments acquire the permissions to perform particular system functions.

In the PTP 850C GUI, these roles are called user profiles. Up to 50 user profiles can be configured. Each profile contains a set of privilege levels per functionality group, and defines the management protocols (access channels) that can be used to access the system by users to whom the user profile is assigned.

The system parameters are divided into the following functional groups:

- Security
- Management
- Radio
- Ethernet
- Synchronization

A user profile defines the permitted access level per functionality group. For each functionality group, the access level is defined separately for read and write operations. The following access levels can be assigned:

- **None** – No access to this functional group.
- **Normal** – The user has access to parameters that require basic knowledge about the functional group.
- **Advance** – The user has access to parameters that require advanced knowledge about the functional group, as well as parameters that have a significant impact on the system as a whole, such as restoring the configuration to factory default settings.

User Identification

PTP 850C supports the following user identification features:

- Configurable inactivity time-out for automatically closing unused management channels
- Optional password strength enforcement. When password strength enforcement is enabled; passwords must comply with the following rules:
  - Password must be at least eight characters long.
  - Password must include characters of at least three of the following character types: lower case letters, upper case letters, digits, and special characters.
  - No character can be repeated three times, e.g., aaa, ###, 333.
  - No more than two consecutive characters can be used, e.g., ABC, DEF, 123.
  - The user name string cannot appear in the password, either in order or in reverse order. For example, if the user name is “admin”, neither of the following passwords are allowed: *%Asreadmin!df23* and *%Asrenimda!df23*.
- Password reuse can be configured so that up to ten previous passwords cannot be reused.
- Users can be prompted to change passwords after a configurable amount of time (password aging).
- Users can be blocked for a configurable time period after a configurable number of unsuccessful login attempts.
- Users can be configured to expire at a certain date
- Mandatory change of password at first time login can be enabled and disabled upon user configuration. It is enabled by default.
- SHA-512 is used to encrypt user passwords.

Remote Authentication

Certificate-based strong standard encryption techniques are used for remote authentication. Users may choose to use this feature or not for all secure communication channels.

Since different operators may have different certificate-based authentication policies (for example, issuing its own certificates vs. using an external CA or allowing the NMS system to be a CA), NEs and NMS software provide the tools required for operators to enforce their policy and create certificates according to their established processes.

Server authentication capabilities are provided.

RADIUS Support

The RADIUS protocol provides centralized user management services. PTP 850C supports RADIUS server and provides a RADIUS client for authentication and authorization.

RADIUS can be enabled or disabled. When RADIUS is enabled, a user attempting to log into the system from any access channel (CLI, WEB, NMS) is not authenticated locally. Instead, the user’s credentials are sent to a centralized standard RADIUS server which indicates to the PTP 850C whether the user is known, and which privilege is to be given to the user. RADIUS uses the same user attributes and privileges defined for the user locally.

> **Note**:
>
> When using RADIUS for user authentication and authorization, the access channels configured per PTP 850C user profile are not applicable. Instead, the access channels must be configured as part of the RADIUS server configuration.

RADIUS login works as follows:

- If the RADIUS server is reachable, the system expects authorization to be received from the server:
  - The server sends the appropriate user privilege to the PTP 850C, or notifies the PTP 850C that the user was rejected.
  - If rejected, the user will be unable to log in. Otherwise, the user will log in with the appropriate privilege and will continue to operate normally.
- If the RADIUS server is unavailable, the PTP 850C will attempt to authenticate the user locally, according to the existing list of defined users.

> **Note**:
>
> Local login authentication is provided in order to enable users to manage the system in the event that RADIUS server is unavailable. This requires previous definition of users in the system. If the user is only defined in the RADIUS server, the user will be unable to login locally in case the RADIUS server is unavailable.

In order to support PTP 850C - specific privilege levels, the vendor-specific field is used. Cambium’s IANA number for this field is 2281.

The following RADIUS servers are supported:

- FreeRADIUS
- RADIUS on Windows Server (IAS)
  - Windows Server 2008
  - Windows Server 2003
- Cisco ACS

TACACS+ Support

PTP 850C supports TACACS+ for remote access user authentication and authorization. Using TACACS+, the PTP 850 device acts as the client, working with a TACACS+ server to authenticate and authorize users.

The TACACS+ protocol provides centralized user management services. TACACS+ separates the functions of Authentication, Authorization, and Accounting (AAA). It enables arbitrary length and content authentication exchanges, in order to support future authentication mechanisms. It is extensible to provide for site customization and future development features, and uses TCP to ensure reliable communication.

> **Note**:
>
> PTP 850 supports session-based TACACS+ authorization, but not command-based.

When TACACS+ is enabled, a user attempting to log into the system from any access channel (CLI, WEB, NMS) is not authenticated locally. Instead, the user’s credentials are sent to a centralized standard

TACACS+ server which indicates to the PTP 850 device whether the user is known, and which privilege is to be given to the user.

Cambium's TACACS+ solution is compliant with any standard TACACS+ server. Testing has been performed, and interoperability confirmed, with the following TACACS+ servers:

- Cisco ISE - Version 2.6.0.156
- Tacacs.net - Version 1.2
- tac_plus version F4.0.4.27a

Up to four TACACS+ servers can be defined to work with an PTP 850 device. When a user attempts to log into the device, the device attempts to contact the first TACACS+ server to authenticate the user. If no response is received from the server within the user-defined timeout period, the device tries again to contact the server up to the user-configured number of retries. Then, if no response is received from the server, the device attempts to contact the second user-defined TACACS+ server. If no response is received from any of the servers, the device performs user authentication locally.

SSO Web Login with Microsoft Entra ID

System Release devices support remote user login via Microsoft Entra ID. Microsoft Entra ID is a cloud-based identity and access management service. It helps organizations securely manage users, applications, and devices by providing authentication, authorization, and identity protection. Through Entra ID, users can securely access external resources.

The following options are available for System Release devices:

- **Single Sign-On (SSO)** – Enables users to log in once and access multiple applications without needing to re-enter credentials.
- **Multi-Factor Authentication (MFA)** – Adds an extra layer of security beyond just a password. MFA is optional, and must be arranged by the customer as part of the customer's Microsoft Entra ID implementation.

SSO is only active for the browser type on which the user logs in with Microsoft. For example, if the user logs in with a Microsoft Edge browser, the user will be logged in via SSO while using a Microsoft Edge browser but will not be logged in via SSO from a Google Chrome browser, and vice versa.

When a user logs into a device with SSO enabled, the user is given the option to log in normally with the user's credentials or to log in via Microsoft.

When a user logs out of a device to which the user is logged in with SSO, the user is given the option to log out of the local session only or to log out of Microsoft.

Secure Communication Channels

PTP 850C supports a variety of standard encryption protocols and algorithms, as described in the following sections.

SSH (Secured Shell)

SSH protocol can be used as a secured alternative to Telnet. In PTP 850C:

- SSHv2 is supported.
- SSH protocol will always be operational. Admin users can choose whether to enable Telnet protocol, which is disabled by default. Server authentication is based on PTP 850C's public key.
- RSA and DSA key types are supported.
- MAC (Message Authentication Code): SHA-1-96 (MAC length = 96 bits, key length = 160 bit). Supported MAC: hmac-md5, hmac-sha1, hmac-ripemd160, hmac-sha1-96, hmac-md5-96'
- The server authenticates the user based on user name and password. The number of failed authentication attempts is not limited.
- The server timeout for authentication is 10 minutes. This value cannot be changed.

HTTPS (Hypertext Transfer Protocol Secure)

HTTPS combines the Hypertext Transfer protocol with the TLS (1.0, 1.1, 1.2, 1.3) protocol to provide encrypted communication and secure identification of a network web server. PTP 850C enables administrators to configure secure access via HTTPS protocol.

For a list of supported HTTPS ciphers, including an indication of which ciphers are supported in HTTPS strong mode, see *Annex A – Supported Ciphers for Secured Communication Protocols* in the Release Notes for the System Release version you are using. From System Release 12.0, all supported HTTPS ciphers are also supported in FIPS mode.

SFTP (Secure FTP)

SFTP can be used for the following operations:

- Configuration upload and download,
- Uploading unit information
- Uploading a public key
- Downloading certificate files
- Downloading software

Creation of Certificate Signing Request (CSR) File

In order to create a digital certificate for the NE, a Certificate Signing Request (CSR) file should be created by the NE. The CSR contains information that will be included in the NE's certificate such as the organization name, common name (domain name), locality, and country. It also contains the public key that will be included in the certificate. Certificate authority (CA) will use the CSR to create the desired certificate for the NE.

While creating the CSR file, the user will be asked to input the following parameters that should be known to the operator who applies the command:

- **Common name** – The identify name of the element in the network (e.g., the IP address). The common name can be a network IP or the FQDN of the element.
- **Organization** – The legal name of the organization.
- **Organizational Unit** - The division of the organization handling the certificate.
- **City/Locality** - The city where the organization is located.
- **State/County/Region** - The state/region where the organization is located.
- **Country** - The two-letter ISO code for the country where the organization is location.
- **Email address** - An email address used to contact the organization.

RSA Keys

PTP 850 devices support RSA keys for communication using HTTPS and SSH protocol. The PTP 850 device comes with randomly generated private and public RSA keys. However, customers can replace the private/public key pair with customer-defined private key. The corresponding RSA public key will be generated based on this private keys. The file must be in PEM format. Supported RSA private key sizes are 2048, 4096, and 8192. The customer-defined private key can be downloaded to the device via HTTPS or SFTP. It is recommended to use HTTPS.

SNMP

PTP 850C supports SNMP v1, V2c, and v3. The default community string in NMS and the SNMP agent in the embedded SW are disabled. Users are allowed to set community strings for access to network elements.

PTP 850C supports the following MIBs:

- RFC-1213 (MIB II)
- RMON MIB
- Cambium (proprietary) MIB.

Access to all network elements in a node is provided by making use of the community and context fields in SNMPv1 and SNMPv2c/SNMPv3, respectively.

Server Authentication (TLS 1.0, 1.1, 1.2, 1.3)

- All protocols making use of SSL (such as HTTPS) use TLS (1.0, 1.1, 1.2, 1.3) and support X.509 certificates-based server authentication.
- Users with type of “administrator” or above can perform the following server (network element) authentication operations for certificates handling:
  - Generate server key pairs (private + public)
  - Export public key (as a file to a user-specified address)
  - Install third-party certificates

        - The Admin user is responsible for obtaining a valid certificate.
    - Load a server RSA key pair that was generated externally for use by protocols making use of SSL.
- Non-SSL protocols using asymmetric encryption, such as SSH and SFTP, can make use of public-key based authentication.
    - Users can load trusted public keys for this purpose.

Encryption

Encryption algorithms for secure management protocols include:

- Symmetric key algorithms: 128-bit AES
- Asymmetric key algorithms: 1024-bit RSA

Security Log

The security log is an internal system file which records all changes performed to any security feature, as well as all security related events.

> **Note**:
>
> In order to read the security log, the user must upload the log to his or her server.

The security log file has the following attributes:

- The file is of a “cyclic” nature (fixed size, newest events overwrite oldest).
- The log can only be read by users with "admin" or above privilege.
- The contents of the log file are cryptographically protected and digitally signed.
    - In the event of an attempt to modify the file, an alarm will be raised.
- Users may not overwrite, delete, or modify the log file.

The security log records:

- Changes in security configuration
    - Carrying out “security configuration copy-to-mate”
    - Management channels time-out
    - Password aging time
    - Number of unsuccessful login attempts for user suspension
    - Warning banner change
    - Adding/deleting of users
    - Password changed
    - SNMP enable/disable
    - SNMP version used (v1/v3) change

  - SNMPv3 user added or deleted
  - SNMPv3 parameters change
    - Security mode
    - Authentication algorithm
    - User
    - Password
  - SNMPv1 parameters change
    - Read community
    - Write community
    - Trap community for any manager
  - HTTP/HTTPS change
  - FTP/SFTP change
  - Telnet and web interface enable/disable
  - FTP enable/disable
  - Loading certificates
  - RADIUS server
  - Radius enable/disable
  - TACACS+ server
  - TACACS+ enable/disable
  - Remote logging enable/disable (for security and configuration logs)
  - System clock change
  - NTP enable/disable
- Security events
- Successful and unsuccessful login attempts
- N consecutive unsuccessful login attempts (blocking)
- Configuration change failure due to insufficient permissions
- SNMPv3/PV authentication failures
- User logout
- User account expired

For each recorded event the following information is available:

- User ID
- Communication channel (WEB, terminal, telnet/SSH, SNMP, NMS, etc.)

- IP address, if applicable
- Date and time

Access Control Lists

Access control lists enable operators to define rules to limit management traffic, i.e., traffic destined to the logical management interface. This includes both in-band and out-of-band management traffic. These rules are added to an access control list. PTP 850 devices maintain separate access control lists for IPv4 addresses and IPv6 addresses. Each list can include up to 40 rules.

Access control rules can be based on the following criteria:

- Source IP address
- Network subnet prefix length
- Protocol type
- Destination port

Each rule is either an “accept” rule or a “drop” rule. By using combinations of accept and drop rules, operators can ensure that only certain traffic is permitted to ingress the management interface. Traffic received by the logical management interface is checked against the rules in the access control list in the order of priority configured by the user, from highest priority to lowest priority. Once a matching rule is found, the rule is applied to accept or drop the packet, and the checking stops for that packet.

Standards and Certifications

This chapter includes:

- Supported Ethernet Standards
- MEF Specifications for Ethernet Services

Supported Ethernet Standards

Table 21 *Supported Ethernet Standards*

Standard	Description
802.3	10base-T, 100base-T, 1000base-T, 1000base-X, 10GBase-LR
802.3ac	Ethernet VLANs
802.1Q	Virtual LAN (VLAN)
802.1p	Class of service
802.1ad	Provider bridges (QinQ)
802.1AX	Link aggregation
Auto MDI/MDIX for 1000baseT	
RFC 1349	IPv4 TOS
RFC 2474	IPv4 DSCP
RFC 2460	IPv6 Traffic Classes

MEF Specifications for Ethernet Services

PTP 850C supports the specifications listed in the following table.

Table 22 *Supported MEF Specifications*

Specification	Description
MEF-2	Requirements and Framework for Ethernet Service Protection
MEF-6.1	Metro Ethernet Services Definitions Phase 2
MEF-10.3	Ethernet Services Attributes Phase 3
MEF 22.1	Mobile Backhaul Implementation Agreement Phase 2
MEF-30.1	Service OAM Fault Management Implementation Agreement Phase 2
MEF-35	Service OAM Performance Monitoring Implementation Agreement

Specification	Description
CE 2.0	Second generation Carrier Ethernet certification
MEF-9	Abstract Test Suite for Ethernet Services at the UNI. Certified for all service types (EPL, EVPL & E-LAN). This is a first generation certification. It is fully covered as part of CE2.0)
MEF-14	Abstract Test Suite for Traffic Management Phase 1. Certified for all service types (EPL, EVPL & E-LAN). This is a first generation certification. It is fully covered as part of CE2.0)

Specifications

This chapter includes:

- General Radio Specifications
- Radio Scripts
- Supported Modulations per Frequency and Channel Bandwidth
- Radio Capacity Specifications
- Transmit Power Specifications
- Receiver Threshold Specifications (dBm@ 10E-6)
- Frequency Bands
- Ethernet Latency Specifications
- Mediation Device Losses
- Interface Specifications
- Carrier Ethernet Functionality
- Synchronization Protocols
- Network Management, Diagnostics, Status, and Alarms
- Mechanical Specifications
- Standards Compliance
- Environmental Specifications
- Antenna Specifications
- Power Input Specifications
- Power Consumption Specifications
- Power Connection Options
- PoE Injector Specifications
- Cable Specifications

Related Topics:

- Standards and Certifications

Note:

All specifications are subject to change without prior notification.

General Radio Specifications

Table 23 *Radio Frequencies*

Frequency (GHz)	Operating Frequency Range (GHz)	Tx/Rx Spacing (MHz)
6L,6H	5.85-6.45, 6.4-7.1	252.04, 240, 266, 300, 340, 160, 170, 500
7,8	7.1-7.9, 7.7-8.5	154, 119, 161, 168, 182, 196, 208, 245, 250, 266, 300,310, 311.32, 500, 530
10	10.0-10.7	91, 168,350, 550
11	10.7-11.7	490, 520, 530
13	12.75-13.3	266
15	14.4-15.35	315, 420, 475, 644, 490, 728
18	17.7-19.7	1010, 1120, 1008, 1560
23	21.2-23.65	1008, 1200, 1232
24UL	24.0-24.25	Customer-defined
26	24.2-26.5	800, 1008
28	27.35-29.5	350, 450, 490, 1008
32	31.8-33.4	812
38	37-40	1000, 1260, 700
42	40.55-43.45	1500

Table 24 *General Radio Specifications*

Standards	ETSI, ITU-R, CEPT
Frequency Source	Synthesizer
Frequency Accuracy	±5 ppm
RF Channel Selection	Via EMS/NMS
Tx Range (Manual/ATPC)	The dynamic TX range with ATPC is the same as the manual TX range, and depends on the frequency and the ACM profile. The maximum TX power with ATPC is no higher than the maximum manually configured TX power.

