Cambium PTP 650 Series

(Release 01-00)

Sales Guide

Cambium Networks – Confidential and Proprietary

KEY SELLING POINTS

The sub-6 GHz, PTP 650 Series solutions are engineered and built for reliable, secure, high-performance wireless broadband connectivity and backhaul in virtually any path conditions.

VERTICAL MARKETS:

- Wireless and Wireline Service Providers
- Industries (Oil, Gas, Transportation, Mining)
- Government Public Safety Sector
- Utilities (Electricity, Water)
- Enterprise Private Networks (Healthcare, Education, Hospitality)

KEY CAPABILITIES OF A PTP 650 SOLUTION:

- 4.9 to 6.05 GHz wide-band operation
- Up to 450 Mbps aggregate throughput
- Dynamic Spectrum Optimization (DSO) enabling automatic, self-optimizing channel selection that delivers the best combination of reliability and performance
- Most reliable communications in non-line-of-sight (NLOS), long-distance line-of-sight (LOS) and high-interference environments
- Most reliable communications over water and desert terrain and in severe weather conditions
- Up to 10 bps/Hz spectral efficiency, delivering more speed while using less spectrum
- Selectable channel sizes from 5 to 45 MHz
- Robust, multi-level security
- Wireless communications over distances up to 124 miles (200 km)
- Consistent, low latency – 1 to 3 ms one way
- IPv6/IPv4 dual-stack management
- Line-rate packet processing (more than 900K packets per second)
- MPLS support to the edge (jumbo frame support – up to 9600 bytes) – MEF9

PTP 650 SOLUTIONS CAN ADDRESS THE FOLLOWING KEY APPLICATIONS:

- Provide video surveillance backhaul – personnel safety and asset protection
- Reduce operating expenses by replacing leased lines
- Extend reach of wireline and fiber networks
- Add/overlay wireless capacity on top of wired capacities for applications such as VoIP, on-demand video, video conferencing, distance learning and telemedicine
- Backhaul 4G/LTE, 2G, 3G, macro-cell, and small-cell networks
- Supply network redundancy for disaster preparedness
- Rapidly deploy wireless communications for disaster recovery, emergencies, and event security
- Enable high-speed, reliable communications in previously inaccessible areas with NLOS capabilities for “not-spot coverage”
- Backhaul public safety radio voice networks
- Provide last-mile access and offload Wi-Fi communications
- Connect buildings in a campus setting without digging trenches

WHY CHOOSE A PTP 650 SOLUTION?

The PTP 650 solution offers the best combination of:

- Performance
- Reliability
- Security
- Versatility

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ACRONYM REFERENCES

AES	Advanced Encryption Standard
DSO	Dynamic Spectrum Optimization
FIPS	Federal Information Processing Standard
HTTP	Hypertext Transfer Protocol
LOS	Line-of-sight (clear line-of-sight and Fresnel zone is clear)
MIMO	Multiple-Input Multiple-Output
nLOS	Near-line-of-sight (clear line-of-sight but Fresnel zone is blocked)
NLOS	Non-line-of-sight (no line-of-sight and Fresnel zone is blocked)
NMS	Network Management System
ODU	Outdoor Unit (Integrated or Connectorized radio)
OFDM	Orthogonal Frequency Division Multiplexing
OOBM	Out-of-Band Management
PPS	Packets-per-Second
PoE	Power-over-Ethernet
PTP	Point-to-Point
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RADIUS	Remote Authentication Dial In User Service
RF	Radio Frequency
SFP	Small Form-Factor Pluggable/Plug-in
SNMP	Simple Network Management Protocol
SyncE	Synchronous Ethernet
TDD	Time Division Duplex
TDM	Time-Division Multiplexing

1.0 EXECUTIVE SUMMARY

THE OPPORTUNITY: RELIABLE, HIGH-PERFORMANCE, SECURE, AND VERSATILE WIRELESS CONNECTIVITY AND BACKHAUL FOR MULTI-SERVICE NETWORKS

Key Applications for Wireless Service Providers

- Provide 4G/LTE, 2G, 3G, macro-cell, and small-cell backhaul
- Add/overlay wireless backbone capacity
- Extend network quickly while license applications are pursued
- Provide disaster preparation with resilient links
- Supply last-mile access and service extensions
- Provide backhaul to temporary deployments (Cell on Wheels)

Key Applications for Wireline Service Providers

- Rapidly extend network without digging trenches
- Add/overlay backbone capacity
- Provide disaster preparation – resilient links
- Supply last-mile access and service extensions to high-value enterprise customers
- Eliminate or reduce leased-line or fiber costs

Key Applications for Government Public Safety Sector

- Eliminate or reduce leased-lines
- Backhaul traffic from surveillance cameras and Land Mobile Radios (LMRs)
- Supply rapid-response emergency preparedness and disaster recovery for first responders

Key Applications for Oil and Gas Companies and Industries Such as Mining and Transportation

- Backhaul Process Control Systems (PCS) and SCADA networks
- Extend video surveillance for personnel safety and asset protection
- Provide platform to shore, ship to shore, platform to ship, and platform to platform broadband
- Supply communications and network redundancy in remote, hard-to-reach locations
- Extend back-office expertise and applications into field operations

Key Applications for Utilities

- Supply backbone connectivity for Advanced Metering Infrastructure (AMI)
- Migrate from analog to digital communications
- Extend video surveillance for personnel safety and asset protection
- Monitor remote resources and facilities
- Establish communications and network redundancy in remote, hard-to-reach locations

Key Applications for Enterprise Private Networks

- Eliminate or reduce leased-lines
- Provide video surveillance for personnel safety and asset protection
- Provide added throughput and bandwidth for on-demand and HD video
- Enhance business continuity with disaster preparedness and recovery

THE SOLUTION: CAMBIUM POINT-TO-POINT (PTP) 650 SERIES WIRELESS ETHERNET BRIDGES

Our PTP 650 Series wireless Ethernet solutions offer all the capabilities that service providers and network operators need, even in the most challenging paths and extreme weather conditions. The sub-6 GHz, PTP 650 systems are highly flexible, wide-band radios that operate in the 4.9 to 6.05 GHz frequencies, over channel widths from 5 to 45 MHz, and at Ethernet data rates up to 450 Mbps. Able to span distances up to 124 miles (200 km), our Dynamic Spectrum Optimization, narrow channel operations, and high spectral efficiency make the PTP 650 the lowest-risk approach to sub-6 deployment. The security features of the PTP 650 meet strict IT and government requirements for deployment in sensitive operations. The systems offer superb performance for virtually any applications where reliability, speed, security and versatility are major requirements.

Connectorized – Front

Integrated – Back

Integrated – Front

Cambium Networks' PTP 650 Series wireless bridges are based on the industry-vetted, field-proven Cambium Networks technologies that drive our best-in-class PTP 600 systems. That means you can be confident that the PTP 650 system you choose will deliver the reliability and performance promised, wherever you need connectivity and backhaul communications.

2.0 PRODUCT OVERVIEW

PTP 650 systems are ideal sub-6 GHz solutions when you need to deploy reliable, high-performance, secure communications in virtually any environment.

2.1 PTP 650, RELEASE 01-00

As the latest addition to our widely-deployed PTP portfolio, PTP 650 systems are designed and engineered to deliver carrier-class, high-performance backhaul connectivity. These cost-effective systems can be deployed quickly and easily and provide everywhere, future-proof, scalable communications to support the ever-increasing demands being placed on evolving, multi-service networks. With a PTP 650 solution, your network can supply the critical communications you need to accomplish your communication objectives both today and tomorrow.