Radio Scripts

Note:

224 MHz is only supported with certain hardware versions. For details, ask your Cambium representative..

Table 25 *Radio Scripts*

Script ID	Channel BW	Occupied BW	Standard	ETSI System Class	XPIC (CCDP)	MIMO SD	Highest Spectral Efficiency Class	Max Profile (ACM)	Max Profile (Fixed)
4509	14	13.3	ETSI	ACCP	Yes	No	7B	11 (2048 QAM)	10 (1024 QAM Light FEC)
4521	20	18.57	FCC	n/a	Yes	No	n/a	11 (2048 QAM)	10 (1024 QAM Light FEC)
4525	25	23.4	FCC	n/a	Yes	No	n/a	12 (4096 QAM)	11 (2048 QAM)
4504	28	26.5	ETSI	ACCP	Yes	No	8B	12	11
4505	28/30	28	ETSI/FCC	ACAP	Yes	No	8A	12	11
4514	28	26	ETSI	ACCP	Yes	Yes	8B	12	11
4901 See Note 1	28/30	26.5	ETSI/FCC	ACCP	Yes	Yes	8B	12	11
4507	40	37.4	ETSI/FCC	ACCP	Yes	No	8B	12	11
490215	40	37.6	ETSI/FCC	ACCP	Yes	Yes	8B	12	11
4510	50	47.2	FCC	n/a	Yes	No	n/a	12	11
4502	56	53	ETSI	ACCP	Yes	No	8B	12	11
490315	56/60	53	ETSI/FCC	ACCP	Yes	Yes	8B	12	11
4506	56/60	55.7	ETSI/FCC	ACAP	Yes	No	8A	12	11
4513	70	64.8	ETSI	ACCP	Yes	No	8B	12	11

Script ID	Channel BW	Occupied BW	Standard	ETSI System Class	XPIC (CCDP)	MIMO SD	Highest Spectral Efficiency Class	Max Profile (ACM)	Max Profile (Fixed)
4501 See Note 2	80	74	ETSI/FCC	ACCP	Yes	No	8B	12	11
490515	80	74.1	ETSI/FCC	ACCP	Yes	Yes	8B	12	11
4588	80	79.2	ETSI	ACAP	Yes	No	8A	12	11
451116	112	106	ETSI	ACCP	Yes	No	8B	12	11
4911 15	112	106	ETSI	ACCP	Yes	Yes	8B	12	11
4518	140	127.5	ETSI	ACCP	Yes	No	8B	10 (2048 QAM)	9 (1024 QAM)
4515	150	141.6	FCC	ACCP	Yes	No	8B	10	9
4516	160	148.2	FCC	ACCP	Yes	No	8B	10	9
4522	200	181.6	ETSI/FCC	ACCP	Yes	No	8B	10	9
4524	224	212	ETSI	ACCP	Yes	No	8B	10	9

Note:

1. These scripts are exclusively to be used for MIMO and Space Diversity, which are planned for future release.
2. The maximum profiles listed for this script are relevant for 1+0 and 2+0 XPIC configurations. For configurations using system class ACCP, the maximum profile is limited to Profile 10 (1024 QAM).

Supported Modulations per Frequency and Channel Bandwidth

Table 26 shows the highest modulation possible for each frequency and channel bandwidth combination.

Table 26 *Supported Modulations per Frequency and Channel Bandwidth*

	14-20 MHz	25-30 MHz	40 MHz	50-60 MHz	80 MHz	112 MHz	120-224 MHz
6GHz	2048QAM	4096QAM	4096QAM	4096QAM	4096QAM	4096QAM 18	NA
7-8GHz	2048QAM	4096QAM	4096QAM	4096QAM	4096QAM	4096QAM	NA

	14-20 MHz	25-30 MHz	40 MHz	50-60 MHz	80 MHz	112 MHz	120-224 MHz
						18	
10 GHz	2048QAM	4096QAM	4096QAM	4096QAM	4096QAM	4096QAM 18	2048QAM
11GHz	2048QAM	4096QAM	4096QAM	4096QAM	4096QAM	4096QAM 18	2048QAM
13GHz	2048QAM	4096QAM	4096QAM	4096QAM	4096QAM	4096QAM 18	NA
15GHz	2048QAM	4096QAM	4096QAM	4096QAM	4096QAM	4096QAM 18	2048QAM
18GHz	2048QAM	4096QAM	4096QAM	4096QAM	4096QAM	4096QAM 18	2048QAM 18
23GHz	2048QAM	4096QAM	4096QAM	4096QAM 18	4096QAM 18	4096QAM 18 See Note 1	2048QAM 18
26GHz	2048QAM	4096QAM See Note 2	4096QAM 18	4096QAM 18	4096QAM 18	2048QAM 18	2048QAM 18
28GHz	2048QAM	4096QAM 18	4096QAM 18	2048QAM	4096QAM 18	4096QAM 1718	2048QAM 18
32GHz	2048QAM	4096QAM 18	4096QAM 18	2048QAM	4096QAM 18	4096QAM 1718	2048QAM 18
36GHz	2048QAM	2048QAM	2048QAM	2048QAM	2048QAM	2048QAM	2048QAM 18
38GHz	2048QAM	2048QAM	2048QAM	2048QAM	2048QAM	2048QAM	2048QAM 18
42GHz	2048QAM	2048QAM	2048QAM	2048QAM	2048QAM 17	2048QAM 17	2048QAM 1718

Note:

1. Not supported for all sub-bands.
2. One profile lower when AES-256 is enabled.

Radio Capacity Specifications

Note:

The figures in this section are indicative only. Exact results will depend on multiple factors, such as packet size, type of traffic, headers, etc.

Ethernet capacity depends on average frame size.

ACAP and ACCP represent compliance with different ETSI mask requirements. ACCP represents compliance with more stringent interference requirements.

14 MHz – Script ID 4509 (ETSI)

Table 27 *Radio Capacity with 14 MHz (Script 4509)*

Profile	Modulation	Minimum required capacity activation key	Ethernet Throughput (Mbps)
1	QPSK	50	16-20
2	8 QAM	50	26-32
3	16 QAM	50	37-46
4	32 QAM	50	50-61
5	64 QAM	50	62-76
6	128 QAM	100	76-93
7	256 QAM	100	87-106
8	512 QAM	100	96-118
9	1024 QAM (Strong FEC)	100	102-125
10	1024 QAM (Light FEC)	100	108-132
11	2048 QAM	100	113-138

20 MHz – Script ID 4521 (ANSI)

Table 28 *Radio Capacity with 20 MHz (Script 4521)*

Profile	Modulation	Minimum required capacity activation key	Ethernet Throughput (Mbps)
0	BPSK	-	10-13
1	QPSK	50	25-30
2	8 QAM	50	39-47
3	16 QAM	50	54-66
4	32 QAM	100	72-88
5	64 QAM	100	89-109

Profile	Modulation	Minimum required capacity activation key	Ethernet Throughput (Mbps)
6	128 QAM	100	108-132
7	256 QAM	150	123-150
8	512 QAM	150	134-164
9	1024 QAM (Strong FEC)	150	143-175
10	1024 QAM (Light FEC)	150	152-186
11	2048 QAM	200	162-198

25 MHz – Script ID 4525

Table 29 *Radio Capacity with 25 MHz (Script 4525)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	14-17
1	QPSK	50	32-40
2	8 QAM	50	50-61
3	16 QAM	100	69-84
4	32 QAM	100	92-112
5	64 QAM	100	113-139
6	128 QAM	150	137-168
7	256 QAM	150	157-192
8	512 QAM	200	174-212
9	1024 QAM (Strong FEC)	200	185-226
10	1024 QAM (Light FEC)	200	196-240
11	2048 QAM	225	211-258
12	4096 QAM	225	228-279

28 MHz – Script ID 4504 (ETSI)

Table 30 *Radio Capacity with 28 MHz (Script 4504)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	17-20
1	QPSK	50	37-46
2	8 QAM	50	57-70
3	16 QAM	100	79-96
4	32 QAM	100	105-128
5	64 QAM	150	130-158
6	128 QAM	150	157-191
7	256 QAM	200	179-218
8	512 QAM	200	198-242
9	1024 QAM (Strong FEC)	225	210-257
10	1024 QAM (Light FEC)	225	223-273
11	2048 QAM	250	240-293
12	4096 QAM	250	260-317

28/30 MHz – Script ID 4505 (ETSI and ANSI)

Table 31 *Radio Capacity with 28/30 MHz (Script 4505)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	18-22
1	QPSK	50	40-48
2	8 QAM	50	59-72
3	16 QAM	100	84-102
4	32 QAM	100	111-136
5	64 QAM	150	138-168
6	128 QAM	150	166-203

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
7	256 QAM	200	192-234
8	512 QAM	200	204-249
9	1024 QAM (Strong FEC)	225	223-272
10	1024 QAM (Light FEC)	225	236-289
11	2048 QAM	250	258-315
12	4096 QAM	300	275-336

28 MHz – Script ID 4514 (ETSI)

Table 32 *Radio Capacity with 28 MHz (Script 4514)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	16-19
1	QPSK	50	36-44
2	8 QAM	50	55-67
3	16 QAM	100	76-93
4	32 QAM	100	101-124
5	64 QAM	150	126-153
6	128 QAM	150	151-185
7	256 QAM	150	173-211
8	512 QAM	200	191-234
9	1024 QAM (Strong FEC)	200	204-249
10	1024 QAM (Light FEC)	225	216-264
11	2048 QAM	225	232-284
12	4096 QAM	250	247-302

40 MHz – Script ID 4507 (ETSI and ANSI)

Table 33 *Radio Capacity with 40 MHz (Script 4507)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	25-31
1	QPSK	50	54-67
2	8 QAM	100	83-101
3	16 QAM	100	113-139
4	32 QAM	150	150-184
5	64 QAM	200	185-227
6	128 QAM	225	225-275
7	256 QAM	250	242-296
8	512 QAM	300	265-324
9	1024 QAM (Strong FEC)	300	301-368
10	1024 QAM (Light FEC)	300	320-391
11	2048 QAM	350	346-423
12	4096 QAM	400	366-448

50 MHz – Script ID 4510 (ANSI)

Table 34 *Radio Capacity with 50 MHz (Script 4510)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	33-40
1	QPSK	100	67-82
2	8 QAM	100	105-129
3	16 QAM	150	144-176
4	32 QAM	200	181-222
5	64 QAM	225	235-287
6	128 QAM	300	275-336

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
7	256 QAM	300	326-399
8	512 QAM	350	354-433
9	1024 QAM (Strong FEC)	400	386-472
10	1024 QAM (Light FEC)	400	410-501
11	2048 QAM	450	442-541
12	4096 QAM	450	459-561

56 MHz – Script ID 4502 (ETSI)

Table 35 *Radio Capacity with 56 MHz (Script 4502)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	38-46
1	QPSK	100	79-97
2	8 QAM	100	119-146
3	16 QAM	150	163-200
4	32 QAM	225	216-264
5	64 QAM	300	265-324
6	128 QAM	300	322-393
7	256 QAM	400	368-450
8	512 QAM	400	400-489
9	1024 QAM (Strong FEC)	450	435-532
10	1024 QAM (Light FEC)	450	462-565
11	2048 QAM	500	487-595
12	4096 QAM	500	516-631

56/60 MHz – Script ID 4506 (ETSI and ANSI)

Table 36 *Radio Capacity for 56/60 MHz (Script 4506)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	40-49
1	QPSK	100	83-102
2	8 QAM	150	123-150
3	16 QAM	200	172-210
4	32 QAM	225	227-277
5	64 QAM	300	279-341
6	128 QAM	350	338-413
7	256 QAM	400	391-478
8	512 QAM	450	420-514
9	1024 QAM (Strong FEC)	450	457-559
10	1024 QAM (Light FEC)	500	486-594
11	2048 QAM	500	527-644
12	4096 QAM	500	542-663

70 MHz – Script ID 4513 (ETSI)

Table 37 *Radio Capacity for 70 MHz (Script 4513)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	47-57
1	QPSK	100	96-118
2	8 QAM	150	138-168
3	16 QAM	200	198-242
4	32 QAM	250	261-318
5	64 QAM	300	319-390
6	128 QAM	400	378-462

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
7	256 QAM	450	436-532
8	512 QAM	500	479-585
9	1024 QAM (Strong FEC)	500	521-637
10	1024 QAM (Light FEC)	650	553-676
11	2048 QAM	650	586-716
12	4096 QAM	650	618-756

80 MHz – Script ID 4501 (ETSI and ANSI)

Table 38 *Radio Capacity for 80 MHz (Script 4501)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	55-67
1	QPSK	100	114-139
2	8 QAM	150	162-198
3	16 QAM	225	229-280
4	32 QAM	300	304-371
5	64 QAM	400	373-456
6	128 QAM	450	448-547
7	256 QAM	500	514-628
8	512 QAM	650	564-690
9	1024 QAM (Strong FEC)	650	606-741
10	1024 QAM (Light FEC)	650	645-789
11	2048 QAM	650	683-835
12	4096 QAM	650	719-879

80 MHz – Script ID 4588 (ETSI)

Table 39 *Radio Capacity for 80 MHz (Script 4588)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	50	59-72
1	QPSK	100	122-149
2	8 QAM	200	174-213
3	16 QAM	250	245-299
4	32 QAM	300	325-398
5	64 QAM	400	399-488
6	128 QAM	500	479-586
7	256 QAM	500	550-673
8	512 QAM	650	604-739
9	1024 QAM (Strong FEC)	650	649-793
10	1024 QAM (Light FEC)	650	691-844
11	2048 QAM	1000	731-894
12	4096 QAM	1000	769-940

112 MHz - Script ID 4511 (ETSI)

Table 40 *Radio Capacity for 112 MHz (Script 4511)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	100	79-97
1	QPSK	150	162-198
2	8 QAM	250	242-296
3	16 QAM	350	330-404
4	32 QAM	450	435-532
5	64 QAM	500	535-654
6	128 QAM	650	647-791

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
7	256 QAM	1000	740-905
8	512 QAM	1000	804-983
9	1024 QAM (Strong FEC)	1000	872-1066
10	1024 QAM (Light FEC)	1000	926-1132
11	2048 QAM	1000	999-1221
12	4096 QAM	1000	1034-1264

140 MHz – Script ID 4518 (ETSI)

Table 41 *Radio Capacity for 70 MHz (Script 4518)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	100	100-122
1	QPSK	200	204-249
2	8 QAM	300	304-371
3	16 QAM	400	414-506
4	32 QAM	500	545-666
5	64 QAM	650	694-848
6	128 QAM	1000	810-990
7	256 QAM	1000	926-1132
8	512 QAM	1000	1047-1280
9	1024 QAM	1600	1163-1422
10	2048 QAM	1600	1280-1564

150 MHz – Script ID 4515 (ANSI)

Table 42 *Radio Capacity for 150 MHz (Script 4515)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	100	107-131
1	QPSK	225	218-266

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
2	8 QAM	300	325-397
3	16 QAM	450	442-541
4	32 QAM	650	583-712
5	64 QAM	1000	742-906
6	128 QAM	1000	865-1058
7	256 QAM	1000	990-1210
8	512 QAM	1600	1119-1368
9	1024 QAM	1600	1243-1520
10	2048 QAM	1600	1368-1672

160 MHz – Script ID 4516 (ANSI)

Table 43 *Radio Capacity with 160 MHz (Script 4516)*

Profile	Modulation	Minimum required capacity activation key	Ethernet Throughput (Mbps)
0	BPSK	100	112-137
1	QPSK	225	229-280
2	8 QAM	350	341-417
3	16 QAM	500	464-567
4	32 QAM	650	611-747
5	64 QAM	1000	778-951
6	128 QAM	1000	908-1109
7	256 QAM	1000	1037-1268
8	512 QAM	1600	1173-1434
9	1024 QAM	1600	1302-1591
10	2048 QAM	1600	1431-1750

200 MHz – Script ID 4522 (ETSI and ANSI)

Table 44 *Radio Capacity with 200 MHz (Script 4522)*

Profile	Modulation	Minimum required capacity activation key	Ethernet Throughput (Mbps)
0	BPSK	150	144-176

Profile	Modulation	Minimum required capacity activation key	Ethernet Throughput (Mbps)
1	QPSK	300	292-357
2	8 QAM	450	435-531
3	16 QAM	650	591-723
4	32 QAM	1000	778-951
5	64 QAM	1000	989-1209
6	128 QAM	1600	1155-1412
7	256 QAM	1600	1321-1615
8	512 QAM	1600	1494-1826
9	1024 QAM	1600	1655-2023
10	2048 QAM	2000	1787-2185

224 MHz – Script ID 4524 (ETSI)

Table 45 *Radio Capacity for 224 MHz (Script 4524)*

Profile	Modulation	Minimum required capacity activation key	Ethernet throughput (Mbps)
0	BPSK	150	162-198
1	QPSK	350	328-401
2	8 QAM	500	489-597
3	16 QAM	500	665-812
4	32 QAM	1000	875-1069
5	64 QAM	1600	1111-1358
6	128 QAM	1600	1298-1587
7	256 QAM	1600	1484-1815
8	512 QAM	1600	1678-2051
9	1024 QAM (Strong FEC)	2000	1860-2274
10	2048 QAM	2000	2009-2456

Note:

224 MHz is only supported with certain hardware versions. For details, ask your Cambium representative.

Transmit Power Specifications

Note:

Nominal TX power is subject to change until the relevant frequency band is formally released. See the frequency rollout plan.

The values listed in this section are typical. Actual values may differ in either direction by up to 2 dB.

Table 46 *Transmit Power Specifications (dBm)*

Modulation	6 GHz	7-8 GHz	10-11 GHz	13 GHz	15 GHz	18 GHz	23 GHz	26 GHz	28 GHz	32 GHz	38 GHz	42 GHz
BPSK	28	28	28	26	25	24	24	22	22	22	22	15
QPSK	28	28	28	26	25	24	24	22	22	22	22	15
8 QAM	28	28	28	26	25	24	24	22	22	22	22	15
16 QAM	28	27	28	25	24	24	24	22	21	21	21	15
32 QAM	28	27	28	24	24	24	24	22	21	21	21	14
64 QAM	28	26	27	24	24	23	24	21	20	20	20	13
128 QAM	27	26	26	24	24	23	24	21	20	20	20	13
256 QAM	27	26	26	24	23	23	23	20	19	19	19	13
512 QAM	27	25	26	23	22	22	22	20	19	19	19	11
1024 QAM	26	24	25	22	21	21	21	20	18	18	18	11
2048 QAM	25	23	24	21	21	20	20	19	18	18	18	10
4096 QAM	24	21	22	20	20	19	19	18	17	17	17	

Pmin Power

Table 47 *Pmin Power*

Frequency Band	Pmin	Frequency Band	Pmin
6-11 GHz	4	18 GHz	1
13, 15, and 23 GHz	2	26 GHz	-1
28-42 GHz	2		

Receiver Threshold Specifications (dBm@ $10E^{-6}$)

Note:

The RSL values listed in this section refer to fixed profiles. When ACM is enabled, the RSL levels may be different when the radio switches to other profiles.

The values listed in this section are typical. Actual values may differ in either direction by up to 2dB.

160 MHz and 224 MHz channels are not supported with 6 GHz. For 7-8 GHz, support for 160 MHz and 224 MHz channels may be offered in future releases.

Table 48 *14 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	14 MHz	-93.5	-93.0	-93.0	-92.0	-92.0	-92.0	-92.0	-93.0
1	QPSK		-90.6	-90.1	-90.1	-89.1	-89.1	-89.1	-89.1	-90.1
2	8 QAM		-86.7	-86.2	-86.2	-85.2	-85.2	-85.2	-85.2	-86.2
3	16 QAM		-83.6	-83.1	-83.1	-82.1	-82.1	-82.1	-82.1	-83.1
4	32 QAM		-80.3	-79.8	-79.8	-78.8	-78.8	-78.8	-78.8	-79.8
5	64 QAM		-77.1	-76.6	-76.6	-75.6	-75.6	-75.6	-75.6	-76.6
6	128 QAM		-74.0	-73.5	-73.5	-72.5	-72.5	-72.5	-72.5	-73.5
7	256 QAM		-70.6	-70.1	-70.1	-69.1	-69.1	-69.1	-69.1	-70.1
8	512 QAM		-67.7	-67.2	-67.2	-66.2	-66.2	-66.2	-66.2	-67.2
9	1024 QAM (Strong FEC)		-64.2	-63.7	-63.7	-62.7	-62.7	-62.7	-62.7	-63.7
10	1024 QAM (Light FEC)		-63.3	-62.8	-62.8	-61.8	-61.8	-61.8	-61.8	-62.8
11	2048 QAM		-60.1	-59.6	-59.6	-58.6	-58.6	-58.6	-58.6	-59.6

Table 49 *20 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	20 MHz	-92.1	-91.6	-91.6	-90.6	-90.6	-90.6	-90.6	-91.6
1	QPSK		-89.2	-88.7	-88.7	-87.7	-87.7	-87.7	-87.7	-88.7
2	8 QAM		-85.2	-84.7	-84.7	-83.7	-83.7	-83.7	-83.7	-84.7
3	16 QAM		-82.3	-81.8	-81.8	-80.8	-80.8	-80.8	-80.8	-81.8
4	32 QAM		-78.9	-78.4	-78.4	-77.4	-77.4	-77.4	-77.4	-78.4
5	64 QAM		-75.7	-75.2	-75.2	-74.2	-74.2	-74.2	-74.2	-75.2
6	128 QAM		-72.7	-72.2	-72.2	-71.2	-71.2	-71.2	-71.2	-72.2
7	256 QAM		-69.6	-69.1	-69.1	-68.1	-68.1	-68.1	-68.1	-69.1
8	512 QAM		-66.8	-66.3	-66.3	-65.3	-65.3	-65.3	-65.3	-66.3
9	1024 QAM (Strong FEC)		-63.9	-63.4	-63.4	-62.4	-62.4	-62.4	-62.4	-63.4
10	1024 QAM (Light FEC)		-63.2	-62.7	-62.7	-61.7	-61.7	-61.7	-61.7	-62.7
11	2048 QAM		-60.7	-60.2	-60.2	-59.2	-59.2	-59.2	-59.2	-60.2

Table 50 *25 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	25 MHz	-91.1	-90.6	-90.6	-89.6	-89.6	-89.6	-89.6	-90.6
1	QPSK		-88.1	-87.6	-87.6	-86.6	-86.6	-86.6	-86.6	-87.6
2	8 QAM		-84.1	-83.6	-83.6	-82.6	-82.6	-82.6	-82.6	-83.6
3	16 QAM		-81.2	-80.7	-80.7	-79.7	-79.7	-79.7	-79.7	-80.7
4	32 QAM		-77.9	-77.4	-77.4	-76.4	-76.4	-76.4	-76.4	-77.4
5	64 QAM		-74.8	-74.3	-74.3	-73.3	-73.3	-73.3	-73.3	-74.3
6	128 QAM		-71.7	-71.2	-71.2	-70.2	-70.2	-70.2	-70.2	-71.2
7	256 QAM		-68.6	-68.1	-68.1	-67.1	-67.1	-67.1	-67.1	-68.1
8	512 QAM		-65.7	-65.2	-65.2	-64.2	-64.2	-64.2	-64.2	-65.2
9	1024 QAM (Strong FEC)		-62.8	-62.3	-62.3	-61.3	-61.3	-61.3	-61.3	-62.3
10	1024 QAM (Light FEC)		-61.9	-61.4	-61.4	-60.4	-60.4	-60.4	-60.4	-61.4
11	2048 QAM		-59.8	-59.3	-59.3	-58.3	-58.3	-58.3	-58.3	-59.3
12	4096 QAM		-55.7	-55.2	-55.2	-54.2	-54.2	-54.2	-54.2	-55.2

Table 51 *25 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	28 MHz	-90.5	-90.0	-90.0	-89.0	-89.0	-89.0	-89.0	-90.0
1	QPSK		-87.5	-87.0	-87.0	-86.0	-86.0	-86.0	-86.0	-87.0
2	8 QAM		-83.6	-83.1	-83.1	-82.1	-82.1	-82.1	-82.1	-83.1
3	16 QAM		-80.6	-80.1	-80.1	-79.1	-79.1	-79.1	-79.1	-80.1
4	32 QAM		-77.3	-76.8	-76.8	-75.8	-75.8	-75.8	-75.8	-76.8
5	64 QAM		-74.3	-73.8	-73.8	-72.8	-72.8	-72.8	-72.8	-73.8
6	128 QAM		-71.2	-70.7	-70.7	-69.7	-69.7	-69.7	-69.7	-70.7
7	256 QAM		-68.1	-67.6	-67.6	-66.6	-66.6	-66.6	-66.6	-67.6
8	512 QAM		-65.3	-64.8	-64.8	-63.8	-63.8	-63.8	-63.8	-64.8
9	1024 QAM (Strong FEC)		-62.4	-61.9	-61.9	-60.9	-60.9	-60.9	-60.9	-61.9
10	1024 QAM (Light FEC)		-61.7	-61.2	-61.2	-60.2	-60.2	-60.2	-60.2	-61.2
11	2048 QAM		-59.2	-58.7	-58.7	-57.7	-57.7	-57.7	-57.7	-58.7
12	4096 QAM		-55.2	-54.7	-54.7	-53.7	-53.7	-53.7	-53.7	-54.7

Table 52 *30 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	30 MHz	-90.4	-89.9	-89.9	-88.9	-88.9	-88.9	-88.9	-89.9
1	QPSK		-87.4	-86.9	-86.9	-85.9	-85.9	-85.9	-85.9	-86.9
2	8 QAM		-83.4	-82.9	-82.9	-81.9	-81.9	-81.9	-81.9	-82.9
3	16 QAM		-80.4	-79.9	-79.9	-78.9	-78.9	-78.9	-78.9	-79.9
4	32 QAM		-77.1	-76.6	-76.6	-75.6	-75.6	-75.6	-75.6	-76.6
5	64 QAM		-74.0	-73.5	-73.5	-72.5	-72.5	-72.5	-72.5	-73.5
6	128 QAM		-71.0	-70.5	-70.5	-69.5	-69.5	-69.5	-69.5	-70.5
7	256 QAM		-67.8	-67.3	-67.3	-66.3	-66.3	-66.3	-66.3	-67.3
8	512 QAM		-65.5	-65.0	-65.0	-64.0	-64.0	-64.0	-64.0	-65.0
9	1024 QAM (Strong FEC)		-62.2	-61.7	-61.7	-60.7	-60.7	-60.7	-60.7	-61.7
10	1024 QAM (Light FEC)		-61.4	-60.9	-60.9	-59.9	-59.9	-59.9	-59.9	-60.9
11	2048 QAM		-58.9	-58.4	-58.4	-57.4	-57.4	-57.4	-57.4	-58.4
12	4096 QAM		-55.2	-54.7	-54.7	-53.7	-53.7	-53.7	-53.7	-54.7

Table 53 *50 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	50 MHz	-88.2	-87.7	-87.7	-86.7	-86.7	-86.7	-86.7	-87.7
1	QPSK		-85.3	-84.8	-84.8	-83.8	-83.8	-83.8	-83.8	-84.8
2	8 QAM		-81.0	-80.5	-80.5	-79.5	-79.5	-79.5	-79.5	-80.5
3	16 QAM		-78.1	-77.6	-77.6	-76.6	-76.6	-76.6	-76.6	-77.6
4	32 QAM		-75.1	-74.6	-74.6	-73.6	-73.6	-73.6	-73.6	-74.6
5	64 QAM		-71.7	-71.2	-71.2	-70.2	-70.2	-70.2	-70.2	-71.2
6	128 QAM		-69.2	-68.7	-68.7	-67.7	-67.7	-67.7	-67.7	-68.7
7	256 QAM		-65.6	-65.1	-65.1	-64.1	-64.1	-64.1	-64.1	-65.1
8	512 QAM		-63.1	-62.6	-62.6	-61.6	-61.6	-61.6	-61.6	-62.6
9	1024 QAM (Strong FEC)		-59.7	-59.2	-59.2	-58.2	-58.2	-58.2	-58.2	-59.2
10	1024 QAM (Light FEC)		-58.9	-58.4	-58.4	-57.4	-57.4	-57.4	-57.4	-58.4
11	2048 QAM		-56.6	-56.1	-56.1	-55.1	-55.1	-55.1	-55.1	-56.1
12	4096 QAM		-53.1	-52.6	-52.6	-51.6	-51.6	-51.6	-51.6	-52.6

Table 54 *56 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	56 MHz	-87.7	-87.2	-87.2	-86.2	-86.2	-86.2	-86.2	-87.2
1	QPSK		-84.5	-84.0	-84.0	-83.0	-83.0	-83.0	-83.0	-84.0
2	8 QAM		-80.4	-79.9	-79.9	-78.9	-78.9	-78.9	-78.9	-79.9
3	16 QAM		-77.5	-77.0	-77.0	-76.0	-76.0	-76.0	-76.0	-77.0
4	32 QAM		-74.2	-73.7	-73.7	-72.7	-72.7	-72.7	-72.7	-73.7
5	64 QAM		-71.2	-70.7	-70.7	-69.7	-69.7	-69.7	-69.7	-70.7
6	128 QAM		-68.3	-67.8	-67.8	-66.8	-66.8	-66.8	-66.8	-67.8
7	256 QAM		-65.1	-64.6	-64.6	-63.6	-63.6	-63.6	-63.6	-64.6
8	512 QAM		-62.5	-62.0	-62.0	-61.0	-61.0	-61.0	-61.0	-62.0
9	1024 QAM (Strong FEC)		-59.2	-58.7	-58.7	-57.7	-57.7	-57.7	-57.7	-58.7
10	1024 QAM (Light FEC)		-58.3	-57.8	-57.8	-56.8	-56.8	-56.8	-56.8	-57.8
11	2048 QAM		-56.5	-56.0	-56.0	-55.0	-55.0	-55.0	-55.0	-56.0
12	4096 QAM		-52.6	-52.1	-52.1	-51.1	-51.1	-51.1	-51.1	-52.1

Table 55 *60 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	60 MHz	-87.5	-87.0	-87.0	-86.0	-86.0	-86.0	-86.0	-87.0
1	QPSK		-84.3	-83.8	-83.8	-82.8	-82.8	-82.8	-82.8	-83.8
2	8 QAM		-80.5	-80.0	-80.0	-79.0	-79.0	-79.0	-79.0	-80.0
3	16 QAM		-77.3	-76.8	-76.8	-75.8	-75.8	-75.8	-75.8	-76.8
4	32 QAM		-74.0	-73.5	-73.5	-72.5	-72.5	-72.5	-72.5	-73.5
5	64 QAM		-70.9	-70.4	-70.4	-69.4	-69.4	-69.4	-69.4	-70.4
6	128 QAM		-68.1	-67.6	-67.6	-66.6	-66.6	-66.6	-66.6	-67.6
7	256 QAM		-64.9	-64.4	-64.4	-63.4	-63.4	-63.4	-63.4	-64.4
8	512 QAM		-62.4	-61.9	-61.9	-60.9	-60.9	-60.9	-60.9	-61.9
9	1024 QAM (Strong FEC)		-59.1	-58.6	-58.6	-57.6	-57.6	-57.6	-57.6	-58.6
10	1024 QAM (Light FEC)		-58.3	-57.8	-57.8	-56.8	-56.8	-56.8	-56.8	-57.8
11	2048 QAM		-56.0	-55.5	-55.5	-54.5	-54.5	-54.5	-54.5	-55.5
12	4096 QAM		-52.2	-51.7	-51.7	-50.7	-50.7	-50.7	-50.7	-51.7

Table 56 *70 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	70 MHz	-86.7	-86.2	-86.2	-85.2	-85.2	-85.2	-85.2	-86.2
1	QPSK		-83.9	-83.4	-83.4	-82.4	-82.4	-82.4	-82.4	-83.4
2	8 QAM		-80.2	-79.7	-79.7	-78.7	-78.7	-78.7	-78.7	-79.7
3	16 QAM		-77.2	-76.7	-76.7	-75.7	-75.7	-75.7	-75.7	-76.7
4	32 QAM		-73.6	-73.1	-73.1	-72.1	-72.1	-72.1	-72.1	-73.1
5	64 QAM		-70.7	-70.2	-70.2	-69.2	-69.2	-69.2	-69.2	-70.2
6	128 QAM		-67.9	-67.4	-67.4	-66.4	-66.4	-66.4	-66.4	-67.4
7	256 QAM		-65.1	-64.6	-64.6	-63.6	-63.6	-63.6	-63.6	-64.6
8	512 QAM		-62.4	-61.9	-61.9	-60.9	-60.9	-60.9	-60.9	-61.9
9	1024 QAM (Strong FEC)		-59.5	-59.0	-59.0	-58.0	-58.0	-58.0	-58.0	-59.0
10	1024 QAM (Light FEC)		-58.8	-58.3	-58.3	-57.3	-57.3	-57.3	-57.3	-58.3
11	2048 QAM		-56.6	-56.1	-56.1	-55.1	-55.1	-55.1	-55.1	-56.1
12	4096 QAM		-53.2	-52.7	-52.7	-51.7	-51.7	-51.7	-51.7	-52.7

Table 57 *70 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	80 MHz	-86.1	-85.6	-85.6	-84.6	-84.6	-84.6	-84.6	-85.6
1	QPSK		-83.3	-82.8	-82.8	-81.8	-81.8	-81.8	-81.8	-82.8
2	8 QAM		-79.8	-79.3	-79.3	-78.3	-78.3	-78.3	-78.3	-79.3
3	16 QAM		-76.8	-76.3	-76.3	-75.3	-75.3	-75.3	-75.3	-76.3
4	32 QAM		-73.2	-72.7	-72.7	-71.7	-71.7	-71.7	-71.7	-72.7
5	64 QAM		-70.1	-69.6	-69.6	-68.6	-68.6	-68.6	-68.6	-69.6
6	128 QAM		-67.0	-66.5	-66.5	-65.5	-65.5	-65.5	-65.5	-66.5
7	256 QAM		-64.2	-63.7	-63.7	-62.7	-62.7	-62.7	-62.7	-63.7
8	512 QAM		-61.3	-60.8	-60.8	-59.8	-59.8	-59.8	-59.8	-60.8
9	1024 QAM (Strong FEC)		-58.5	-58.0	-58.0	-57.0	-57.0	-57.0	-57.0	-58.0
10	1024 QAM (Light FEC)		-57.4	-56.9	-56.9	-55.9	-55.9	-55.9	-55.9	-56.9
11	2048 QAM		-54.9	-54.4	-54.4	-53.4	-53.4	-53.4	-53.4	-54.4
12	4096 QAM		-51.7	-51.2	-51.2	-50.2	-50.2	-50.2	-50.2	-51.2