2.2 HIGH-LEVEL FEATURE SET

Key Features for PTP 650 Solutions	
RF Bands	Wide-band operation from 4.9 to 6.05 GHz: 4.940 – 4.990 GHz (Public Safety) 5.150 – 5.250 GHz 5.250 – 5.350 GHz 5.470 – 5.725 GHz 5.725 – 5.850 GHz 5.825 – 6.050 GHz Allowable frequencies and bands are dictated by individual country regulations. The most common bands are listed above. (Regulatory conditions for RF bands should be confirmed prior to system purchase.)
Multi-band Capability	4.9 to 6.05 GHz in a single radio
Channel Sizes	5, 10, 15, 20, 30, 40, and 45 MHz channels (5, 15, and 30 MHz channel widths will be available in a future release. Channel sizes depend on individual country regulations and the capacity license.)
Channel Selection	By Dynamic Spectrum Optimization or manual intervention; automatic selection on start-up and continual self-optimization to avoid interference
Spectral Efficiency	10 bps/Hz maximum – highest in the category
SyncE and 1588v2	Supports 1588v2 timing and Synchronous Ethernet frequency delivery over wireless backhaul links; important for 4G networks such as LTE (available in a future release)
Packet Performance	Line rate >900K pps (packets per second)
Jumbo Frame Support	Up to 9600 bytes
Robust Security	• FIPS-197 compliant 128-bit and 256-bit AES encryption (optional) • Identity-based user accounts • Configurable password rules • User authentication and RADIUS support • Event logging and management; optional logging via syslog • Disaster recovery and vulnerability management

Key Features for PTP 650 Solutions (continued)	
User Data Throughput	Dynamically variable up to 450 Mbps at the Ethernet Maximum conditions – 2x2, 45 MHz channel, 256 QAM Flexible capacity licensing: • Lite Capacity – up to 125 Mbps • Mid Capacity – up to 250 Mbps • Full Capacity – up to 450 Mbps
Antenna Configuration	• Integrated systems offer an attached 23 dBi, flat-panel antenna • Connectorized systems offer the high-gain advantage of external single- and dual-polarity antennas (antennas purchased separately)
Range	Up to 124 miles (200 km)
Operating Temperatures	-40° to +140° F (-40° to +60° C), including solar radiation
Wind Speed Survival	Up to 200 mph (322 kph)
Flexible I/O	  **AC Power Injector:** Lower-cost option that accepts AC input only – 35 W, 90-240 VAC, 50/60 Hz **AC+DC Power Injector:** Enhanced injector that accepts both AC and DC input (70 W, 90-240 VAC, 50/60 Hz), tolerates a greater temperature range, and can power a device such as a video camera or wireless access point on the AUX port of the ODU
T1/E1 TDM Support	• 8 x T1/E1 TDM module (optional indoor unit available in a future release) • G.823-compliant timing; DC power input (compatible with AC+DC Power Injector output)
Low Latency for T1/E1 (one way)	• 1 to 3 ms typical, depending on model, range, bandwidth, modulation mode and number of T1/E1 ports • Accurate latency figures can be determined for any given configuration using the PTP LINKPlanner
Flexible System Management Options	• In-band and out-of-band (OOBM) management (OOBM in a future release) • IPv6/IPv4 dual-stack management • Remote management via Web browser using HTTP or HTTPS/TLS • Integrate with existing NMS via SNMP v1, v2c or v3, proprietary PTP MIB and MIB-II • Cambium Wireless Manager, version WM4.0/SP4 or higher
Powerful Technology Combination	Based on the industry-vetted, field-proven Cambium technology combination: • 2x2 MIMO-enhanced link budget, dual payload • *Intelligent* Orthogonal Frequency Division Multiplexing (*i*-OFDM) • Dynamic Spectrum Optimization (DSO) • Fast preemptive adaptive modulation • High spectral efficiency • Best-in-class radios – highest system gain in the category

Key Features for PTP 650 Solutions (continued)	
Easy-to-Use, Accurate Link Planner	Available as a free stand-alone tool, PTP LINKPlanner is our industry-leading link planning tool, enabling fast and accurate performance planning prior to purchase based on variables specific to your deployment. Single or multiple links can be planned simultaneously, and the detailed performance report provides information to help installers deploy the system quickly and easily. You can also obtain a PTP 650 Bill-of-Materials (BOM) to simplify the ordering process.
12-Month Standard Warranty	With the purchase of each PTP 650 system, we provide a 12-month (one-year) limited warranty on hardware components with repair-and-return terms for damaged units. Typical turn-around time for repair and return of a damaged unit is less than 30 days. This Standard Warranty also includes minor software enhancements as available and 24x7 telephone technical support. Each new hardware device must be registered online at cambiumnetworks.com/registration to activate the free 12-month warranty period and receive notification of software updates.
PTP 650 Extended Warranties	At time of purchase or any time prior to the end of the 12-month standard warranty, we recommend that you purchase an Extended Warranty to upgrade and/or extend equipment coverage and protect your investment. **Extended Warranty with All Risks Advanced Replacement**: This warranty upgrades and extends the initial 12-month Standard Warranty to include All Risks equipment coverage and the Advanced Replacement Program. The All Risks feature provides coverage for virtually all types of equipment damage, including lightning, dropped units, vandalism, fire and hardware failure. Replacement units are shipped from Cambium Networks the next business day after receipt of a confirmed Cambium RMA, and Cambium pays shipping costs. Delivery time is dependent on the ship-to location and customs. This warranty also includes 24x7 telephone technical support. **Extended Warranty with Repair-and-Return:** This warranty option extends the term of the initial 12-month Standard Warranty with repair-and-return terms through the second, third or fifth years of ownership. Typical turn-around time for repair and return of a damaged unit is less than 30 days. This option is beneficial when your organization purchases one or more spare PTP links for use as replacement units and, therefore, fast replacement is not necessary. Also included in this warranty is 24x7 telephone technical support.

2.3 PTP 650 OVERVIEW

With more than 75,000 point-to-point links deployed in more than 150 countries worldwide, the PTP 650 represents the culmination of eight years of point-to-point deployment experiences and customer feedback. The systems are engineered with advanced technology that serves a wide range of connectivity and backhaul requirements, supports diverse and evolving multi-service networks, and empowers users through wireless innovation.

With wireless communications, there are many environments that pose serious performance and reliability challenges such as obstructions, weather, water, distance, and interference. In these situations, the solution's technology is really tested. Many comparable systems drop packets or cannot sustain a connection. However, PTP 650 systems are built to handle these challenges while delivering carrier-grade reliability and high-performance connectivity, even in the most challenging conditions. You can rely on your PTP 650 system to out-perform comparable systems and operate dependably virtually anywhere.

Cambium PTP 650 Series Solutions
PTP 650 (4.9 TO 6.05 GHz) Integrated
PTP 650 (4.9 TO 6.05 GHz) Connectorized

PTP 650 radios provide the versatility you need to configure and deploy a broadband solution that works with your existing network and network management infrastructure. Available in Integrated and Connectorized versions, the systems provide multi-band functionality operating between 4.9 and 6.05 GHz radio frequencies, using channel widths from 5 to 45 MHz (where local regulations allow). With the system's wide-band functionality, your PTP 650 hardware is tunable across the full operational band (4.9 to 6.05 GHz). This means that you are certain to find some combination of operational bands that complies with your regional, in-country regulations.

PTP 650 systems offer selectable channel sizes and varying data rates, allowing you to choose the bandwidth and throughput you need based on your requirements. The systems provide tiered capacity levels from 125 Mbps to 450 Mbps. Each PTP 650 system is shipped with the Lite Capacity. If you want a higher capacity level, you can order the desired capacity upgrade at order time or anytime after order.

PTP 650 CAPACITY TIERS	
Capacity Level	**Maximum Throughput**
Lite Capacity	125 Mbps
Mid Capacity	250 Mbps
Full Capacity	450 Mbps

Upgrading Capacity:
As an example, you can begin with a Lite system with up to 125 Mbps. At any time, you can increase throughput and bandwidth in a single step or incremental steps up to 450 Mbps. To achieve the maximum 450 Mbps throughput, your channel size must be 45 MHz. Each capacity increase is initiated via a software-activated license key and does not require hardware changes. Once the license key is installed on the ODU and activated, the capacity upgrade is effective immediately. The system upgrades are architected to ensure that each software capacity upgrade will provide an increase in capacity. For example, upgrading from Lite Capacity to Mid Capacity will always result in a doubling of usable throughput.

Trial Capacity Upgrades: Each PTP 650 comes with a 60-day trial period that can be enabled and disabled at any time to allow the end user to try the full capacity of the radio and determine the specific increase in capacity to be expected with each upgrade.