Table 58 *112 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	112 MHz	-84.0	-83.5	-83.5	-82.5	-82.5	-82.5	-82.5	-83.5
1	QPSK		-81.6	-81.1	-81.1	-80.1	-80.1	-80.1	-80.1	-81.1
2	8 QAM		-77.6	-77.1	-77.1	-76.1	-76.1	-76.1	-76.1	-77.1
3	16 QAM		-74.7	-74.2	-74.2	-73.2	-73.2	-73.2	-73.2	-74.2
4	32 QAM		-71.3	-70.8	-70.8	-69.8	-69.8	-69.8	-69.8	-70.8
5	64 QAM		-68.3	-67.8	-67.8	-66.8	-66.8	-66.8	-66.8	-67.8
6	128 QAM		-65.4	-64.9	-64.9	-63.9	-63.9	-63.9	-63.9	-64.9
7	256 QAM		-62.4	-61.9	-61.9	-60.9	-60.9	-60.9	-60.9	-61.9
8	512 QAM		-60.0	-59.5	-59.5	-58.5	-58.5	-58.5	-58.5	-59.5
9	1024 QAM (Strong FEC)		-57.0	-56.5	-56.5	-55.5	-55.5	-55.5	-55.5	-56.5
10	1024 QAM (Light FEC)		-56.3	-55.8	-55.8	-54.8	-54.8	-54.8	-54.8	-55.8
11	2048 QAM		-53.7	-53.2	-53.2	-52.2	-52.2	-52.2	-52.2	-53.2
12	4096 QAM		-51.0	-50.5	-50.5	-49.5	-49.5	-49.5	-49.5	-50.5

Table 59 *112 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	140 MHz		-83.4	-83.4	-82.4	-82.4	-82.4	-82.4	-83.4
1	QPSK			-80.1	-80.1	-79.1	-79.1	-79.1	-79.1	-80.1
2	8 QAM			-76.5	-76.5	-75.5	-75.5	-75.5	-75.5	-76.5
3	16 QAM			-73.4	-73.4	-72.4	-72.4	-72.4	-72.4	-73.4
4	32 QAM			-69.8	-69.8	-68.8	-68.8	-68.8	-68.8	-69.8
5	64 QAM			-66.4	-66.4	-65.4	-65.4	-65.4	-65.4	-66.4
6	128 QAM			-63.9	-63.9	-62.9	-62.9	-62.9	-62.9	-63.9
7	256 QAM			-60.9	-60.9	-59.9	-59.9	-59.9	-59.9	-60.9
8	512 QAM			-58.0	-58.0	-57.0	-57.0	-57.0	-57.0	-58.0
9	1024 QAM			-54.9	-54.9	-53.9	-53.9	-53.9	-53.9	-54.9
10	2048 QAM			-51.8	-51.8	-50.8	-50.8	-50.8	-50.8	-51.8

Table 60 *150 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	150 MHz		-83.1	-83.1	-82.1	-82.1	-82.1	-82.1	-83.1
1	QPSK			-80.0	-80.0	-79.0	-79.0	-79.0	-79.0	-80.0
2	8 QAM			-76.2	-76.2	-75.2	-75.2	-75.2	-75.2	-76.2
3	16 QAM			-73.0	-73.0	-72.0	-72.0	-72.0	-72.0	-73.0
4	32 QAM			-69.6	-69.6	-68.6	-68.6	-68.6	-68.6	-69.6
5	64 QAM			-66.2	-66.2	-65.2	-65.2	-65.2	-65.2	-66.2
6	128 QAM			-63.7	-63.7	-62.7	-62.7	-62.7	-62.7	-63.7
7	256 QAM			-60.7	-60.7	-59.7	-59.7	-59.7	-59.7	-60.7
8	512 QAM			-57.8	-57.8	-56.8	-56.8	-56.8	-56.8	-57.8
9	1024 QAM			-54.8	-54.8	-53.8	-53.8	-53.8	-53.8	-54.8
10	2048 QAM			-51.5	-51.5	-50.5	-50.5	-50.5	-50.5	-51.5

Table 61 *160 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	160 MHz		-82.0	-82.0	-81.0	-81.0	-81.0	-81.0	-82.0
1	QPSK			-79.8	-79.8	-78.8	-78.8	-78.8	-78.8	-79.8
2	8 QAM			-75.3	-75.3	-74.3	-74.3	-74.3	-74.3	-75.3
3	16 QAM			-72.9	-72.9	-71.9	-71.9	-71.9	-71.9	-72.9
4	32 QAM			-69.5	-69.5	-68.5	-68.5	-68.5	-68.5	-69.5
5	64 QAM			-66.2	-66.2	-65.2	-65.2	-65.2	-65.2	-66.2
6	128 QAM			-63.4	-63.4	-62.4	-62.4	-62.4	-62.4	-63.4
7	256 QAM			-60.3	-60.3	-59.3	-59.3	-59.3	-59.3	-60.3
8	512 QAM			-57.6	-57.6	-56.6	-56.6	-56.6	-56.6	-57.6
9	1024 QAM			-54.3	-54.3	-53.3	-53.3	-53.3	-53.3	-54.3
10	2048 QAM			-50.5	-50.5	-49.5	-49.5	-49.5	-49.5	-50.5

Table 62 *200 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	200 MHz		-81.4	-81.4	-80.4	-80.4	-80.4	-80.4	-81.4
1	QPSK			-78.5	-78.5	-77.5	-77.5	-77.5	-77.5	-78.5
2	8 QAM			-74.6	-74.6	-73.6	-73.6	-73.6	-73.6	-74.6
3	16 QAM			-71.7	-71.7	-70.7	-70.7	-70.7	-70.7	-71.7
4	32 QAM			-68.1	-68.1	-67.1	-67.1	-67.1	-67.1	-68.1
5	64 QAM			-64.8	-64.8	-63.8	-63.8	-63.8	-63.8	-64.8
6	128 QAM			-62.2	-62.2	-61.2	-61.2	-61.2	-61.2	-62.2
7	256 QAM			-59.2	-59.2	-58.2	-58.2	-58.2	-58.2	-59.2
8	512 QAM			-55.9	-55.9	-54.9	-54.9	-54.9	-54.9	-55.9
9	1024 QAM			-52.4	-52.4	-51.4	-51.4	-51.4	-51.4	-52.4
10	2048 QAM			-48.7	-48.7	-47.7	-47.7	-47.7	-47.7	-48.7

Table 63 *224 MHz Receiver Thresholds (6-18 GHz)*

Profile	Modulation	Channel Spacing	6	7	8	10	11	13	15	18
0	BPSK	224 MHz See Note.		-81.3	-81.3	-80.3	-80.3	-80.3	-80.3	-81.3
1	QPSK			-78.2	-78.2	-77.2	-77.2	-77.2	-77.2	-78.2
2	8 QAM			-74.4	-74.4	-73.4	-73.4	-73.4	-73.4	-74.4
3	16 QAM			-71.4	-71.4	-70.4	-70.4	-70.4	-70.4	-71.4
4	32 QAM			-67.8	-67.8	-66.8	-66.8	-66.8	-66.8	-67.8
5	64 QAM			-64.5	-64.5	-63.5	-63.5	-63.5	-63.5	-64.5
6	128 QAM			-61.9	-61.9	-60.9	-60.9	-60.9	-60.9	-61.9
7	256 QAM			-58.9	-58.9	-57.9	-57.9	-57.9	-57.9	-58.9
8	512 QAM			-55.5	-55.5	-54.5	-54.5	-54.5	-54.5	-55.5
9	1024 QAM			-51.9	-51.9	-50.9	-50.9	-50.9	-50.9	-51.9
10	2048 QAM			-48.2	-48.2	-47.2	-47.2	-47.2	-47.2	-48.2

Note:

224 MHz is only supported with certain hardware versions. For details, ask your Cambium representative.

Table 64 *14 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	14 MHz	-92.0	-91.0	-91.5	-91.5	-91.5	-91.5	-91.5	-90.5
1	QPSK		-89.1	-88.1	-88.6	-88.6	-88.6	-88.6	-88.6	-87.6
2	8 QAM		-85.2	-84.2	-84.7	-84.7	-84.7	-84.7	-84.7	-83.7
3	16 QAM		-82.1	-81.1	-81.6	-81.6	-81.6	-81.6	-81.6	-80.6
4	32 QAM		-78.8	-77.8	-78.3	-78.3	-78.3	-78.3	-78.3	-77.3
5	64 QAM		-75.6	-74.6	-75.1	-75.1	-75.1	-75.1	-75.1	-74.1
6	128 QAM		-72.5	-71.5	-72.0	-72.0	-72.0	-72.0	-72.0	-71.0
7	256 QAM		-69.1	-68.1	-68.6	-68.6	-68.6	-68.6	-68.6	-67.6
8	512 QAM		-66.2	-65.2	-65.7	-65.7	-65.7	-65.7	-65.7	-64.7
9	1024 QAM (Strong FEC)		-62.7	-61.7	-62.2	-62.2	-62.2	-62.2	-62.2	-61.2
10	1024 QAM (Light FEC)		-61.8	-60.8	-61.3	-61.3	-61.3	-61.3	-61.3	-60.3
11	2048 QAM		-58.6	-57.6	-58.1	-58.1	-58.1	-58.1	-58.1	-57.0

Table 65 *20 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	20 MHz	-90.6	-89.6	-90.1	-90.1	-90.1	-90.1	-90.1	
1	QPSK		-87.7	-86.7	-87.2	-87.2	-87.2	-87.2	-87.2	
2	8 QAM		-83.7	-82.7	-83.2	-83.2	-83.2	-83.2	-83.2	
3	16 QAM		-80.8	-79.8	-80.3	-80.3	-80.3	-80.3	-80.3	
4	32 QAM		-77.4	-76.4	-76.9	-76.9	-76.9	-76.9	-76.9	
5	64 QAM		-74.2	-73.2	-73.7	-73.7	-73.7	-73.7	-73.7	
6	128 QAM		-71.2	-70.2	-70.7	-70.7	-70.7	-70.7	-70.7	
7	256 QAM		-68.1	-67.1	-67.6	-67.6	-67.6	-67.6	-67.6	
8	512 QAM		-65.3	-64.3	-64.8	-64.8	-64.8	-64.8	-64.8	
9	1024 QAM (Strong FEC)		-62.4	-61.4	-61.9	-61.9	-61.9	-61.9	-61.9	
10	1024 QAM (Light FEC)		-61.7	-60.7	-61.2	-61.2	-61.2	-61.2	-61.2	
11	2048 QAM		-59.2	-58.2	-58.7	-58.7	-58.7	-58.7	-58.7	

Table 66 *25 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	25 MHz	-89.6	-88.6	-89.1	-89.1	-89.1	-89.1	-89.1	
1	QPSK		-86.6	-85.6	-86.1	-86.1	-86.1	-86.1	-86.1	
2	8 QAM		-82.6	-81.6	-82.1	-82.1	-82.1	-82.1	-82.1	
3	16 QAM		-79.7	-78.7	-79.2	-79.2	-79.2	-79.2	-79.2	
4	32 QAM		-76.4	-75.4	-75.9	-75.9	-75.9	-75.9	-75.9	
5	64 QAM		-73.3	-72.3	-72.8	-72.8	-72.8	-72.8	-72.8	
6	128 QAM		-70.2	-69.2	-69.7	-69.7	-69.7	-69.7	-69.7	
7	256 QAM		-67.1	-66.1	-66.6	-66.6	-66.6	-66.6	-66.6	
8	512 QAM		-64.2	-63.2	-63.7	-63.7	-63.7	-63.7	-63.7	
9	1024 QAM (Strong FEC)		-61.3	-60.3	-60.8	-60.8	-60.8	-60.8	-60.8	
10	1024 QAM (Light FEC)		-60.4	-59.4	-59.9	-59.9	-59.9	-59.9	-59.9	
11	2048 QAM		-58.3	-57.3	-57.8	-57.8	-57.8	-57.8	-57.8	
12	4096 QAM		-54.2	-53.2	-53.7	-53.7	-53.7			

Table 67 *28 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	28 MHz	-89.0	-88.0	-88.5	-88.5	-88.5	-88.5	-88.5	-87.5
1	QPSK		-86.0	-85.0	-85.5	-85.5	-85.5	-85.5	-85.5	-84.5
2	8 QAM		-82.1	-81.1	-81.6	-81.6	-81.6	-81.6	-81.6	-80.6
3	16 QAM		-79.1	-78.1	-78.6	-78.6	-78.6	-78.6	-78.6	-77.6
4	32 QAM		-75.8	-74.8	-75.3	-75.3	-75.3	-75.3	-75.3	-74.3
5	64 QAM		-72.8	-71.8	-72.3	-72.3	-72.3	-72.3	-72.3	-71.3
6	128 QAM		-69.7	-68.7	-69.2	-69.2	-69.2	-69.2	-69.2	-68.2
7	256 QAM		-66.6	-65.6	-66.1	-66.1	-66.1	-66.1	-66.1	-65.1
8	512 QAM		-63.8	-62.8	-63.3	-63.3	-63.3	-63.3	-63.3	-62.3
9	1024 QAM (Strong FEC)		-60.9	-59.9	-60.4	-60.4	-60.4	-60.4	-60.4	-59.4
10	1024 QAM (Light FEC)		-60.2	-59.2	-59.7	-59.7	-59.7	-59.7	-59.7	-58.7
11	2048 QAM		-57.7	-56.7	-57.2	-57.2	-57.2	-57.2	-57.2	-56.2
12	4096 QAM		-53.7	-52.7	-53.2	-53.2	-53.2	-	-	-

Table 68 *30 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	30 MHz	-88.9	-87.9	-88.4	-88.4	-88.4	-88.4	-88.4	
1	QPSK		-85.9	-84.9	-85.4	-85.4	-85.4	-85.4	-85.4	
2	8 QAM		-81.9	-80.9	-81.4	-81.4	-81.4	-81.4	-81.4	
3	16 QAM		-78.9	-77.9	-78.4	-78.4	-78.4	-78.4	-78.4	
4	32 QAM		-75.6	-74.6	-75.1	-75.1	-75.1	-75.1	-75.1	
5	64 QAM		-72.5	-71.5	-72.0	-72.0	-72.0	-72.0	-72.0	
6	128 QAM		-69.5	-68.5	-69.0	-69.0	-69.0	-69.0	-69.0	
7	256 QAM		-66.3	-65.3	-65.8	-65.8	-65.8	-65.8	-65.8	
8	512 QAM		-64.0	-63.0	-63.5	-63.5	-63.5	-63.5	-63.5	
9	1024 QAM (Strong FEC)		-60.7	-59.7	-60.2	-60.2	-60.2	-60.2	-60.2	
10	1024 QAM (Light FEC)		-59.9	-58.9	-59.4	-59.4	-59.4	-59.4	-59.4	
11	2048 QAM		-57.4	-56.4	-56.9	-56.9	-56.9	-56.9	-56.9	
12	4096 QAM		-53.7	-52.7	-53.2	-53.2	-53.2	-	-	

Table 69 *40 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	40 MHz	-87.8	-86.8	-87.3	-87.3	-87.3	-87.3	-87.3	-86.3
1	QPSK		-84.6	-83.6	-84.1	-84.1	-84.1	-84.1	-84.1	-83.1
2	8 QAM		-80.6	-79.6	-80.1	-80.1	-80.1	-80.1	-80.1	-79.1
3	16 QAM		-77.7	-76.7	-77.2	-77.2	-77.2	-77.2	-77.2	-76.2
4	32 QAM		-74.3	-73.3	-73.8	-73.8	-73.8	-73.8	-73.8	-72.8
5	64 QAM		-71.2	-70.2	-70.7	-70.7	-70.7	-70.7	-70.7	-69.7
6	128 QAM		-68.2	-67.2	-67.7	-67.7	-67.7	-67.7	-67.7	-66.7
7	256 QAM		-65.9	-64.9	-65.4	-65.4	-65.4	-65.4	-65.4	-64.4
8	512 QAM		-63.1	-62.1	-62.6	-62.6	-62.6	-62.6	-62.6	-61.6
9	1024 QAM (Strong FEC)		-59.6	-58.6	-59.1	-59.1	-59.1	-59.1	-59.1	-58.1
10	1024 QAM (Light FEC)		-58.9	-57.9	-58.4	-58.4	-58.4	-58.4	-58.4	-57.4
11	2048 QAM		-56.6	-55.6	-56.1	-56.1	-56.1	-56.1	-56.1	-55.1
12	4096 QAM		-53.5	-52.5	-53.0	-53.0	-53.0	-	-	-

Table 70 *50 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	50 MHz	-86.7	-85.7	-86.2	-86.2	-86.2	-86.2	-86.2	
1	QPSK		-83.8	-82.8	-83.3	-83.3	-83.3	-83.3	-83.3	
2	8 QAM		-79.5	-78.5	-79.0	-79.0	-79.0	-79.0	-79.0	
3	16 QAM		-76.6	-75.6	-76.1	-76.1	-76.1	-76.1	-76.1	
4	32 QAM		-73.6	-72.6	-73.1	-73.1	-73.1	-73.1	-73.1	
5	64 QAM		-70.2	-69.2	-69.7	-69.7	-69.7	-69.7	-69.7	
6	128 QAM		-67.7	-66.7	-67.2	-67.2	-67.2	-67.2	-67.2	
7	256 QAM		-64.1	-63.1	-63.6	-63.6	-63.6	-63.6	-63.6	
8	512 QAM		-61.6	-60.6	-61.1	-61.1	-61.1	-61.1	-61.1	
9	1024 QAM (Strong FEC)		-58.2	-57.2	-57.7	-57.7	-57.7	-57.7	-57.7	
10	1024 QAM (Light FEC)		-57.4	-56.4	-56.9	-56.9	-56.9	-56.9	-56.9	
11	2048 QAM		-55.1	-54.1	-54.6	-54.6	-54.6	-54.6	-54.6	
12	4096 QAM		-51.6	-50.6	-51.1	-	-	-	-	

Table 71 *56 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	56 MHz	-86.2	-85.2	-85.7	-85.7	-85.7	-85.7	-85.7	-84.7
1	QPSK		-83.0	-82.0	-82.5	-82.5	-82.5	-82.5	-82.5	-81.5
2	8 QAM		-78.9	-77.9	-78.4	-78.4	-78.4	-78.4	-78.4	-77.4
3	16 QAM		-76.0	-75.0	-75.5	-75.5	-75.5	-75.5	-75.5	-74.5
4	32 QAM		-72.7	-71.7	-72.2	-72.2	-72.2	-72.2	-72.2	-71.2
5	64 QAM		-69.7	-68.7	-69.2	-69.2	-69.2	-69.2	-69.2	-68.2
6	128 QAM		-66.8	-65.8	-66.3	-66.3	-66.3	-66.3	-66.3	-65.3
7	256 QAM		-63.6	-62.6	-63.1	-63.1	-63.1	-63.1	-63.1	-62.1
8	512 QAM		-61.0	-60.0	-60.5	-60.5	-60.5	-60.5	-60.5	-59.5
9	1024 QAM (Strong FEC)		-57.7	-56.7	-57.2	-57.2	-57.2	-57.2	-57.2	-56.2
10	1024 QAM (Light FEC)		-56.8	-55.8	-56.3	-56.3	-56.3	-56.3	-56.3	-55.3
11	2048 QAM		-55.0	-54.0	-54.5	-54.5	-54.5	-54.5	-54.5	-53.5
12	4096 QAM		-51.1	-50.1	-50.6	-	-	-	-	-

Table 72 *60 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	60 MHz	-86.0	-85.0	-85.5	-85.5	-85.5	-85.5	-85.5	
1	QPSK		-82.8	-81.8	-82.3	-82.3	-82.3	-82.3	-82.3	
2	8 QAM		-79.0	-78.0	-78.5	-78.5	-78.5	-78.5	-78.5	
3	16 QAM		-75.8	-74.8	-75.3	-75.3	-75.3	-75.3	-75.3	
4	32 QAM		-72.5	-71.5	-72.0	-72.0	-72.0	-72.0	-72.0	
5	64 QAM		-69.4	-68.4	-68.9	-68.9	-68.9	-68.9	-68.9	
6	128 QAM		-66.6	-65.6	-66.1	-66.1	-66.1	-66.1	-66.1	
7	256 QAM		-63.4	-62.4	-62.9	-62.9	-62.9	-62.9	-62.9	
8	512 QAM		-60.9	-59.9	-60.4	-60.4	-60.4	-60.4	-60.4	
9	1024 QAM (Strong FEC)		-57.6	-56.6	-57.1	-57.1	-57.1	-57.1	-57.1	
10	1024 QAM (Light FEC)		-56.8	-55.8	-56.3	-56.3	-56.3	-56.3	-56.3	
11	2048 QAM		-54.5	-53.5	-54.0	-54.0	-54.0	-54.0	-54.0	
12	4096 QAM		-50.7	-49.7	-50.2	-	-	-	-	

Table 73 *70 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	70 MHz	-85.2	-84.2	-84.7	-84.7	-84.7	-84.7	-84.7	-83.7
1	QPSK		-82.4	-81.4	-81.9	-81.9	-81.9	-81.9	-81.9	-80.9
2	8 QAM		-78.7	-77.7	-78.2	-78.2	-78.2	-78.2	-78.2	-77.2
3	16 QAM		-75.7	-74.7	-75.2	-75.2	-75.2	-75.2	-75.2	-74.2
4	32 QAM		-72.1	-71.1	-71.6	-71.6	-71.6	-71.6	-71.6	-70.6
5	64 QAM		-69.2	-68.2	-68.7	-68.7	-68.7	-68.7	-68.7	-67.7
6	128 QAM		-66.4	-65.4	-65.9	-65.9	-65.9	-65.9	-65.9	-64.9
7	256 QAM		-63.6	-62.6	-63.1	-63.1	-63.1	-63.1	-63.1	-62.1
8	512 QAM		-60.9	-59.9	-60.4	-60.4	-60.4	-60.4	-60.4	-59.4
9	1024 QAM (Strong FEC)		-58.0	-57.0	-57.5	-57.5	-57.5	-57.5	-57.5	-56.5
10	1024 QAM (Light FEC)		-57.3	-56.3	-56.8	-56.8	-56.8	-56.8	-56.8	-55.8
11	2048 QAM		-55.1	-54.1	-54.6	-54.6	-54.6	-54.6	-54.6	-53.6
12	4096 QAM		-51.7	-50.7	-51.2	-51.2	-51.2			

Table 74 *80 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	80 MHz	-84.6	-83.6	-84.1	-84.1	-84.1	-84.1	-84.1	-83.1
1	QPSK		-81.8	-80.8	-81.3	-81.3	-81.3	-81.3	-81.3	-80.3
2	8 QAM		-78.3	-77.3	-77.8	-77.8	-77.8	-77.8	-77.8	-76.8
3	16 QAM		-75.3	-74.3	-74.8	-74.8	-74.8	-74.8	-74.8	-73.8
4	32 QAM		-71.7	-70.7	-71.2	-71.2	-71.2	-71.2	-71.2	-70.2
5	64 QAM		-68.6	-67.6	-68.1	-68.1	-68.1	-68.1	-68.1	-67.1
6	128 QAM		-65.5	-64.5	-65.0	-65.0	-65.0	-65.0	-65.0	-64.0
7	256 QAM		-62.7	-61.7	-62.2	-62.2	-62.2	-62.2	-62.2	-61.2
8	512 QAM		-59.8	-58.8	-59.3	-59.3	-59.3	-59.3	-59.3	-58.3
9	1024 QAM (Strong FEC)		-57.0	-56.0	-56.5	-56.5	-56.5	-56.5	-56.5	-55.5
10	1024 QAM (Light FEC)		-55.9	-54.9	-55.4	-55.4	-55.4	-55.4	-55.4	-54.4
11	2048 QAM		-53.4	-52.4	-52.9	-52.9	-52.9	-52.9	-52.9	-51.9
12	4096 QAM		-50.2	-49.2	-49.7	-49.7	-49.7		-	-

Table 75 *112 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	112 MHz	-82.5	-81.5	-82.0	-82.0	-82.0	-82.0	-82.0	-81.0
1	QPSK		-80.1	-79.1	-79.6	-79.6	-79.6	-79.6	-79.6	-78.6
2	8 QAM		-76.1	-75.1	-75.6	-75.6	-75.6	-75.6	-75.6	-74.6
3	16 QAM		-73.2	-72.2	-72.7	-72.7	-72.7	-72.7	-72.7	-71.7
4	32 QAM		-69.8	-68.8	-69.3	-69.3	-69.3	-69.3	-69.3	-68.3
5	64 QAM		-66.8	-65.8	-66.3	-66.3	-66.3	-66.3	-66.3	-65.3
6	128 QAM		-63.9	-62.9	-63.4	-63.4	-63.4	-63.4	-63.4	-62.4
7	256 QAM		-60.9	-59.9	-60.4	-60.4	-60.4	-60.4	-60.4	-59.4
8	512 QAM		-58.5	-57.5	-58.0	-58.0	-58.0	-58.0	-58.0	-57.0
9	1024 QAM (Strong FEC)		-55.5	-54.5	-55.0	-55.0	-55.0	-55.0	-55.0	-54.0
10	1024 QAM (Light FEC)		-54.8	-53.8	-54.3	-54.3	-54.3	-54.3	-54.3	-53.3
11	2048 QAM		-52.2	-51.2	-51.7	-51.7	-51.7	-51.7	-51.7	-50.7
12	4096 QAM		-49.5	-48.5	-49.0	-49.0	-49.0	-	-	-

Table 76 *140 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	140 MHz	-82.4	-81.4	-81.9	-81.9	-81.9	-81.9	-81.9	-80.9
1	QPSK		-79.1	-78.1	-78.6	-78.6	-78.6	-78.6	-78.6	-77.6
2	8 QAM		-75.5	-74.5	-75.0	-75.0	-75.0	-75.0	-75.0	-74.0
3	16 QAM		-72.4	-71.4	-71.9	-71.9	-71.9	-71.9	-71.9	-70.9
4	32 QAM		-68.8	-67.8	-68.3	-68.3	-68.3	-68.3	-68.3	-67.3
5	64 QAM		-65.4	-64.4	-64.9	-64.9	-64.9	-64.9	-64.9	-63.9
6	128 QAM		-62.9	-61.9	-62.4	-62.4	-62.4	-62.4	-62.4	-61.4
7	256 QAM		-59.9	-58.9	-59.4	-59.4	-59.4	-59.4	-59.4	-58.4
8	512 QAM		-57.0	-56.0	-56.5	-56.5	-56.5	-56.5	-56.5	-55.5
9	1024 QAM		-53.9	-52.9	-53.4	-53.4	-53.4	-53.4	-53.4	-52.4
10	2048 QAM		-50.8	-49.8	-50.3	-50.3	-50.3	-50.3	-50.3	-49.3

Table 77 *150 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	150 MHz	-82.1	-81.1	-81.6	-81.6	-81.6	-81.6	-81.6	-80.6
1	QPSK		-79.0	-78.0	-78.5	-78.5	-78.5	-78.5	-78.5	-77.5
2	8 QAM		-75.2	-74.2	-74.7	-74.7	-74.7	-74.7	-74.7	-73.7
3	16 QAM		-72.0	-71.0	-71.5	-71.5	-71.5	-71.5	-71.5	-70.5
4	32 QAM		-68.6	-67.6	-68.1	-68.1	-68.1	-68.1	-68.1	-67.1
5	64 QAM		-65.2	-64.2	-64.7	-64.7	-64.7	-64.7	-64.7	-63.7
6	128 QAM		-62.7	-61.7	-62.2	-62.2	-62.2	-62.2	-62.2	-61.2
7	256 QAM		-59.7	-58.7	-59.2	-59.2	-59.2	-59.2	-59.2	-58.2
8	512 QAM		-56.8	-55.8	-56.3	-56.3	-56.3	-56.3	-56.3	-55.3
9	1024 QAM		-53.8	-52.8	-53.3	-53.3	-53.3	-53.3	-53.3	-52.3
10	2048 QAM		-50.5	-49.5	-50.0	-50.0	-50.0	-50.0	-50.0	-49.0

Table 78 *160 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	160 MHz	-81.0	-80.0	-80.5	-80.5	-80.5	-80.5	-80.5	-79.5
1	QPSK		-78.8	-77.8	-78.3	-78.3	-78.3	-78.3	-78.3	-77.3
2	8 QAM		-74.3	-73.3	-73.8	-73.8	-73.8	-73.8	-73.8	-72.8
3	16 QAM		-71.9	-70.9	-71.4	-71.4	-71.4	-71.4	-71.4	-70.4
4	32 QAM		-68.5	-67.5	-68.0	-68.0	-68.0	-68.0	-68.0	-67.0
5	64 QAM		-65.2	-64.2	-64.7	-64.7	-64.7	-64.7	-64.7	-63.7
6	128 QAM		-62.4	-61.4	-61.9	-61.9	-61.9	-61.9	-61.9	-60.9
7	256 QAM		-59.3	-58.3	-58.8	-58.8	-58.8	-58.8	-58.8	-57.8
8	512 QAM		-56.6	-55.6	-56.1	-56.1	-56.1	-56.1	-56.1	-55.1
9	1024 QAM		-53.3	-52.3	-52.8	-52.8	-52.8	-52.8	-52.8	-51.8
10	2048 QAM		-49.5	-48.5	-49.0	-49.0	-49.0	-49.0	-49.0	-48.0

Table 79 *200 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	200 MHz	-80.9	-79.9	-80.4	-80.4	-80.4	-80.4	-80.4	-79.4
1	QPSK		-78.5	-77.5	-78.0	-78.0	-78.0	-78.0	-78.0	-77.0
2	8 QAM		-74.1	-73.1	-73.6	-73.6	-73.6	-73.6	-73.6	-72.6
3	16 QAM		-71.6	-70.6	-71.1	-71.1	-71.1	-71.1	-71.1	-70.1
4	32 QAM		-68.2	-67.2	-67.7	-67.7	-67.7	-67.7	-67.7	-66.7
5	64 QAM		-64.9	-63.9	-64.4	-64.4	-64.4	-64.4	-64.4	-63.4
6	128 QAM		-62.1	-61.1	-61.6	-61.6	-61.6	-61.6	-61.6	-60.6
7	256 QAM		-59.0	-58.0	-58.5	-58.5	-58.5	-58.5	-58.5	-57.5
8	512 QAM		-56.2	-55.2	-55.7	-55.7	-55.7	-55.7	-55.7	-54.7
9	1024 QAM		-52.8	-51.8	-52.3	-52.3	-52.3	-52.3	-52.3	-51.3
10	2048 QAM		-49.0	-48.0	-48.5	-48.5	-48.5	-48.5	-48.5	-47.5

Table 80 *224 MHz Receiver Thresholds (23-42 GHz)*

Profile	Modulation	Channel Spacing	23	24 See Note 2	26	28-31	32	36	38	42
0	BPSK	224 MHz See Note 1	-80.3	-79.3	-79.8	-79.8	-79.8	-79.8	-79.8	-78.8
1	QPSK		-77.2	-76.2	-76.7	-76.7	-76.7	-76.7	-76.7	-75.7
2	8 QAM		-73.4	-72.4	-72.9	-72.9	-72.9	-72.9	-72.9	-71.9
3	16 QAM		-70.4	-69.4	-69.9	-69.9	-69.9	-69.9	-69.9	-68.9
4	32 QAM		-66.8	-65.8	-66.3	-66.3	-66.3	-66.3	-66.3	-65.3
5	64 QAM		-63.5	-62.5	-63.0	-63.0	-63.0	-63.0	-63.0	-62.0
6	128 QAM		-60.9	-59.9	-60.4	-60.4	-60.4	-60.4	-60.4	-59.4
7	256 QAM		-57.9	-56.9	-57.4	-57.4	-57.4	-57.4	-57.4	-56.4
8	512 QAM		-54.5	-53.5	-54.0	-54.0	-54.0	-54.0	-54.0	-53.0
9	1024 QAM		-50.9	-49.9	-50.4	-50.4	-50.4	-50.4	-50.4	-49.4
10	2048 QAM		-47.2	-46.2	-46.7	-46.7	-46.7	-46.7	-46.7	-45.7

Note:

1. 224 MHz is only supported with certain hardware versions. For details, ask your Cambium representative.
2. Customers in countries following EC Directive 2006/771/EC (incl. amendments) must observe the 100mW EIRP obligation by adjusting transmit power according to antenna gain and RF line losses.

Overload Thresholds

The overload threshold for all modulations is -20dBm.

Frequency Bands

Table 81 *6L GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
6L GHz	6332.5-6393	5972-6093	300A
	5972-6093	6332.5-6393	
	6191.5-6306.5	5925.5-6040.5	266A
	5925.5-6040.5	6191.5-6306.5	
	6303.5-6418.5	6037.5-6152.5	
	6037.5-6152.5	6303.5-6418.5	
	6245-6290.5	5939.5-6030.5	260A
	5939.5-6030.5	6245-6290.5	
	6365-6410.5	6059.5-6150.5	
	6059.5-6150.5	6365-6410.5	
	6226.89-6286.865	5914.875-6034.825	252B
	5914.875-6034.825	6226.89-6286.865	
	6345.49-6405.465	6033.475-6153.425	
	6033.475-6153.425	6345.49-6405.465	
	6179.415-6304.015	5927.375-6051.975	252A
	5927.375-6051.975	6179.415-6304.015	
	6238.715-6363.315	5986.675-6111.275	
	5986.675-6111.275	6238.715-6363.315	
	6298.015-6422.615	6045.975-6170.575	
	6045.975-6170.575	6298.015-6422.615	
	6235-6290.5	5939.5-6050.5	240A
	5939.5-6050.5	6235-6290.5	
	6355-6410.5	6059.5-6170.5	
	6059.5-6170.5	6355-6410.5	

Table 82 *6H GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
6H GHz	6920-7080	6420-6580	500A
	6420-6580	6924.5-7075.5	
	7032.5-7091.5	6692.5-6751.5	340C
	6692.5-6751.5	7032.5-7091.5	
	6764.5-6915.5	6424.5-6575.5	340B
	6424.5-6575.5	6764.5-6915.5	
	6924.5-7075.5	6584.5-6735.5	
	6584.5-6735.5	6924.5-7075.5	
	6781-6939	6441-6599	340A
	6441-6599	6781-6939	
	6941-7099	6601-6759	
	6601-6759	6941-7099	
	6707.5-6772.5	6537.5-6612.5	160A
	6537.5-6612.5	6707.5-6772.5	
	6767.5-6832.5	6607.5-6672.5	
	6607.5-6672.5	6767.5-6832.5	
	6827.5-6872.5	6667.5-6712.5	
	6667.5-6712.5	6827.5-6872.5	

Table 83 *7 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
7 GHz	7783.5-7898.5	7538.5-7653.5	245A
	7538.5-7653.5	7783.5-7898.5	
	7301.5-7388.5	7105.5-7192.5	196A
	7105.5-7192.5	7301.5-7388.5	
	7357.5-7444.5	7161.5-7248.5	
	7161.5-7248.5	7357.5-7444.5	