PTP 650 END KITS:

PTP 650 Integrated End Kit


+

OR

+


+ **AC Power Cable**

Integrated ODU | **AC Power Injector or AC+DC Power Injector** | **Mounting Bracket** | **Cable**

PTP 650 Connectorized End Kit


+

OR

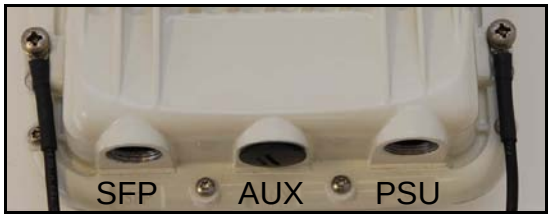
+


+ **AC Power Cable**

Connectorized ODU | **AC Power Injector or AC+DC Power Injector** | **Mounting Bracket** | **Cable**

When ordering a system, two PTP 650 End Kits are required per link, with one kit at each end of the link. Each kit includes an ODU, a power supply unit, bracket, and line cord plus the software that allows operators to set up and manage the link (via a local web interface on each ODU).

- **Outdoor Units (ODUs):** The ODU is a self-contained transceiver that houses both the radio and networking electronics. The unit's small size and neutral color make it ideal for aesthetically restrictive areas. Outdoor units come in two versions – Integrated and Connectorized. The Integrated version has a 23 dBi, flat-plate antenna attached to the ODU, while the Connectorized version can be fitted with up to an 8-foot external antenna (purchased separately). An external antenna increases signal gain, and, therefore, the range and robustness of the link. Using our PTP LINKPlanner tool will help you determine whether the Integrated or the Connectorized version is more appropriate for a particular application.



Each ODU provides three flexible input/output interfaces:

– SFP Port: The SFP (Small Form Factor Pluggable) port allows the user to add either an optical or copper Gigabit Ethernet interface for out-of-band management or user data, user data with in-band management, ODU-to-ODU links, SyncE or source. The SFP modules are optional accessories that include the selected interface and a license key to activate the port.

- AUX Port: The Auxiliary port is a built-in, standard 1000BaseT Gigabit Ethernet port that also provides 802.3at PoE output to deliver data and power to a directly connected device such as a video camera or wireless access point. The ODU must be powered with the Enhanced AC+DC Power Injector to use the PoE output capability of this port.
- PSU Port: This 1000BaseT Gigabit Ethernet port is used to power the ODU using the proprietary power-over-Ethernet Power Injectors from Cambium and also connects to the management and data networks via 100 BaseT or 1000 BaseT Ethernet.

With this wide range of configuration options, you can customize PTP 650 links based on your individual network infrastructure, communication objectives, and environmental conditions.

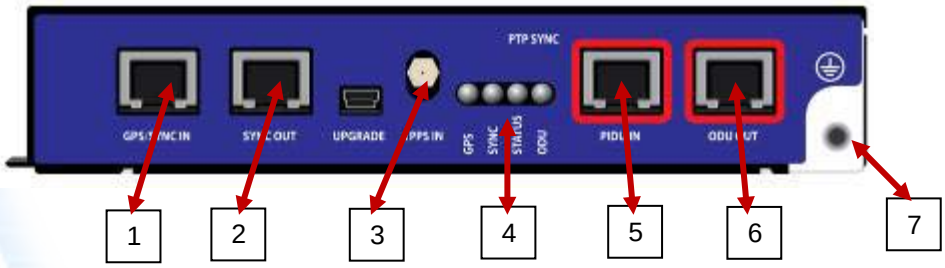
- **Power Injectors:** The power injector is an indoor unit that connects to the PSU interface on the ODU and also to the network equipment using Cat5e cable with RJ45 connectors. The unit is also plugged into an AC or DC power source so that it can inject Power-over-Ethernet (PoE) into the ODU. One power injector is required at each end of a link. You have the following two options:
  - **AC Power Injector:** This power injector accepts AC input only and is a lower-cost unit that supports 32° to 104° F (0° to 40° C) temperature ranges.
  - **AC+DC Power Injector:** This is an enhanced power injector that accepts either 100-240VAC or 48VDC input. It also tolerates a greater temperature range (-40° to 140° F or -40° to 60° C) and can power a device such as a video camera or wireless access point on the Auxiliary port of the ODU. The AC+DC injector can also be configured in redundant configurations for high availability requirements.

PTP-SYNC SYNCHRONIZATION MODULE

In deployments where a number of radios are installed on the same tower or rooftop or where a large number of links are installed in a sizeable, dense network configuration, it is possible that the performance or throughput of some of the links can be reduced. The degradation in performance is caused by cross interference between the collocated units, and the level of interference can worsen when the links operate on the same or adjacent channels. Such cross interference is typically called “self-interference.” It can be reduced greatly by synchronizing a radio’s transmit and receive frames so that none are transmitting while their neighbors are receiving. To achieve this synchronization, an external timing module is required that can provide timing reference signals to the radios.

PTP 650 Series radios use a Time Division Duplex (TDD) cycle in which the ODUs alternately transmit and receive TDD bursts. The systems also include synchronization technology which introduces a fixed TDD framing mode and allows the frame timing in a link to be synchronized with other PTP 650 units or an external Global Positioning System (GPS) timing module. To provide a reliable and convenient timing reference for PTP 650 links, we offer a synchronization module, the Cambium PTP-SYNC. The PTP-SYNC unit receives a time signal from a clock source and sends it to the PTP 650 outdoor radio unit. The radio adjusts its own timing until precise synchronization is achieved. Then, the system synchronizes transmit and receive frames to ensure that all radios send at the same time and all receive at the same time.

PTP-SYNC Module



PTP-SYNC Interfaces:

1) GPS/SYNC IN
2) SYNC OUT
3) 1 PPS IN (SMA, coax alternative to GPS/SYNC IN”)
4) LEDs: GPS, SYNC, STATUS, ODU
5) PIDU IN
6) ODU OUT
7) Earthing point

One PTP-SYNC module is required per link, and you can daisy-chain up to 10 PTP-SYNC units together to share the timing information among a group of radios. The PTP LINKPlanner tool makes it easy to accurately project link performance with a PTP-SYNC unit as the timing reference.

PTP LIGHTNING PROTECTION UNIT (PTP-LPU)

Although PTP 650 radios are designed to withstand extreme conditions, they are often mounted on high towers, frequently with external antennas. This makes the radios prime targets for lightning strikes. Our Cambium PTP Lightning Protection Unit (PTP-LPU) is designed to protect a PTP 650 radio from the harmful effects of power surges induced in the cables by nearby lightning strikes. By grounding the power surges before they can harm the units, the PTP-LPU gives the radios the best protection from the harmful effects of lightning, although 100% protection is neither implied nor possible.

The PTP-LPU is a high-speed, high-current, solid-state device that is encased in a rugged metal case designed to hold up against ice, snow and rain and to withstand winds up to 150 mph (242 kph). The projected operational life of a PTP-LPU is 10 years, even when continually exposed to the elements. Because of its small form factor and minimum number of components, the unit is easy to transport and install. Plus, the cost-effective PTP-LPU is affordably priced.

For the best possible protection, each PTP 650 radio requires two Lightning Protection Units (PTP-LPUs), one installed adjacent to the radio on the wall, tower or mast, and one installed at the cable entry point of the building in which the network resides. The unit near the base of the wall or tower protects the LAN network inside the building. Because the units can be installed with new deployments or easily added to existing PTP 650 radios, you can reap the benefits of the PTP-LPU's lightning protection capabilities for an existing or planned PTP 650 network.

Parameter	Remark
Transfer rate	1000 Base T
Connectors	RJ 45
Protection mode	Line-to-line and line-to-ground
Response time	5 nanoseconds
Mounting	Pole mount 1-3" (25-75 mm) or wall mount
Metal enclosure	Projected 10-year operational life
Dimensions (including glands)	6.3" Length (16 cm), 4" (10 cm) Width, 3.5" (9 cm) Height
Weight	1.5 lbs (700 g)
Wind loading	150 mph (242 kph)
Operating temperature	-40° F to +140° F (-40° C to +60° C)
Humidity	100% condensing
Tested to IEEE / ANSI C62.41 10/1000 long wave	120 amp peak, peak power 14,000 watts
Environmental protection	IP66 / NEMA-3R

2.4 TECHNICAL FEATURES

Regardless of the application, each PTP 650 system operates as a transparent, Layer 2 Ethernet bridge that creates a wireless link between two points. The two endpoints communicate via radio waves over channels varying in bandwidth between 5 and 45 MHz in spectrum between 4.9 GHz and 6.05 GHz. The wireless link is TDD based and supports both symmetric and asymmetric configurations.