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
7 GHz	7440.5-7499.5	7622.5-7681.5	182A
	7678.5-7737.5	7496.5-7555.5	
	7496.5-7555.5	7678.5-7737.5	
	7580.5-7639.5	7412.5-7471.5	168C
	7412.5-7471.5	7580.5-7639.5	
	7608.5-7667.5	7440.5-7499.5	
	7440.5-7499.5	7608.5-7667.5	
	7664.5-7723.5	7496.5-7555.5	
	7496.5-7555.5	7664.5-7723.5	
	7609.5-7668.5	7441.5-7500.5	168B
	7441.5-7500.5	7609.5-7668.5	
	7637.5-7696.5	7469.5-7528.5	
	7469.5-7528.5	7637.5-7696.5	
	7693.5-7752.5	7525.5-7584.5	
	7525.5-7584.5	7693.5-7752.5	
	7273.5-7332.5	7105.5-7164.5	168A
	7105.5-7164.5	7273.5-7332.5	
	7301.5-7360.5	7133.5-7192.5	
	7133.5-7192.5	7301.5-7360.5	
	7357.5-7416.5	7189.5-7248.5	
	7189.5-7248.5	7357.5-7416.5	
	7280.5-7339.5	7119.5-7178.5	161P
	7119.5-7178.5	7280.5-7339.5	
	7308.5-7367.5	7147.5-7206.5	
	7147.5-7206.5	7308.5-7367.5	
	7336.5-7395.5	7175.5-7234.5	
	7175.5-7234.5	7336.5-7395.5	
	7364.5-7423.5	7203.5-7262.5	
	7203.5-7262.5	7364.5-7423.5	

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
7 GHz	7597.5-7622.5	7436.5-7461.5	161O
	7436.5-7461.5	7597.5-7622.5	
	7681.5-7706.5	7520.5-7545.5	
	7520.5-7545.5	7681.5-7706.5	
	7587.5-7646.5	7426.5-7485.5	161M
	7426.5-7485.5	7587.5-7646.5	
	7615.5-7674.5	7454.5-7513.5	
	7454.5-7513.5	7615.5-7674.5	
	7643.5-7702.5	7482.5-7541.5	161K
	7482.5-7541.5	7643.5-7702.5	
	7671.5-7730.5	7510.5-7569.5	
	7510.5-7569.5	7671.5-7730.5	
	7580.5-7639.5	7419.5-7478.5	161J
	7419.5-7478.5	7580.5-7639.5	
	7608.5-7667.5	7447.5-7506.5	
	7447.5-7506.5	7608.5-7667.5	
	7664.5-7723.5	7503.5-7562.5	
	7503.5-7562.5	7664.5-7723.5	
	7580.5-7639.5	7419.5-7478.5	161I
	7419.5-7478.5	7580.5-7639.5	
	7608.5-7667.5	7447.5-7506.5	
	7447.5-7506.5	7608.5-7667.5	
	7664.5-7723.5	7503.5-7562.5	
	7503.5-7562.5	7664.5-7723.5	

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
7 GHz	7273.5-7353.5	7112.5-7192.5	161F
	7112.5-7192.5	7273.5-7353.5	
	7322.5-7402.5	7161.5-7241.5	
	7161.5-7241.5	7322.5-7402.5	
	7573.5-7653.5	7412.5-7492.5	
	7412.5-7492.5	7573.5-7653.5	
	7622.5-7702.5	7461.5-7541.5	
	7461.5-7541.5	7622.5-7702.5	
	7709-7768	7548-7607	161D
	7548-7607	7709-7768	
	7737-7796	7576-7635	
	7576-7635	7737-7796	
	7765-7824	7604-7663	
	7604-7663	7765-7824	
	7793-7852	7632-7691	
	7632-7691	7793-7852	
	7584-7643	7423-7482	161C
	7423-7482	7584-7643	
	7612-7671	7451-7510	
	7451-7510	7612-7671	
	7640-7699	7479-7538	
	7479-7538	7640-7699	
	7668-7727	7507-7566	
	7507-7566	7668-7727	

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
7 GHz	7409-7468	7248-7307	161B
	7248-7307	7409-7468	
	7437-7496	7276-7335	
	7276-7335	7437-7496	
	7465-7524	7304-7363	
	7304-7363	7465-7524	
	7493-7552	7332-7391	
	7332-7391	7493-7552	
	7284-7343	7123-7182	161A
	7123-7182	7284-7343	
	7312-7371	7151-7210	
	7151-7210	7312-7371	
	7340-7399	7179-7238	
	7179-7238	7340-7399	
	7368-7427	7207-7266	
	7207-7266	7368-7427	
	7280.5-7339.5	7126.5-7185.5	154C
	7126.5-7185.5	7280.5-7339.5	
	7308.5-7367.5	7154.5-7213.5	
	7154.5-7213.5	7308.5-7367.5	
	7336.5-7395.5	7182.5-7241.5	
	7182.5-7241.5	7336.5-7395.5	
	7364.5-7423.5	7210.5-7269.5	
	7210.5-7269.5	7364.5-7423.5	

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
7 GHz	7594.5-7653.5	7440.5-7499.5	154B
	7440.5-7499.5	7594.5-7653.5	
	7622.5-7681.5	7468.5-7527.5	
	7468.5-7527.5	7622.5-7681.5	
	7678.5-7737.5	7524.5-7583.5	
	7524.5-7583.5	7678.5-7737.5	
	7580.5-7639.5	7426.5-7485.5	154A
	7426.5-7485.5	7580.5-7639.5	
	7608.5-7667.5	7454.5-7513.5	
	7454.5-7513.5	7608.5-7667.5	
	7636.5-7695.5	7482.5-7541.5	
	7482.5-7541.5	7636.5-7695.5	
	7664.5-7723.5	7510.5-7569.5	
	7510.5-7569.5	7664.5-7723.5	

Table 84 *8 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
8 GHz	8396.5-8455.5	8277.5-8336.5	119A
	8277.5-8336.5	8396.5-8455.5	
	8438.5 – 8497.5	8319.5 – 8378.5	
	8319.5 – 8378.5	8438.5 – 8497.5	
	8274.5-8305.5	7744.5-7775.5	530A
	7744.5-7775.5	8274.5-8305.5	
	8304.5-8395.5	7804.5-7895.5	500A
	7804.5-7895.5	8304.5-8395.5	
	8023-8186.32	7711.68-7875	311C-J
	7711.68-7875	8023-8186.32	

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
8 GHz	8028.695-8148.645	7717.375-7837.325	311B
	7717.375-7837.325	8028.695-8148.645	
	8147.295-8267.245	7835.975-7955.925	
	7835.975-7955.925	8147.295-8267.245	
	8043.52-8163.47	7732.2-7852.15	311A
	7732.2-7852.15	8043.52-8163.47	
	8162.12-8282.07	7850.8-7970.75	
	7850.8-7970.75	8162.12-8282.07	
	8212-8302	7902-7992	310D
	7902-7992	8212-8302	
	8240-8330	7930-8020	
	7930-8020	8240-8330	
	8296-8386	7986-8076	
	7986-8076	8296-8386	
	8212-8302	7902-7992	310C
	7902-7992	8212-8302	
	8240-8330	7930-8020	
	7930-8020	8240-8330	
	8296-8386	7986-8076	
	7986-8076	8296-8386	
	8380-8470	8070-8160	
	8070-8160	8380-8470	
	8408-8498	8098-8188	
	8098-8188	8408-8498	
	8039.5-8150.5	7729.5-7840.5	310A
	7729.5-7840.5	8039.5-8150.5	
	8159.5-8270.5	7849.5-7960.5	
	7849.5-7960.5	8159.5-8270.5	

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
8 GHz	8024.5-8145.5	7724.5-7845.5	300A
	7724.5-7845.5	8024.5-8145.5	
	8144.5-8265.5	7844.5-7965.5	
	7844.5-7965.5	8144.5-8265.5	
	8302.5-8389.5	8036.5-8123.5	266C
	8036.5-8123.5	8302.5-8389.5	
	8190.5-8277.5	7924.5-8011.5	266B
	7924.5-8011.5	8190.5-8277.5	
	8176.5-8291.5	7910.5-8025.5	266A
	7910.5-8025.5	8176.5-8291.5	
	8288.5-8403.5	8022.5-8137.5	
	8022.5-8137.5	8288.5-8403.5	
	8226.52-8287.52	7974.5-8035.5	252A
	7974.5-8035.5	8226.52-8287.52	
	8270.5-8349.5	8020.5-8099.5	250A
	8016.5-8156.5	7733-7873	283A
	7733-7873	8016.5-8156.5	
	8128.5-8268.5	7845-7985	
	7845-7985	8128.5-8268.5	

Table 85 *10 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
10 GHz	10501-10563	10333-10395	168A
	10333-10395	10501-10563	
	10529-10591	10361-10423	
	10361-10423	10529-10591	
	10585-10647	10417-10479	
	10417-10479	10585-10647	
	10501-10647	10151-10297	350A
	10151-10297	10501-10647	
	10498-10652	10148-10302	350B
	10148-10302	10498-10652	
	10561-10707	10011-10157	550A
	10011-10157	10561-10707	
	10701-10847	10151-10297	
	10151-10297	10701-10847	
	10590-10622	10499-10531	91A
	10499-10531	10590-10622	
	10618-10649	10527-10558	
	10527-10558	10618-10649	
	10646-10677	10555-10586	
	10555-10586	10646-10677	

Table 86 *11 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
11 GHz	11425-11725	10915-11207	All
	10915-11207	11425-11725	
	11185-11485	10695-10955	
	10695-10955	11185-11485	

Table 87 *13 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
13 GHz	13002-13141	12747-12866	266
	12747-12866	13002-13141	
	13127-13246	12858-12990	
	12858-12990	13127-13246	
	12807-12919	13073-13185	266A
	13073-13185	12807-12919	
	12700-12775	12900-13000	200
	12900-13000	12700-12775	
	12750-12825	12950-13050	
	12950-13050	12750-12825	
	12800-12870	13000-13100	
	13000-13100	12800-12870	
	12850-12925	13050-13150	
	13050-13150	12850-12925	

Table 88 *15 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
15 GHz	15110-15348	14620-14858	490
	14620-14858	15110-15348	
	14887-15117	14397-14627	
	14397-14627	14887-15117	
	15144-15341	14500-14697	644
	14500-14697	15144-15341	
	14975-15135	14500-14660	475
	14500-14660	14975-15135	
	15135-15295	14660-14820	
	14660-14820	15135-15295	
	14921-15145	14501-14725	420
	14501-14725	14921-15145	
	15117-15341	14697-14921	
	14697-14921	15117-15341	
	14963-15075	14648-14760	315
	14648-14760	14963-15075	
	15047-15159	14732-14844	
	14732-14844	15047-15159	
	15229-15375	14500-14647	728
	14500-14647	15229-15375	

Table 89 *18 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
18 GHz	19160-19700	18126-18690	1010
	18126-18690	19160-19700	
	18710-19220	17700-18200	
	17700-18200	18710-19220	
	19260-19700	17700-18140	1560
	17700-18140	19260-19700	

Table 90 *23 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
23 GHz	23000-23600	22000-22600	1008
	22000-22600	23000-23600	
	22400-23020	21200-21800	1232 /1200
	21200-21800	22400-23020	
	23000-23600	21780-22400	
	21780-22400	23000-23600	

Table 91 *24UL GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
24UL GHz	24000 - 24250	24000 - 24250	All

Note:

Customers in countries following EC Directive 2006/771/EC (incl. amendments) must observe the 100mW EIRP obligation by adjusting transmit power according to antenna gain and RF line losses.

Table 92 *26 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
26 GHz	25530-26030	24520-25030	1008
	24520-25030	25530-26030	
	25980-26480	24970-25480	
	24970-25480	25980-26480	
	25266-25350	24466-24550	800
	24466-24550	25266-25350	
	25050-25250	24250-24450	
	24250-24450	25050-25250	

Table 93 *28 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
28 GHz	28150-28350	27700-27900	450
	27700-27900	28150-28350	
	27950-28150	27500-27700	
	27500-27700	27950-28150	
	28050-28200	27700-27850	350
	27700-27850	28050-28200	
	27960-28110	27610-27760	
	27610-27760	27960-28110	
	28090-28315	27600-27825	490
	27600-27825	28090-28315	
	29004-29453	27996-28445	1008
	27996-28445	29004-29453	
	28556-29005	27548-27997	
	27548-27997	28556-29005	
	29100-29125	29225-29250	125
	29225-29250	29100-29125	

Table 94 *31 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
31 GHz	31000-31085	31215-31300	175
	31215-31300	31000-31085	

Table 95 *32 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
32 GHz	31815-32207	32627-33019	812
	32627-33019	31815-32207	
	32179-32571	32991-33383	
	32991-33383	32179-32571	

Table 96 *38 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
38 GHz	38820-39440	37560-38180	1260
	37560-38180	38820-39440	
	38316-38936	37045-37676	
	37045-37676	38316-38936	
	39650-40000	38950-39300	700
	38950-39300	39500-40000	
	39300-39650	38600-38950	
	38600-38950	39300-39650	
	37700-38050	37000-37350	
	37000-37350	37700-38050	
	38050-38400	37350-37700	
	37350-37700	38050-38400	

Table 97 *42 GHz Frequency Bands*

Frequency Band	TX Range	RX Range	Tx/Rx Spacing
42 GHz	40550-41278	42050-42778	1500
	42050-42778	40550-41278	
	41222-41950.5	42722-43450	
	42722-43450	41222-41950.5	

Ethernet Latency Specifications

The specifications in this section are for 1+0 configurations.

Ethernet Latency – 14 MHz Channel Bandwidth

Table 98 *Ethernet Latency with 14 MHz Channel Bandwidth (Script 4509)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
1	QPSK		994	995	996	1246	1499	1750

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
2	8 QAM		681	682	686	841	1000	1158
3	16 QAM		498	498	500	611	723	835
4	32 QAM		403	403	406	487	571	649
5	64 QAM		344	344	347	412	481	548
6	128 QAM		303	303	305	359	416	471
7	256 QAM		270	270	273	319	369	418
8	512 QAM		274	274	276	319	364	405
9	1024 QAM (Strong FEC)		256	257	259	299	341	383
10	1024 QAM (Light FEC)		253	253	255	293	333	372
11	2048 QAM		246	246	248	284	323	361

Ethernet Latency – 20 MHz Channel Bandwidth

Table 99 *Ethernet Latency – 20 MHz Channel Bandwidth (Script 4521)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		1492	1493	1497	1884	2277	2669
1	QPSK		691	691	696	860	1028	1197
2	8 QAM		479	479	481	587	696	797
3	16 QAM		355	356	359	434	513	586
4	32 QAM		290	290	292	349	409	467
5	64 QAM		249	250	252	297	346	393
6	128 QAM		220	220	222	260	300	340
7	256 QAM		198	198	200	234	269	302
8	512 QAM		203	203	205	236	269	300
9	1024 QAM (Strong FEC)		189	190	191	220	251	280
10	1024 QAM		186	187	188	215	245	271

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
	(Light FEC)							
11	2048 QAM		177	178	179	205	232	259

Ethernet Latency – 25 MHz Channel Bandwidth

Table 100 *Ethernet Latency – 25 MHz Channel Bandwidth (Script 4525)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		1132	1133	1139	1425	1719	2011
1	QPSK		539	539	541	668	797	925
2	8 QAM		377	378	380	462	547	630
3	16 QAM		282	282	284	343	405	466
4	32 QAM		231	232	234	278	325	371
5	64 QAM		200	200	202	238	277	314
6	128 QAM		177	177	179	209	241	272
7	256 QAM		160	160	162	188	217	243
8	512 QAM		163	163	165	189	214	238
9	1024 QAM (Strong FEC)		152	153	154	177	201	225
10	1024 QAM (Light FEC)		149	150	151	172	196	216
11	2048 QAM		142	142	143	163	185	206
12	4096 QAM		139	139	141	159	179	199

Ethernet Latency – 28/30 MHz Channel Bandwidth

Table 101 *Ethernet Latency – 28 MHz Channel Bandwidth (Script 4504)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		971	971	973	1219	1468	1700
1	QPSK		471	472	473	584	696	808
2	8 QAM		332	333	335	407	481	554
3	16 QAM		251	252	254	305	360	410
4	32 QAM		206	206	208	247	289	327
5	64 QAM		178	178	180	211	245	278
6	128 QAM		158	158	160	186	215	241
7	256 QAM		143	143	145	168	193	216
8	512 QAM		146	146	148	169	192	214
9	1024 QAM (Strong FEC)		137	137	138	158	180	201
10	1024 QAM (Light FEC)		134	135	136	155	175	195
11	2048 QAM		127	128	129	146	166	183
12	4096 QAM		125	126	127	143	161	178

Table 102 *Ethernet Latency – 28 MHz Channel Bandwidth (Script 4514)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		1019	1019	1022	1279	1539	1799
1	QPSK		488	488	490	604	721	836
2	8 QAM		344	344	347	421	498	574
3	16 QAM		258	259	261	314	370	422
4	32 QAM		212	212	214	255	297	339
5	64 QAM		183	184	185	218	253	285
6	128 QAM		162	163	164	192	221	249

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
7	256 QAM		147	147	149	173	199	224
8	512 QAM		150	151	152	174	197	220
9	1024 QAM (Strong FEC)		141	141	142	163	185	207
10	1024 QAM (Light FEC)		138	138	139	159	180	200
11	2048 QAM		131	132	133	151	171	190
12	4096 QAM		124	125	126	143	162	180

Table 103 *Ethernet Latency – 28/30 MHz Channel Bandwidth (Script 4505)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		921	922	924	1155	1390	1623
1	QPSK		448	448	450	554	660	765
2	8 QAM		316	317	319	388	460	532
3	16 QAM		236	237	239	287	339	389
4	32 QAM		196	196	198	235	274	312
5	64 QAM		169	170	171	201	233	263
6	128 QAM		150	151	152	177	204	230
7	256 QAM		141	141	142	164	188	211
8	512 QAM		140	140	141	162	184	204
9	1024 QAM (Strong FEC)		131	131	132	151	172	191
10	1024 QAM (Light FEC)		128	129	130	148	167	185
11	2048 QAM		120	121	122	138	156	173
12	4096 QAM		119	120	121	136	153	170

Ethernet Latency – 40 MHz Channel Bandwidth

Table 104 *Ethernet Latency– 40 MHz Channel Bandwidth (Script 4507)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		657	657	662	821	984	1147
1	QPSK		333	334	337	411	489	561
2	8 QAM		239	240	242	291	343	394
3	16 QAM		182	182	184	220	259	296
4	32 QAM		151	151	153	180	210	237
5	64 QAM		132	132	134	156	180	203
6	128 QAM		118	118	119	138	159	177
7	256 QAM		106	107	108	125	145	162
8	512 QAM		109	109	110	126	144	161
9	1024 QAM (Strong FEC)		103	103	104	118	134	149
10	1024 QAM (Light FEC)		101	101	102	116	131	145
11	2048 QAM		96	96	97	110	124	137
12	4096 QAM		91	91	93	104	118	130

Ethernet Latency – 50 MHz Channel Bandwidth

Table 105 *Ethernet Latency– 50 MHz Channel Bandwidth (Script 4510)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		528	528	530	655	782	901
1	QPSK		275	276	278	338	402	465
2	8 QAM		192	192	194	233	275	315
3	16 QAM		148	148	149	178	209	239
4	32 QAM		124	124	126	149	174	196

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
5	64 QAM		108	109	110	128	148	166
6	128 QAM		96	97	98	113	131	146
7	256 QAM		88	89	90	103	118	131
8	512 QAM		90	90	91	104	117	130
9	1024 QAM (Strong FEC)		85	85	86	97	110	122
10	1024 QAM (Light FEC)		83	83	85	95	108	119
11	2048 QAM		79	80	81	91	102	113
12	4096 QAM		77	77	78	88	99	109

Ethernet Latency – 56/60 MHz Channel Bandwidth

Table 106 *Ethernet Latency – 56 MHz Channel Bandwidth (Script 4502)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		461	461	463	572	684	795
1	QPSK		236	237	239	290	345	398
2	8 QAM		173	174	175	210	247	282
3	16 QAM		133	134	135	161	188	214
4	32 QAM		112	112	114	133	154	174
5	64 QAM		99	99	100	116	134	151
6	128 QAM		89	89	90	103	119	133
7	256 QAM		81	81	83	94	108	120
8	512 QAM		83	83	84	95	107	118
9	1024 QAM (Strong FEC)		78	78	79	89	101	111
10	1024 QAM (Light FEC)		76	77	78	87	99	109
11	2048 QAM		73	74	75	84	95	104
12	4096 QAM		71	71	72	81	91	100

Table 107 *Ethernet Latency – 56/60 MHz Channel Bandwidth (Script 4506)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		437	437	439	542	648	752
1	QPSK		226	226	228	277	329	379
2	8 QAM		180	180	182	215	251	285
3	16 QAM		127	127	129	153	179	205
4	32 QAM		107	108	109	127	148	167
5	64 QAM		95	95	96	112	129	145
6	128 QAM		85	86	87	99	114	127
7	256 QAM		80	81	82	93	106	117
8	512 QAM		80	80	81	91	104	115
9	1024 QAM (Strong FEC)		75	76	77	86	98	107
10	1024 QAM (Light FEC)		74	74	75	84	95	105
11	2048 QAM		70	71	72	80	90	99
12	4096 QAM		68	69	70	78	88	96

Ethernet Latency – 70 MHz Channel Bandwidth

Table 108 *Ethernet Latency – 70 MHz Channel Bandwidth (Script 4513)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		376	377	379	466	557	641
1	QPSK		199	199	201	244	289	333
2	8 QAM		147	147	149	179	211	242
3	16 QAM		114	114	115	136	159	181
4	32 QAM		96	96	97	114	132	149
5	64 QAM		85	85	87	100	115	129
6	128 QAM		78	78	80	91	104	116

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
7	256 QAM		78	78	79	89	101	111
8	512 QAM		72	72	74	83	94	103
9	1024 QAM (Strong FEC)		68	69	70	78	88	98
10	1024 QAM (Light FEC)		67	67	69	77	86	95
11	2048 QAM		64	65	66	73	83	91
12	4096 QAM		62	63	64	71	80	88

Ethernet Latency – 80 MHz Channel Bandwidth

Table 109 *Ethernet Latency – 80 MHz Channel Bandwidth (Script 4501)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		327	328	331	406	485	562
1	QPSK		174	174	176	213	252	288
2	8 QAM		131	131	133	159	187	213
3	16 QAM		102	103	104	123	144	164
4	32 QAM		87	87	89	103	120	135
5	64 QAM		78	78	80	91	105	118
6	128 QAM		71	71	73	83	95	106
7	256 QAM		71	71	73	81	92	102
8	512 QAM		66	66	68	76	86	95
9	1024 QAM (Strong FEC)		63	64	65	72	82	91
10	1024 QAM (Light FEC)		62	63	64	71	80	89
11	2048 QAM		60	60	62	68	77	85
12	4096 QAM		57	57	58	65	73	80

Figure 111: *Ethernet Latency – 80 MHz Channel Bandwidth (Script 4588)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		306	306	309	379	452	525
1	QPSK		164	164	166	200	237	271
2	8 QAM		123	124	125	150	176	202
3	16 QAM		97	97	99	116	136	154
4	32 QAM		82	83	84	98	113	127
5	64 QAM		74	75	76	87	100	112
6	128 QAM		68	68	69	79	90	100
7	256 QAM		67	68	69	77	88	97
8	512 QAM		63	63	65	72	82	90
9	1024 QAM (Strong FEC)		61	61	62	69	79	87
10	1024 QAM (Light FEC)		59	60	61	68	77	85
11	2048 QAM		57	58	59	65	74	82

Ethernet Latency – 112 MHz Channel Bandwidth

Table 110 *Ethernet Latency – 112 MHz Channel Bandwidth (Script 4511)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		231	232	234	285	340	393
1	QPSK		126	127	128	154	181	208
2	8 QAM		95	96	97	114	133	152
3	16 QAM		76	76	77	90	105	119
4	32 QAM		65	65	67	77	88	99
5	64 QAM		59	59	60	68	78	87
6	128 QAM		54	54	55	62	71	78
7	256 QAM		50	50	52	58	66	72

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
8	512 QAM		51	51	52	58	65	72
9	1024 QAM (Strong FEC)		49	49	50	55	62	68
10	1024 QAM (Light FEC)		48	48	50	54	61	67
11	2048 QAM		46	47	48	53	59	64
12	4096 QAM		44	44	45	49	55	60

Ethernet Latency – 140 MHz Channel Bandwidth

Table 111 *Ethernet Latency – 140 MHz Channel Bandwidth (Script 4518)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		188	189	191	231	275	315
1	QPSK		105	106	107	127	150	170
2	8 QAM		80	81	82	96	112	127
3	16 QAM		65	65	66	77	89	100
4	32 QAM		56	57	58	66	76	85
5	64 QAM		51	52	53	59	67	75
6	128 QAM		47	48	49	55	62	69
7	256 QAM		44	45	46	51	57	63
8	512 QAM		46	46	47	52	58	63
9	1024 QAM		44	44	45	49	55	60
10	2048 QAM		42	42	43	47	52	57

Ethernet Latency – 150 MHz Channel Bandwidth

Table 112 *Ethernet Latency – 150 MHz Channel Bandwidth (Script 4515)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		178	179	180	219	260	300
1	QPSK		101	101	102	122	144	164
2	8 QAM		77	78	79	93	108	123
3	16 QAM		63	63	65	75	87	98
4	32 QAM		55	56	57	65	75	84
5	64 QAM		50	51	52	58	66	74
6	128 QAM		47	47	49	54	61	68
7	256 QAM		44	44	46	50	57	64
8	512 QAM		45	45	47	51	58	63
9	1024 QAM		43	44	45	49	55	60
10	2048 QAM		41	42	43	47	53	58

Ethernet Latency – 160 MHz Channel Bandwidth

Table 113 *Ethernet Latency – 160 MHz Channel Bandwidth (Script 4516)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		171	171	173	210	249	288
1	QPSK		97	97	99	117	138	157
2	8 QAM		75	75	77	89	104	118
3	16 QAM		61	61	63	72	84	95
4	32 QAM		54	54	56	63	73	81
5	64 QAM		49	49	51	57	65	72
6	128 QAM		46	46	47	53	60	66
7	256 QAM		43	43	45	49	56	62
8	512 QAM		44	44	46	50	56	62

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
9	1024 QAM		42	43	44	48	54	59
10	2048 QAM		40	41	42	45	51	55

Ethernet Latency – 200 MHz Channel Bandwidth

Table 114 *Ethernet Latency – 200 MHz Channel Bandwidth (Script 4522)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		138	139	140	169	201	231
1	QPSK		80	81	82	97	114	130
2	8 QAM		63	63	65	75	87	99
3	16 QAM		52	52	54	61	71	80
4	32 QAM		46	47	48	54	62	69
5	64 QAM		43	43	44	49	56	62
6	128 QAM		40	41	42	46	53	58
7	256 QAM		38	38	40	44	49	55
8	512 QAM		39	39	41	44	50	54
9	1024 QAM		37	38	39	43	48	52
10	2048 QAM		36	37	38	41	46	51

Ethernet Latency – 224 MHz Channel Bandwidth

Table 115 *Ethernet Latency – 224 MHz Channel Bandwidth (Script 4524)*

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
0	BPSK		126	126	128	153	181	207
1	QPSK		74	75	76	89	104	118
2	8 QAM		59	59	61	70	81	90
3	16 QAM		50	50	51	58	67	75
4	32 QAM		44	45	46	51	59	65

ACM Working Point	Modulation	Latency (µsec) with GbE Interface						
		Frame Size	64	128	256	512	1024	1518
5	64 QAM		41	42	43	47	53	59
6	128 QAM		39	39	40	44	50	55
7	256 QAM		37	37	39	42	47	52
8	512 QAM		38	38	39	43	48	52
9	1024 QAM		37	37	38	41	46	50
10	2048 QAM		34	35	36	39	44	47

Mediation Device Losses

Table 116 *Mediation Device Losses*

Mediation Devices	Signal Path / Remarks	Maximum Insertion Loss [dB]						
		5.7-8 GHz	11 GHz	13-15 GHz	f18 GHz	23-26 GHz	28-38 GHz	42 GHz
Flex WG	Size varies per frequency.	0.5	0.5	1.2	1.2	1.5	1.8	2.5
OMT	Radio to antenna ports (V or H)	0.3	0.3	0.3	0.3	0.5	0.5	0.5
Splitter	Radio to antenna port	3.6	3.7	3.7	3.7	3.7	4.0	4.0
Dual Coupler	Main Paths	1.6	1.6	1.6	1.8	1.8	2.0	2.0
	Secondary Paths	6±0.7	6±0.7	6±0.7	6±0.8	6±0.8	6±1.0	6±1.0
Dual Splitter	Radio to antenna port	3.6	3.7	3.7	3.7	3.7	4.0	4.0
Dual Circulator	Radio adjacent to antenna port	0.2	0.2	0.2	0.5	0.5	0.5	0.5
	Radio farthest from antenna port	1.4	1.4	1.4	1.4	1.4	1.4	1.4

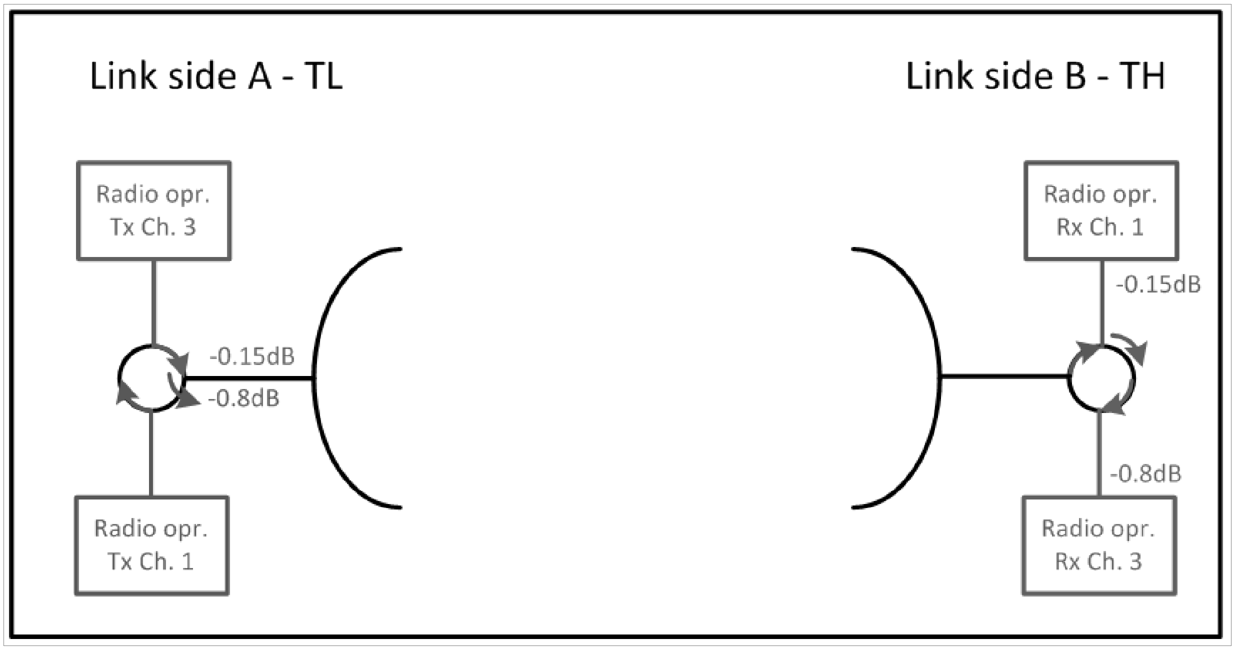
Note:

The antenna interface is always the PTP 850C interface.:

If other antennas are to be used, an adaptor with a 0.1 dB loss should be considered.

The numbers above represent the maximum loss per component.

The following diagram explains the circulators insertion loss:



Interface Specifications

Ethernet Interface Specifications

Supported Ethernet Interfaces for Traffic	1x 1000BASE-T, 2.5GBASE-T, 10GBASE-T (RJ-45) 1x2.5BASE-X (SFP) 1x1000BASE-X or 10GBASE-X (SFP or SFP+) 1x10GBASE-X (SFP+)		
Supported Ethernet Interfaces for Management	10/100/1000 Base-T (RJ-45)	1 x 10/100/1000Base-T (RJ-45) for traffic or management	1 x 10/100/1000Base-T (RJ-45) for management

Table 117 *Approved SFP Transceivers*

Marketing Model	Marketing Description	Item Description
SFP-GE-SX-EXT-TEMP	SFP optical interface 1000Base-SX,EXT-TE	XCVR,SFP,850nm,MM,1.0625 Gbit/s FC/ 1.25 GBE, INDUSTRIAL GRADE,SINGLE PACK KIT
SFP-GE-LX-EXT-TEMP	SFP OPTICAL 1000Base-LX,EXT TEMP	XCVR,SFP,1310nm,1.25Gb,SM,10km,W.DDM,INDUSTRIAL GRADE,SINGLE PACK KIT

Marketing Model	Marketing Description	Item Description
SFP-GE-COPER-EXT-TMP-LOS-DIS	SFP ELECT INT 1000Base-T RX_LOS DIS, IND	XCVR,SFP,COPPER 1000BASE-T,RX_LOS DISABLE,INDUSTRIAL TEMP Note: Not all SFPs with this marketing model are approved for use with PTP 850C. See Table 118 for a list of approved electrical SFP transceivers per manufacturer and manufacturer part number.

Table 118 *Approved Electrical SFP Transceivers per Manufacturer*

Cambium Part Number	Manufacturer	Manufacturer Part Number
AO-0228-0	Axcen	AXGT-R154-0M07
AO-0228-0	Linktel Technologies Co LTD	LX1801INA-CER
AO-0228-0	Linktel Technologies Co LTD	LX1801INX-CER **Note**: This module should not be used with Eth 2 (P3).
AO-0228-0	Syrotech network limited	GOCS-C12-02IND
AO-0228-0	Gigalight	GE-GB-P3RT-C5-CER
AO-0228-0	FINISAR	FCLF8521P2BTL

Table 119 *Approved 2.5 GbE SFP Transceivers*

Marketing Model	Marketing Description	Item Description
SFP-3.7G-SX-EXT-TEMP	SFP-3.7G-SX-EXT-TEMP	XCVR,SFP,850nm,MM,3.7 Gbit/s, INDUSTRIAL GRADE
SFP-3.7G-LX-EXT-TEMP	SFP-3.7G-LX-EXT-TEMP	XCVR,SFP,1310nm,SM,10km,3.7 Gbit/s, INDUSTRIAL GRADE

Table 120 *Approved 10 GbE SFP+ Transceivers*

Note:

Approved SFP+ transceivers can also be used with 2.5 GbE interfaces.