The PTP 650 is a high-capacity radio for transmitting Ethernet and TDM traffic with a maximum aggregate throughput of 450 Mbps. The systems offer exceptional reliability and throughput in NLOS or long-distance LOS conditions, over water and desert terrain, in areas where there is significant RF interference, and through extreme weather conditions. The PTP 650 delivers proven near-line-of-sight and non-line-of-sight performance through a combination of features, including a unique adaptive frame structure; fast, preemptive adaptive modulation; 1024-subcarriers; split-frequency operation; and spatial diversity. These capabilities provide a high tolerance for obstructions and enable you to establish wireless communications in conditions where most comparable systems cannot even make a connection.

PTP 650 systems are built on the Cambium Networks point-to-point technologies that you have come to know and respect. We have sharpened the existing technologies and added new technologies to further increase performance, reliability, and versatility.

- **2x2 Multiple-Input Multiple-Output (MIMO):** PTP 650 radios transmit multiple beams from the antenna which significantly protects against fading and improves performance and link availability. In addition, the radio can intelligently switch to “Dual Payload” mode, if conditions support it. In this mode, different data can be transmitted in parallel on each transmitter, effectively doubling the bandwidth at higher modulation rates.
- ***Intelligent* Orthogonal Frequency Division Multiplexing (*i*-OFDM):** In addition to MIMO transmitting the data twice, *i*-OFDM sends transmissions over multiple frequencies, or sub-carriers. The 1024 sub-carriers result in higher spectral efficiency and higher resistance to:
  (1) Multi-path interference which occurs when objects in the air gap split a beam into parts that travel different paths and interfere with each other at the receiver
  (2) Frequency selective fading which occurs when arriving signals cancel each other out at the receiver
- **Dynamic Spectrum Optimization (DSO):** Our unique DSO functionality self-optimizes each link for maximum reliability and performance. With DSO, PTP 650 links use the in-band, online spectrum analyzer to continually scan the entire operational band, seeking channels that may deliver higher performance and reliability without impacting the operational link. The radios can be configured to jump to the optimal channel with no operator intervention. PTP 650 systems also support split-frequency operation, allowing each direction of a link to operate on a different channel. This mitigates the negative impact of situations where the interference environment is different at each end of the link. The time-stamped database tracks events, alerts you to any interference that triggers channel changes, and provides statistics that help you pinpoint the channels that offer the clearest data paths. Consequently, you can be confident that your PTP 650 links are automatically optimized to operate in the best available channel.
- **Fast, Preemptive Adaptive Modulation** ensures that PTP 650 systems adapt rapidly to changing field conditions. Each radio has error-coding functionality and 13 modulation combinations that are automatically selected for each individual frame. The system automatically analyzes the received signal and notifies the far end of the link of the optimal modulation mode for transmission. These rapid adjustments greatly increase link reliability and efficiency.
- **Time Division Duplex (TDD) Synchronization:** PTP 650 systems operate using a TDD cycle in which the ODUs alternately transmit and receive TDD bursts. Using a reliable timing reference from our PTP-SYNC synchronization module, the TDD capability synchronizes transmit and receive signals to minimize self-interference and promote optimal frequency re-use. Of great importance to service providers, this functionality allows the deployment of multiple radios on a rooftop or tower with greatly reduced self-interference.

- **Spatial Diversity:** Spatial diversity is a method of transmission and/or reception in which the effects of fading are minimized by the simultaneous use of two or more physically separated antennas – typically separated by one or more wave lengths. Our PTP LINKPlanner tool will help to determine the effect of using spatially diverse external antennas with PTP 650 Connectorized systems.
- **Synchronous Ethernet (SyncE) and 1588v2 Precision Timing (Optional Feature Available in a Future Release):** As service providers migrate to 4G next-generation networks such as LTE, sub-6 GHz backhaul is often recommended. Precise timing and frequency references are critical in these networks to support interoperability, frequency re-use, and scalability. PTP 650 systems support both 1588v2 transparent clock (timing) and SyncE (frequency/phase) delivery over the wireless backhaul link.
- **IPv6/IPv4 Dual-Stack Management Support:** As the global supply of IPv4 addresses becomes fully allocated, IPv6 support is becoming more important. PTP 650 systems support a dual-stack, IPv4/IPv6 networking stack, allowing you to deploy and manage PTP 650 systems in an IPv6 or IPv4 network. If a PTP 650 system is initially deployed in an IPv4 network, the system is IPv6-ready for future migration.
- **Split-Frequency Operation:** In some unlicensed environments where noise is localized to one end of a link or in some licensed bands where FDD-like operation is required, the PTP 650 support split-frequency operation, enabling the radio to transmit on one channel and receive on another channel.

2.5 SECURITY FEATURES, CERTIFICATIONS AND DURABILITY

Recognizing the importance of protecting your wireless communications from malicious attack, we have directed significant financial and manpower resources to provide the highest level of information security for your over-the-air transmissions.

- **Encryption:** PTP 650 systems support FIPS-197-compliant 128-bit and 256-bit Advanced Encryption Standard (AES) encryption via an optional software license upgrade.
- **Management Interface Protection:** One area of potential vulnerability for wireless systems is the network management interface. To protect the management interface on your PTP 650 systems, you can utilize HTTPS/TLS, the secure version of HTTP, to remotely access your system's management functions. PTP 650 radios also support implementation of user-provided X.509 digital certificates. SNMP (Simple Network Management Protocol) version 3 adds security to SNMP. In certain cases, a software-activated license key is required to implement these capabilities. (Refer to the PTP 650 User Guide for license key requirements.)
- **Identity and Event Management:** You can enable identity-based user accounts with configurable password rules to control user access to the radios. Remote Authentication Dial-In User Service (RADIUS) may be used to remotely authenticate your users and their levels of access based on your network policies.
- **Auditing and Event Management:** Security and other events are logged locally and optionally can be sent to a centralized logging server using *syslog*. Examples of typical messages include: successful and failed log-in events and changes to a security configuration.
- **Disaster Recovery:** The PTP 650 "save and restore" feature allows you to back up your radio's operating configuration file. Then that file can be restored quickly and easily if a unit needs to be reset or replaced or to configure a replacement unit to the same state. The configuration values are encrypted for security.
- **Vulnerability Management:** We use industry-standard tools to regularly scan PTP 650 software for vulnerabilities, and those that pose risk are resolved.
- **Development Process:** Each new software release goes through software security checks as part of the system testing process that includes code reviews, vulnerability assessment, and best practices review.

In addition to these security features, we have obtained certifications that comply with key industry standards.

- **IP66/67 Rating:** The IP Code, or Ingress Protection Rating, classifies the degrees of protection provided against the intrusion of solid objects, dust and water in electrical enclosures. PTP 650 radios have protective aluminum enclosures that are IP66/67 rated against dust and water intrusion as a result of testing with dust and powerful water jets aimed at the enclosure from any direction.
- **MEF9 Certification:** PTP 650 systems deliver the Ethernet services compliant with Metro Ethernet Forum MEF9 technical specifications. As a result, the systems easily operate with other MEF-certified network equipment.
- **IPv6ready.org:** ipv6ready.org is a conformance and interoperability testing program within the IPv6 forum. The PTP 650 has been tested and validated for deployment in IPv6 networks.

Last, but by no means least, PTP radios have logged more than 4.3 BILLION field hours, confirming the exceptional durability of our PTP radios.