Marketing Model	Marketing Description	Item Description
N800082L013A	XCVR,SFP+,1310nm,SM,10 Gbit/s,10km,INDUSTRIAL GRADE,SINGLE P	XCVR,SFP+,1310nm,SM,10 Gbit/s,10km,INDUSTRIAL GRADE,SINGLE P
N800082L013A	XCVR,SFP+,1310nm,SM,10 Gbit/s,10km,INDUSTRIAL GRADE,SINGLE P	SFP+10GBASE-SR10-EXT-TEMP

Carrier Ethernet Functionality

"Jumbo" Frame Support	Up to 9600 Bytes
General	Enhanced link state propagation
Integrated Carrier Ethernet Switch	Maximum number of Ethernet services: 1024 plus one pre-defined management service MAC address learning with 64K MAC addresses 802.1ad provider bridges (QinQ) 802.3ad link aggregation
QoS	Advanced CoS classification and remarking Per interface CoS based packet queuing/buffering (8 queues) Per queue statistics Tail-drop and WRED with CIR/EIR support Flexible scheduling schemes (SP/WFQ/Hierarchical) Per interface and per queue traffic shaping Hierarchical-QoS (H-QoS) – 64 queues per interface 2 Gbit packet buffer
Network resiliency	MSTP ERP (G.8032)
OAM	CFM (802.1ag)
Performance Monitoring	Per port Ethernet counters (RMON/RMON2) Radio ACM statistics Enhanced radio Ethernet statistics (Throughput, Capacity, Utilization)
Supported Ethernet/IP Standards	10/100/1000base-T/X (IEEE 802.3) Optical 10Gbase-X (IEEE 802.3) Ethernet VLANs (IEEE 802.3ac) Virtual LAN (VLAN, IEEE 802.1Q) Class of service (IEEE 802.1p) Provider bridges (QinQ – IEEE 802.1ad) Link aggregation (IEEE 802.3ad) Auto MDI/MDIX for 1000baseT RFC 1349: IPv4 TOS RFC 2474: IPv4 DSCP

"Jumbo" Frame Support	Up to 9600 Bytes
	RFC 2460: IPv6 Traffic Classes

Synchronization Protocols

- Enhanced Ethernet Equipment Clock (eEEC) Specification (G.8262.1)
- PTP Telecom Class C Boundary Clock (T-BC) and Time Slave Clock (T-TSC) Specification (G.8273.2)
- PTP Telecom Class C Transparent Clock (T-TC) Specification (G.8273.3)
- Enhanced SyncE Network Limits (G.8261, clause 9.2.1)
- Enhanced PTP Network Limits (G.8271.1)
- Ethernet Synchronization Messaging Channel (ESMC) (G.8264, clause 11)
- PTP Telecom Profile for Time (Full Timing Support) (G.8275.1)

Network Management, Diagnostics, Status, and Alarms

Network Management System	Cambium NMS
NMS Interface protocol	SNMPv1/v2c/v3 XML over HTTP/HTTPS toward NMS
Element Management	Web based EMS, CLI
Management Channels & Protocols	HTTP/HTTPS Telnet/SSH-2 FTP/SFTP
Authentication, Authorization & Accounting	User access control X-509 Certificate
Management Interface	Dedicated Ethernet interfaces or in-band in traffic ports
In-Band Management	Support dedicated VLAN for management
TMN	Cambium NMS functions are in accordance with ITU-T recommendations for TMN
RSL Indication	Accurate power reading (dBm) available at PTP 850C, and NMS **Note**: The voltage at the RSL port is 1.XX where XX is the RSL level. For example:

Network Management System	**Cambium NMS**
	1.59V means an RSL of -59 dBm. Note that the voltage measured at the RSL port is not accurate and should be used only as an aid).
Performance Monitoring	Integral with onboard memory per ITU-T G.826/G.828

Mechanical Specifications

Table 121 *Mechanical Specifications*

Module Dimensions	**(H)322mm x (W) 270mm x (D)85mm**
Module Weight	6.23 kg
Pole Diameter Range (for Remote Mount Installation)	8.89 cm – 11.43 cm

Standards Compliance

Specification	**Standard**	
Radio Spectral Efficiency	ETSI: EN 302 217-2 FCC Part 101	*For the applicable frequency bands.
EMC	EN 301 489-1, EN 301 489-4 (Europe) FCC 47 CFR, part 15, subpart B (US) ICES-003 (Canada) TEC/SD/DD/EMC-221/05/OCT-16 (India) IEC 61000-4-29 (India)	
Surge Protection	Surge: EN61000-4-5, Class 4 (for PWR and ETH1/PoE ports)	
Safety	EN 62368-1 (Europe) IEC 62368-1 (International) UL 62368-1 (US) CSA-C22.2 No.62368-1 (Canada)	

Environmental Specifications

- Operating: ETSI EN 300 019-1-4 Class 4.1
  - Temperature range: 33°C to +55°C/-27°F to +131°F
  - Humidity**: 5%RH to 100%RH** IEC529 IP67
- Storage: ETSI EN 300 019-1-1 Class 1.2

Transportation: ETSI EN 300 019-1-2 Class 2

PTP 850C is exempt from the list of equipment subject to EU DIRECTIVE 2000/14/EC regarding noise emission in the environment by equipment for use outdoors.

PTP 850C complies with the 1972 Noise Control Act.

PTP 850C does not include any noise generating components.

Antenna Specifications

- Direct Mount:

  CommScope (VHLP), RFS, Xian Putian (WTG), and Radio Wave
- Remote Mount:

Table 122 *Antenna Specifications, Remote Mount*

Frequency (GHz)	Waveguide Standard	Waveguide Flange	Antenna Flange
6	WR137	PDR70	UDR70
7/8	WR112	PBR84	UBR84
10/11	WR90	PBR100	UBR100
13	WR75	PBR120	UBR120
15	WR62	PBR140	UBR140
18-26	WR42	PBR220	UBR220
28-38	WR28	PBR320	UBR320
42	WR22	UG383/U	UG383/U

If a different antenna type (CPR flange) is used, a flange adaptor is required. Please contact your Cambium representative for details.

Power Input Specifications

Standard Input	-48 VDC
DC Input range	-40.5 to -60 VDC

Power Consumption Specifications

Typical Power Consumption	6-11 GHz	13-42 GHz
2+0 Operation	73W	63W
1+0 Operation (one of the carriers is muted)	63W	55W
Both carriers are muted	38W	40W

Note:

The maximum power consumption can be up to ~20% higher than the typical figures listed above.

Power Connection Options

Table 123 *Power Connection Options*

Interface	Cable Type	Recommended Cable	Maximum Length	
			6-11 GHz	13-42 GHz
Optical	Fiber		300m	
Electrical at 1G (with PoE_Inj_AO_2DC_ 24V_48V or without PoE)	CAT-5e (24 AWG)	CAT5E_SFUTP_ Outdoor_100m_drum	100m	
	CAT-6A (22 AWG)	CAT6A_SFTP_Outdoor_ 305m_drum		
Electrical at 1G (with PoE_Inj_AO)	CAT-5e (24 AWG)	CAT5E_SFUTP_ Outdoor_100m_drum	Not available	80m
	CAT-6A (22 AWG)	CAT6A_SFTP_Outdoor_ 305m_drum		
Electrical at 10G (no PoE)	CAT-6A (22 AWG)	CAT6A_SFTP_Outdoor_ 305m_drum	90m	
DC Power	DC (18 AWG)		50m	
	DC (14 AWG)		120m	
	DC (12 AWG)		200m	

Note:

For details and marketing models of the recommended PoE options and when they are used, see PoE Injector.

PoE Injector Specifications

The specifications in this section are for the standard PoE Injector units with the following marketing models:

- PoE_Inj_AO_2DC_24V_48V
- PoE_Inj_AO

Power Input

Standard Input	-48 VDC
DC Input range	-(18/40.5 to 60) VDC

Environmental

- Operating: ETSI EN 300 019-1-4 Class 4.1
  - Temperature range for continuous operating temperature with high reliability: -33°C to +55°C/-27°F to +131°F
  - Humidity: 5%RH to 100%RH (IEC529 IP66)
- Storage: ETSI EN 300 019-1-1 Class 1.2
- Transportation: ETSI EN 300 019-1-2 Class 2.3

Standards Requirements

Specification	Standard
EMC	EN 301 489-1, EN 301 489-4 (Europe) FCC 47 CFR, part 15, subpart B (US) ICES-003 (Canada) TEC/SD/DD/EMC-221/05/OCT-16 (India) IEC 61000-4-29 (India)
Safety	EN 62368-1 IEC 62368-1 UL 62368-1 CSA-C22.2 No.62368-1

Mechanical

Module Dimensions	(H)134mm x (W)190mm x (D)62mm (H)5.28inch x (W) 7.48inch(D)2.44inch
Module Weight	1kg/2.2lbs

Cable Specifications

Outdoor Ethernet Cable Specifications

Electrical Requirements	
Cable type	CAT-5e SFUTP, 4 pairs, according to ANSI/TIA/EIA-568-B-2
Wire gage	See Power Connection Options
Stranding	Solid
Voltage rating	70V
Shielding	Braid + Foil

RJ-45 Connector Pinout

Pin #	**Wire Color Legend**	**Signal**
1	White/Orange	TX+
2	Orange	TX-
3	White/Green	RX+
4	Blue	TRD2+
5	White/Blue	TRD2
6	Green	RX-
7	White/Brown	TRS3+
8	Brown	TRD3-

Mechanical/ Environmental Requirements	
Jacket	PVC, double, UV resistant
Outer diameter	7-10 mm/0.28 – 0.39 inches
Operating and Storage temperature range	-40°C - 85°C/-40°F - 185°F
Flammability rating	According to UL-1581 VW1, IEC 60332-1
RoHS	According to Directive/2002/95/EC

Outdoor DC Cable Specifications

Electrical Requirements	
Cable type	2 tinned copper wires
Wire gage	See Power Connection Options
Stranding	stranded
Voltage rating	600V
Spark test	4KV
Dielectric strength	2KV AC min

Mechanical/ Environmental Requirements	
Jacket	PVC, double, UV resistant
Outer diameter	7-10 mm/0.28 – 0.39 inches
Operating & Storage temperature range	-40°C - 85°C/-40°F - 185°F
Flammability rating	According to UL-1581 VW1, IEC 60332-1
RoHS	According to Directive/2002/95/EC

Appendix A – Marketing Models

For frequencies of 6 to 11 GHz, PTP 850C uses the Easy Set technology in which two individual units are ordered: a generic radio unit and a diplexer unit.

For frequencies of 13 to 42 GHz, a single PTP 850C unit is ordered, consisting of both the radio and the diplexers.

This section explains how to read PTP 850C marketing models, including marketing models for the diplexer unit for 6-11 GHz links. Constructing a marketing model for the purpose of ordering equipment should always be done using a configurator.

Note:

Not all fields are always necessary to define a valid marketing model. If a specific field is not applicable, it should be omitted.

Marketing Models for Easy Set PTP 850C Radio and Diplexer Units, 6 to 11 GHz

For frequencies of 6 to 11 GHz, the PTP 850C radio unit and diplexer unit are ordered separately. Using Easy Set technology, the diplexer unit is assembled on the PTP 850C radio unit during link installation in the field. The radio unit is generic; only the diplexer unit (DXU) is sub-band specific, which facilities link planning, ordering, and maintenance as described above.

Table 124 provides the marketing model syntax for the PTP 850C Easy Set radio unit.

Table 125 provides the marketing model syntax for the PTP 850C Easy Set diplexer unit.

Table 124 *PTP 850C Marketing Model Syntax, 6 to 11 GHz (Radio Unit)*

Marketing Model	Description
PTP 850C-ff	PTP 850C, Multicore ff GHz, All-Outdoor, Basic Radio

Table 125 *PTP 850C Marketing Model Syntax, 6 to 11 GHz (Diplexer Unit)*

Marketing Model	Description
DXCff-xxxY-ccWdd-t	Diplexers Unit, ff GHz, Block xxxY, ccWdd, High/Low

Table 126 *PTP 850C Marketing Model Structure– Possible Values (Easy Set - Radio Unit Only)*

Placeholder in Marketing Model	Description	Possible Values
ff	Frequency band	06,07,08,10,11

Table 127 *PTP 850C Marketing Model Structure– Possible Values (Easy Set - Diplexer Unit Only)*

Placeholder in Marketing Model	Description	Possible Values
ff	Frequency band	L6,U6,07,08,10,11
xxxY	TX-RX separation and block indication (Cambium internal)	xxx - TRS 3 figures in [MHz]. Y - Letter to indicate frequency block. Example: 266A The frequency block is a Cambium internal parameter which defines different channelization using the same TRS and frequency band.
ccWdd	Channel indication or LOW/HIGH or blank	{Start ch}W{End ch} Example: 10W15
t	TX low / TX high indication	L – TX Low H – TX high

Table 128 provides examples of specific PTP 850C diplexer unit marketing models based on the syntax described above.

Table 128 *PTP 850C Diplexer Unit Marketing Model Examples*

Marketing Model Example	Explanation
N060085L002A	PTP 850C Diplexer Unit, Lower 6 GHz, TRS block 252A, Ch 1 to 4, Tx low
N110085L013A	PTP 850C Diplexer Unit, 11 GHz, TRS block 500, Ch 7 to 13, Tx high

Marketing Model for PTP 850C Unit, 13-42 GHz

When ordering an PTP 850C, a single unit is ordered as a single unit. The following PTP 850C hardware models are available.

Table 129 *PTP 850C Marketing Models*

Marketing Model	TX Range	RX Range
PTP 850C-E-13-266-1W4-H	13002-13141	12745.75-12866
PTP 850C-E-13-266-1W4-L	12745.75-12866	13002-13141
PTP 850C-E-15-420-1W8-H	14921-15145	14501-14725
PTP 850C-E-15-420-1W8-L	14501-14725	14921-15145
PTP 850C-E-18-H-H	19160-19700	18126-18690
PTP 850C-E-18-H-L	18126-18690	19160-19700

Marketing Model	TX Range	RX Range
PTP 850C-E-23-H	23000-23600	22000-22600
PTP 850C-E-23-L	22000-22600	23000-23600

Synonyms and Acronyms

Acronym	Equivalent Term
ACAP	Adjacent Channel Alternate Polarization
ACCP	Adjacent Channel Co-Polarization
ACM	Adaptive Coding Modulation
AES	Advanced Encryption Standard
AIS	Alarm Indication Signal
ATPC	Automatic Tx Power Control
BER	Bit Error Ratio
BPDU	Bridge Protocol Data Units
CBS	Committed Burst Size
CE	Customer Equipment
CET	Carrier-Ethernet Transport
CIR	Committed Information Rate
CLI	Command Line Interface
CoS	Class of Service
CSF	Client Signal Failure
DA	Destination Address
DSCP	Differentiated Service Code Point
EBS	Excess Burst Size
EFM	Ethernet in the First Mile
EIR	Excess Information Rate
EPL	Ethernet Private Line
ETH-BN	Ethernet Bandwidth Notification
EVPL	Ethernet Virtual Private Line
EVC	Ethernet Virtual Connection
FM	Fault Management
FTP (SFTP)	File Transfer Protocol (Secured File Transfer Protocol)
GbE	Gigabit Ethernet

Acronym	Equivalent Term
HTTP (HTTPS)	Hypertext Transfer Protocol (Secured HTTP)
LAN	Local area network
LLF	Link Loss Forwarding
LOC	Loss of Carrier
LOF	Loss of Frame
LOS	Loss of Signal
LTE	Long-Term Evolution
MEN	Metro Ethernet Network
MFA	Multi-Factor Authentication
MPLS	Multiprotocol Label Switching
MRU	Maximum Receive Unit
MSE	Mean Square Error
MSTP	Multiple Spanning Tree Protocol
MTU	Maximum Transmit Capability
NMS	Network Management System
NSMA	National Spectrum Management Association
NTP	Network Time Protocol
OAM	Operation Administration & Maintenance (Protocols)
PDV	Packed Delay Variation
PIR	Peak Information Rate
PM	Performance Monitoring
PTP	Precision Timing-Protocol
QoE	Quality of-Experience
QoS	Quality of Service
RBAC	Role-Based Access Control
RDI	Remote Defect Indication
RMON	Remote Network Monitoring
RSL	Received Signal Level
RSTP	Rapid Spanning Tree Protocol

Acronym	Equivalent Term
SAP	Service Access Point
SDN	Software-Defined Networking
SFTP	Secure FTP
SLA	Service level agreements
SNMP	Simple Network Management Protocol
SNP	Service Network Point
SNTP	Simple Network Time Protocol
SP	Service Point
SSO	Single Sign-On
STP	Spanning Tree Protocol
SSH	Secured Shell (Protocol)
SSM	Synchronization Status Messages
SyncE	Synchronous Ethernet
TACACS+	Terminal Access Controller Access-Control System Plus
TLS	Transport Layer Security
TOS	Type of Service
UNI	User Network Interface
UTC	Coordinated Universal Time
VCC	Common Collector Voltage
Web EMS	Web-Based Element Management System
WFQ	Weighted Fair Queue
WRED	Weighted Random Early Detection

Cambium Networks

Cambium Networks delivers wireless communications that work for businesses, communities, and cities worldwide. Millions of our radios are deployed to connect people, places, and things with a unified wireless fabric that spans multiple standards and frequencies of fixed wireless and Wi-Fi, all managed centrally via the cloud. Our multi-gigabit wireless fabric offers a compelling value proposition over traditional fiber and alternative wireless solutions. We work with our Cambium certified Connected Partners to deliver purpose built networks for service provider, enterprise, industrial, and government connectivity solutions in urban, suburban, and rural environments, with wireless that just works.

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