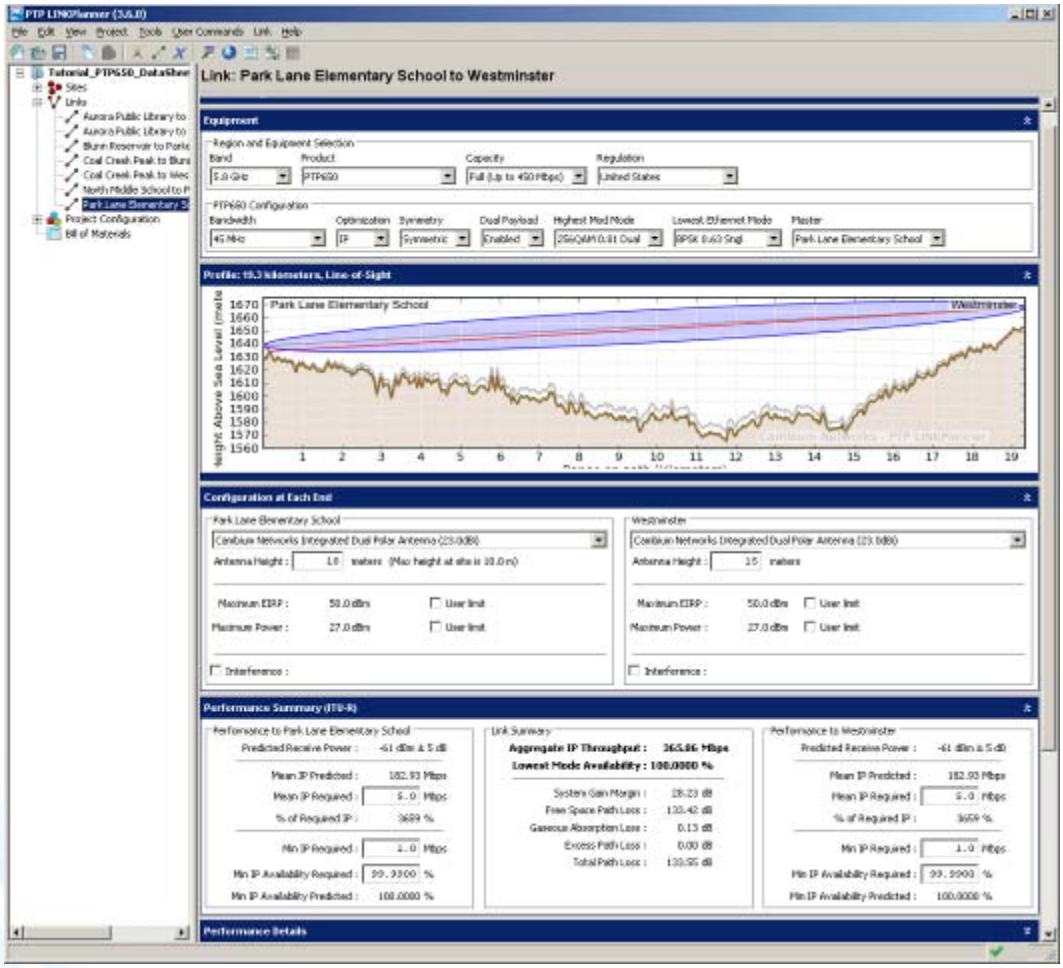
- **Mean Time Between Failures (MTBF):** MTBF is the projected elapsed time between equipment failures. PTP 650 outdoor units average 40 years MTBF based on field component failure rates. The systems perform reliably through winds up to 200 mph (322 kph) and temperatures from -40° to +140° F (-40° to 60° C).

2.6 PTP LINKPLANNER

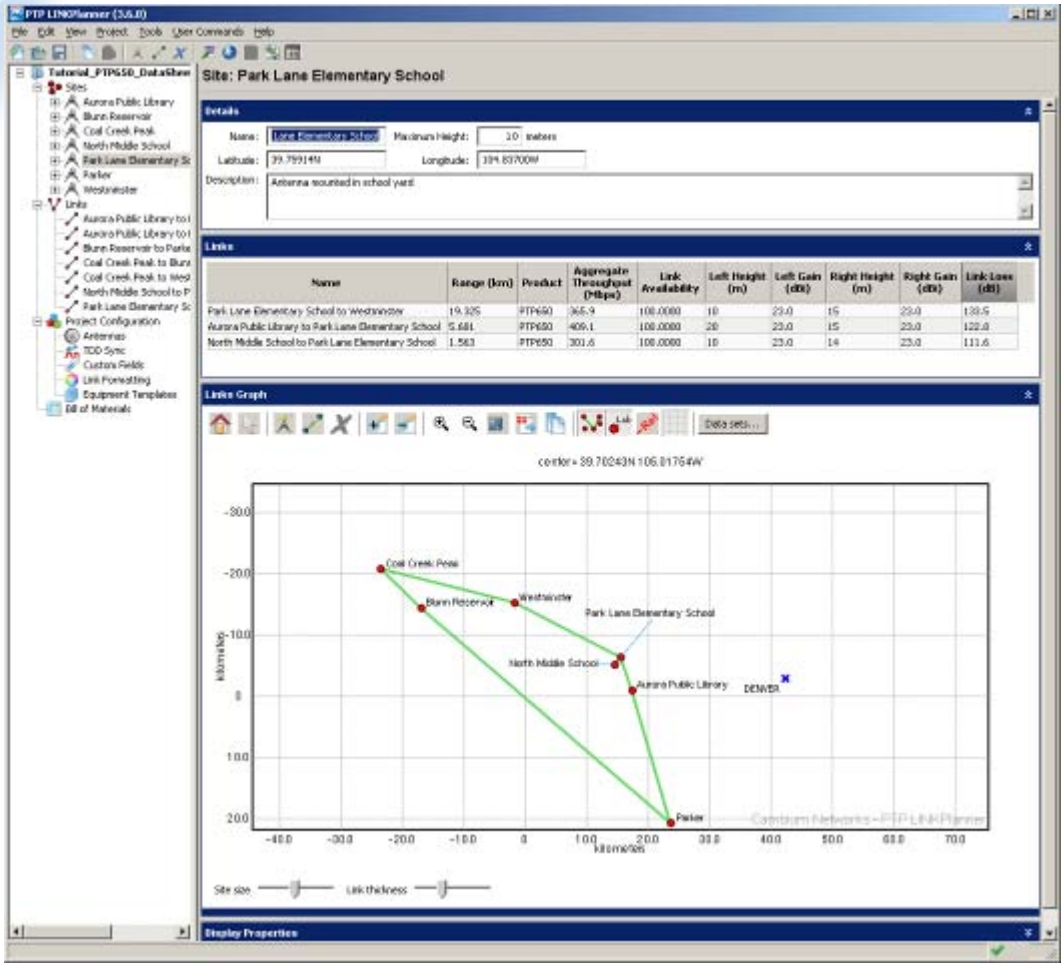
The Cambium PTP LINKPlanner is a link planning and optimization tool designed for use with PTP Series solutions. Based on your specific radio path conditions and tower locations, this planning tool allows you to perform what-if scenario analyses, determine link performance characteristics, and verify the success of your project prior to purchase. PTP LINKPlanner is available as a stand-alone tool. The software can be downloaded free at PTP LINKPlanner/download.

PTP LINKPlanner lets you quickly and easily optimize link performance before purchase and obtain a detailed performance report to use in link planning and deployment. With LINKPlanner you can perform calculations for licensed and unlicensed PTP products, calculate TDD synchronization parameters and set realistic link performance expectations. In addition, PTP LINKPlanner includes capabilities that take link planning to a high level of RF sophistication, including:

- Extra intelligence for designing and optimizing multiple links simultaneously
- A visual overview of the entire network via Google™ Earth
- Automatic loading of path terrain profiles and environmental factors
- Pull-down menus for ease of use
- A detailed performance report that guides your installers through a quick, no-hassle deployment
- PTP 650 Bill-of-Materials (BOM) to simplify the ordering process



Sample Network Results Page



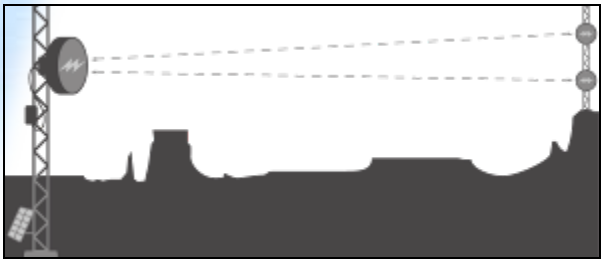
Sample Network Overview Page

Operating range and data throughput are dependent on several factors, including:

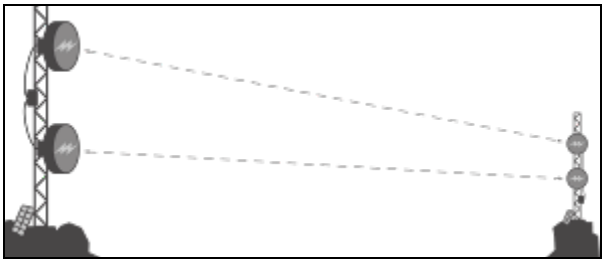
- Path Length
- Antenna heights on local and remote sites
- Obstructions (height and distance)
- Antenna type - Integrated antenna or Connectorized with an external antenna to provide additional system gain
- Connectorized antenna options – choose from a selection of separately-purchased single- and dual-polarity antennas (local regulations should be checked prior to purchase)
- Location of the link – site elevation and terrain
- Local regulatory rules and limits

With the LINKPlanner tool, you can optimize a link before purchase and deployment by changing input data to see the effect on performance and throughput. For example, if a link calculation indicates low throughput, then a number of factors can be changed to improve projected throughput.

Spatial Diversity with Connectorized Radios: PTP LINKPlanner can also be used to determine the effect of using external antennas with PTP 650 Connectorized radios which include spatial diversity. (Each Connectorized radio has two built-in N-type connectors.) Spatial diversity is a method of transmission and/or reception in which the effects of fading are minimized by the simultaneous use of two or more physically separated antennas – typically separated by ten or more wave lengths. The following diagrams show two spatially diverse examples.



One Dual Pole and Two Single Pole Antennas Vertically Separated



Two Single Pole Antennas Vertically Separated

If you have not done so already, you should complete one of our live or recorded tutorials as soon as possible, so you can begin using the PTP LINKPlanner software.

2.7 WIRELESS MANAGER

Flexibility is one of the hallmarks of our point-to-point solutions, especially when it comes to managing the wireless network. You can easily integrate with an existing third-party network management system; manage the wireless network remotely via the Internet and a Web browser; and/or use our Wireless Manager, release WM4.0/SP4 or higher as your wireless network management system.

Wireless Manager (WM) helps organizations manage their wireless networks for maximum reliability and uptime. With WM, Point-to-Point and Point-to-Multipoint sites as well as any other SNMP-enabled devices can be monitored and managed from one live Google™ map-based view. Real-time polled network performance metrics and alarms shown on a unified map enable faster and more efficient issue response.

When paired with our PTP solutions, WM adds these capabilities to PTP bridges:

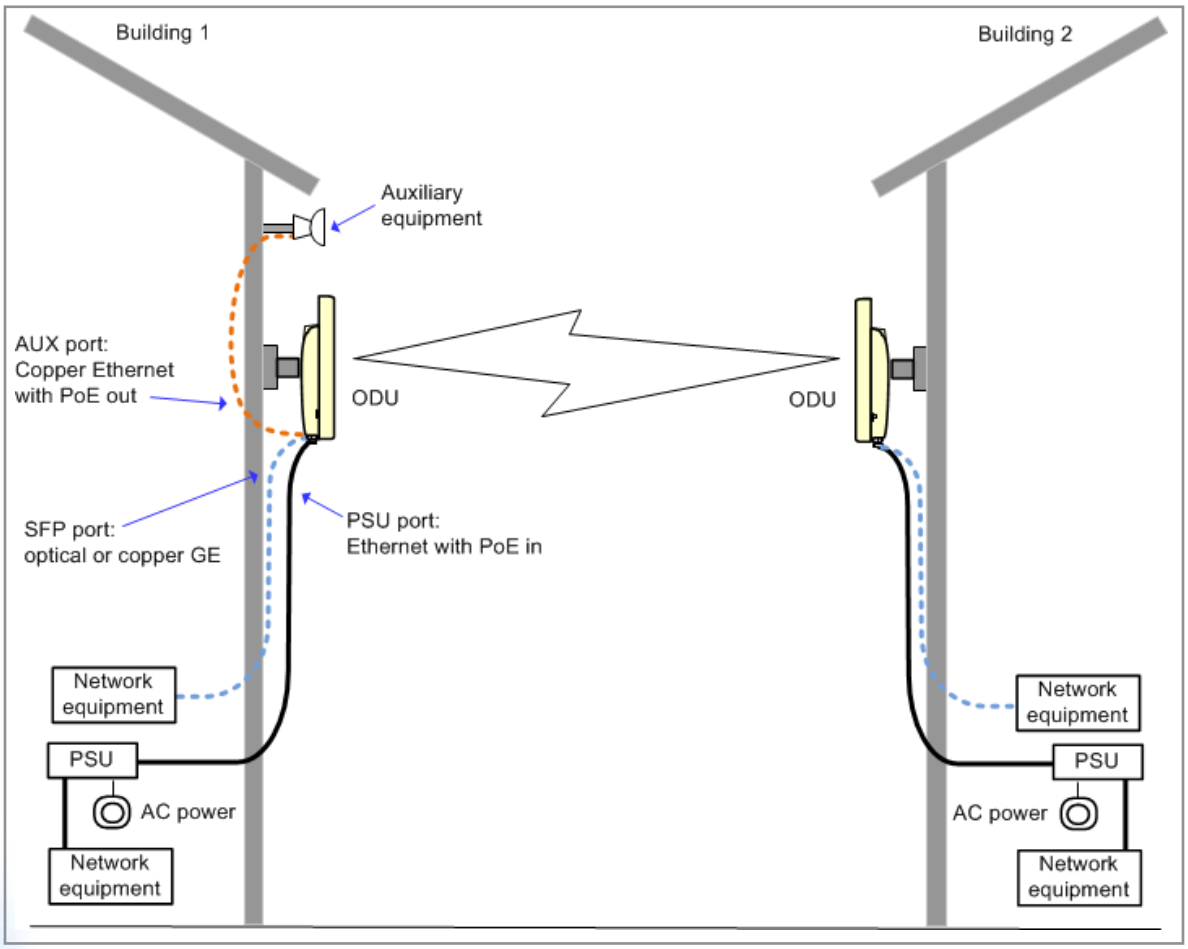
- **Status Monitoring:** WM uses an SNMP status ping to determine if PTP devices in the WM inventory are still responsive and reachable via the network. A failed status check results in a major alarm, which is prominently displayed. An alarm can alert you to failed, destroyed, and/or stolen hardware, including problems such as denial-of-service attacks that make a device effectively offline.
- **Configuration Monitoring:** WM checks the configuration of each PTP device on a regular basis and compares that configuration to the expected settings. If a discrepancy is detected – due to unauthorized tampering with the device, as an example – the system administrator is notified. Then appropriate investigative and corrective action can be taken.
- **Access Control:** WM users can be limited in the scope of their WM activities, including limits on the devices they can view and manage as well as limits on the features they can use (e.g., read-only inventory listings versus writing configuration settings). Password access provides further control.
- **Audit Trail:** WM records the configuration actions of its own users to ensure that a history is maintained of what users changed the settings on each PTP device and when the changes were made. In the event of a problem with settings on a device, the system administrator can determine which user is responsible and assess the reasoning behind the changed configuration.

3.0 CONFIGURATION AND ORDERING

This section of the Sales Guide describes the recommended policies and procedures for ordering PTP 650 solutions. Below are the key steps involved in ordering a PTP 650 system:

1) Use PTP LINKPlanner to plan your link and obtain a PTP 650 Bill-of-Materials (BOM)
2) Select the desired end kits – two per link (one at each end of the link)
3) Select optional software keys
4) Select optional accessories – Lightning Protection
5) Select optional accessories – PTP SYNC for a TDD-synchronized link
6) Select optional accessories – Fiber or GigE SFP port kits
7) Select external antennas for Connectorized links
8) Select optional installation tools such as cable and connectors
9) Select your Extended Warranty period
10) Select any needed spares

3.1 TYPICAL DEPLOYMENT



Example of a PTP 650 Deployment

3.2 STEP-BY-STEP ORDERING

Step 1: Plan the link and obtain a PTP 650 BOM

Our sophisticated, yet easy-to-use Cambium PTP LINKPlanner tool allows you to accurately predict performance characteristics and determine the success of your project prior to purchase based on your individual radio path conditions and tower locations. You can plan and optimize a single link or multiple links simultaneously, apply "what if" scenarios, and see the effect of your changes on performance immediately. Once you have optimized the link to your requirements, the Performance Report reflects the optimal configuration and provides configuration details to speed the deployment process. You can also obtain a PTP 650 BOM to simplify the ordering process. PTP LINKPlanner is available at no charge as a stand-alone tool. You can download it from our web site (see link in section 2.6 PTP LINKPlanner).

Step 2: Select the desired End Kits

Two PTP 650 End Kits are required for each link (one kit per end). Each End Kit includes one ODU, one power supply unit (power injector), a bracket, and a line cord. When you select the end kits, you also need to specify the power injector option needed for the kits.

It is important to note that systems deployed in the U.S., Canada, and other countries follow Federal Communications Commission (FCC) and Industry Canada (IC) rules and regulations. Countries in the EU and most countries outside the U.S. and Canada follow European Telecommunications Standards Institute (ETSI) standards. You will need to order the appropriate kits for deployment in the intended location.

End Kit Description	Connectorized Part Number	Integrated Part Number
U.S. and Other Countries Following FCC Rules (can also be shipped to Canada):		
End Kit with AC Injector	C050065H007	C050065H009
End Kit with AC+DC Injector (with extended temperature range)	C050065H008	C050065H010
EU Only:		
End Kit with AC Injector	C050065H017	C050065H019
End Kit with AC+DC Injector (with extended temperature range)	C050065H018	C050065H020
Most Countries Outside EU and U.S. (these models are preferred for shipment to Canada):		
End Kit with AC Injector	C050065H011	C050065H013
End Kit with AC+DC Injector (with extended temperature range)	C050065H012	C050065H014

Step 3: Select Optional Software Keys

Each software key is for a single end. Two keys are needed for each link. When you order a software key, the Access ID is delivered to you by email. Once you receive your Access ID, you must activate the software key at the Cambium support web site.

- **Capacity Upgrades:** Each ODU ships with the Lite Capacity and up to 125 Mbps throughput. If 125 Mbps meets your capacity requirements, you do not need to specify a capacity upgrade. If you want to increase the throughput to 250 Mbps or 450 Mbps, you will need to add the appropriate software keys for the capacity upgrade. You can order a capacity upgrade at the time of order or anytime after ordering your system. The price and process are the same regardless of when you order the upgrade.
- **Encryption:** To add AES encryption to each end of the link, you need to specify the required encryption option – 128-bit or 256-bit. When you order AES encryption, the software license key also enables HTTPS and SNMPv3.

Software Key	Description	Part Number	Notes
Capacity Upgrades	PTP 650 Lite (125 Mbps) to Mid Capacity (250 Mbps) Upgrade License	C000065K021	One license key per ODU; no penalty to upgrade at initial purchase or later
	PTP 650 Lite (125 Mbps) to Full Capacity (450 Mbps) Upgrade License	C000065K022	
	PTP 650 Mid (250 Mbps) to Full Capacity (450 Mbps) Upgrade License	C000065K023	
Encryption	PTP 650 128-bit AES Encryption	C000065K018	One license key per ODU; also enables HTTPS and SNMPv3
	PTP 650 256-bit AES Encryption	C000065K019	

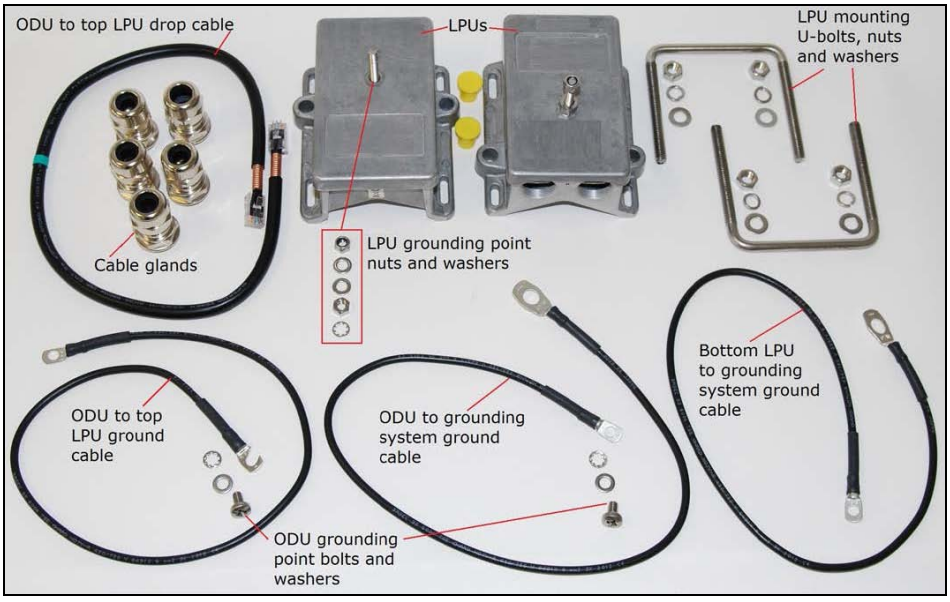
Step 4: Select Optional Accessories – LPU and Grounding Kit

Although Lightning Protection Units (LPUs) are optional accessories, it is highly recommended that you include LPUs with each link to protect the links from the harmful effects of power surges induced in the cables by nearby lightning strikes. By grounding the power surges before they can harm the units, PTP-LPUs give your links the best protection from the harmful effects of lightning, although 100% protection is neither implied nor possible.

Each LPU Kit includes two lightning protection units and the appropriate grounding kits. You need one LPU Kit per end.

For the best possible protection, each PTP 650 radio requires two LPUs, one installed adjacent to the radio on the rooftop, wall, or tower and one installed at the cable entry point of the building in which the network resides. The LPU installed at the building's cable entry point protects the LAN network inside the building.

Description	Part Number	Notes
PTP 650 LPU and Grounding Kit	C000065L007	One LPU Kit per end



PTP 650 LPU and Grounding Kit

Step 5: Select Optional Accessories – TDD SYNC

PTP 650 radios include TDD synchronization technology which allows transmit and receive signals in a radio to be synchronized so that all radios transmit at the same time and all receive at the same time. Of great importance to service providers, this functionality allows the deployment of multiple radios on a rooftop or tower with greatly reduced self-interference. However, you need an external GPS timing module or a Cambium PTP-SYNC synchronization module to provide the radios with an accurate timing reference. (TDD synchronization accessories will be available in a future release.)

Description	Part Number	Notes
PTP-SYNC	WB3665	One per ODU master
Trimble Acutime GPS / Adapter Cable Kit	WB4141	One per tower; antenna and cable kit includes one WB3903 and one WB3961
Rack-Mount Kit for PTP-SYN	WB3486	Optional
PTP-SYNC <-> Trimble Adapter Kit	WB3961	Spare cable

WB3665

PTP-SYNC

Kit - WB4141

WB3486

PTP-SYNC Rack Mount Kit

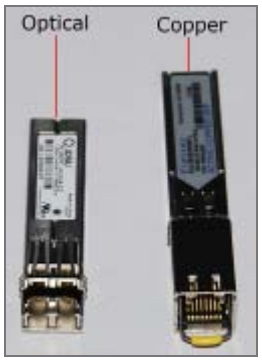
Step 6: Select Optional Accessories – SFP Modules

The PTP 650 provides three flexible input/output (I/O) port options – a PSU port, an SFP port, and an Auxiliary port. The SFP port supports both a single-mode and multi-mode optical interface as well as a Gigabit Ethernet interface. To order either an optical module or Gigabit Ethernet module, you need to specify which SFP Kits you require. Each SFP Kit contains an SFP module, gland, software key, and documentation. One kit is required per ODU (two kits per link).

Single-mode fiber provides a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fiber has a much smaller core than multimode with a wavelength of typically 1300 to 1320 nm. Conversely, multimode fiber gives you high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core which is typically 850 or 1300 nm.

The PTP 650 supports ONLY the SFP modules listed below and is not compatible with other third-party devices. The kits below include a software license key which activates the SFP port on the ODU.

Description	Part Number	Notes
Single-Mode Optical SFP Interface	C000065L008	1310 nm / 1000 BaseLX; one per ODU
Multi-Mode Optical SFP Interface	C000065L009	850 nm / 1000 BaseSX; one per ODU
Gig-Ethernet SFP Interface	C000065L010	1000 BaseT; one per ODU



SFP Modules

Step 7: Select External Antennas for Connectorized Models

When you order a PTP 650 Connectorized system, you need to order external antennas. You can choose any size antennas for the ODUs – up to an 6-foot antenna in FCC regions. Using the PTP LINKPlanner tool will help you determine which antenna will provide the desired reach and reliability needed for your requirements. One antenna is required at each end (two antennas per link). For your convenience, you can order the antennas from Cambium Networks or your authorized Cambium distributor.

Description	Part Number
2-ft (0.6m), 5.25 – 5.85 GHz Antenna, with Fine Adjustments	RDH4503
3-ft (0.9m), 5.25 – 5.85 GHz Antenna, Dual-Pol, H-Pol & V-Pol	RDH4504
4-ft (1.2m), 5.25 – 5.85 GHz Antenna, Dual-Pol, H-Pol & V-Pol	RDH4505
6-ft (1.8m), 5.25 – 5.85 GHz Antenna, Dual-Pol, H-Pol & V-Pol	RDH4506
8-ft (2.4m), 5.25 – 5.85 GHz Antenna, Dual-Pol, H-Pol & V-Pol	RDH4507
2-ft (0.6m), High Performance Dual-Pol Antenna, 5.25 – 5.85 GHz	RDH4508
3-ft (0.9m), High Performance Dual-Pol Antenna, 5.25 – 5.85 GHz	RDH4509
4-ft (1.2m), High Performance Dual-Pol Antenna, 5.25 – 5.85 GHz	RDH4510
6-ft (1.8m), High Performance Dual-Pol Antenna, 5.25 – 5.85 GHz	RDH4511
3-ft (0.9m), 5.25 – 5.85 GHz, Single-Pol Antenna	RDH4513
5.25 – 5.85 GHz, 4-ft (1.2m), High Performance, Single-Pol Antenna	RDH4524
5.25 – 5.85 GHz, 6-ft (1.8m), High Performance, Single-Pol Antenna	RDH4525
5.25 – 5.85 GHz, 4-ft (1.2m), Dual-Pol Parabolic Dish, NF Conn	RDG4453

Step 8: Select Optional Installation Tools

In this step, you can order any needed installation tools.

Description	Part Number
Cable Grounding Kits for 1/4” and 3/8” Cable	1010419001
1000 ft. Reel Outdoor Copper Clad CAT5E (Recommended for PTP)	WB3175
328 ft (100 m) Reel Outdoor Copper Clad CAT5E (Recommended for PTP)	WB3176
Tyco/AMP, Mod Plug RJ45 Unscreened, 25 pk	WB3177
Tyco/AMP Crimp Tool	WB3211
Extended Diameter Mast Mounting Kit 3.5” and 4.5”	N000065L030

Step 9: Select a Warranty and Software Support

Each ODU ships with a one-year hardware warranty. In addition, we recommend that you order an Extended Warranty to upgrade and/or extend equipment coverage and protect your investment. There are two extended warranty options. In addition, a software support contract is required after the first year of ownership.

- **Extended Warranty with All Risks Advanced Replacement**: This warranty upgrades and extends the initial 12-month Standard Warranty to include All Risks equipment coverage and the Advanced Replacement Program. The All Risks feature provides coverage for virtually all types of equipment damage, including lightning, dropped units, vandalism, fire and hardware failure. This warranty also includes 24x7 telephone technical support.
- **Extended Warranty with Repair-and-Return:** This warranty option extends the term of the initial 12-month Standard Warranty with repair-and-return terms through the second, third, fourth, or fifth years of ownership. Typical turn-around time for repair and return of a damaged unit is less than 30 days. This option is beneficial when your organization purchases one or more spare PTP links for use as replacement units and, therefore, fast replacement is not necessary. This option also includes 24x7 telephone technical support.
- **Software Support:** The software support contract includes access to software upgrades, including corrections of defects and minor software enhancements as they become available.

Description	Part Number
Extended Warranties	
PTP 650 Extended Warranty (with 30-day Repair and Return), 1 Additional Year	C000065S011
PTP 650 Extended Warranty (with 30-day Repair and Return), 2 Additional Years	C000065S012
PTP 650 Extended Warranty (with 30-day Repair and Return), 3 Additional Years	C000065S037
PTP 650 Extended Warranty (with 30-day Repair and Return), 4 Additional Years	C000065S013
PTP 650 Upgrade to All Risks Advanced Replacement During 1st Year Warranty	C000065S014
PTP 650 Extended Warranty and All Risks Advanced Replacement, 1 Additional Year	C000065S015
PTP 650 Extended Warranty and All Risks Advanced Replacement, 2 Additional Years	C000065S016
PTP 650 Extended Warranty and All Risks Advanced Replacement, 3 Additional Years	C000065S038
PTP 650 Extended Warranty and All Risks Advanced Replacement, 4 Additional Years	C000065S017
Software Support	
1 Year PTP Software Support Contract (1-2 Links)	WB3106
1 Year PTP Software Support Contract (3-5 Links)	WB3107
1 Year PTP Software Support Contract (6+ Links)	WB3108

After receiving an Extended Warranty, the Warranty must be activated online at Warranty Registration within the current warranty period. You will be asked to enter the module serial number and warranty key provided with the Extended Warranty.

Step 10: Select Any Needed Spares

When you choose the Extended Warranty with 30-day or less repair and return terms, you may want to purchase spare PTP 650 ODUs to replace damaged units and not wait for repair and return of damaged units. Other examples of when spare units may be beneficial include:

- You operate multiple PTP 650 links
- You operate one or more mission-critical networks
- Your PTP 650 system is integrated into a larger network without redundancy
- You need units for demonstrations and trade shows

In addition to spare ODUs, you also have the option to maintain spare power supplies, mounting brackets and line cords.

Description	Part Number
ODU Spares	
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (FCC)	C050065B001
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (FCC)	C050065B002
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (ROW)	C050065B003
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (ROW)	C050065B004
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (EU)	C050065B005
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (EU)	C050065B006
Mechanical-Only Samples (Tradeshows/Demos Only)	
ODU Integrated Mechanical Samples	C000065L034
ODU Connectorized Mechanical Samples	C000065L034
Power Supplies	
PTP 650 AC Power Injector	N000065L001
PTP 650 AC+DC Enhanced Power Injector	C000065L002
Mounting Brackets	
Extended Diameter Mast Mounting Kit 3.5” and 4.5”	N000065L030
PTP 650 Mounting Bracket (Integrated) – one required with each Integrated ODU spare	N000065L031
PTP 650 Mounting Bracket (Connectorized) – included with Connectorized ODU spare	N000065L032
Line Cords	
US Line Cord Fig 8	N000065L003
UK Line Cord Fig 8	N000065L004
EU Line Cord Fig 8	N000065L005
Australia Line Cord Fig 8	N000065L006
Spare Glands	
RJ-45 Gland Spare – PG16 Style (Qty 10)	N000065L033
PTP 650 Series Blanking Plug Pack (Qty 10)	N000065L036

3.3 SAMPLE BILL-OF-MATERIALS (BOM)

When you plan and optimize a link using the Cambium PTP LINKPlanner tool, the tool can generate a BOM to simplify your ordering process. The following is a sample BOM based on:

- Integrated link deployed in the U.S. with an AC+DC power injector
- Link upgraded to 128-bit AES and Mid Level capacity (up to 250 Mbps)
- Lightning Protection Units and Grounding Kits
- Extended Warranty for two additional years of coverage for a total warranty period of three years

Part Number	Description	Qty
C050065H010A	PTP 650 Integrated ODU with AC+DC Enhanced Power Injector (FCC/IC)	2
C000065K021A	PTP 650 Lite (125 Mbps) to Mid Capacity Level (250 Mbps) Upgrade License per ODU	2
C000065K018A	PTP 650 128-bit AES Encryption – per ODU	2
C000065L007A	PTP 650 LPU and Grounding Kit (1 kit per ODU)	2
C000065S012A	PTP 650 Extended Warranty, 2 additional years	2
01010419001	Coaxial Cable Grounding Kits	4
WB3176	328 ft (100m) Reel Outdoor Copper Clad CAT5E	1

4.0 PTP 650 SERIES SALES TOOLS

4.1 APPLICATIONS FOR END CUSTOMERS

PTP 650 solutions represent the culmination of deployment experiences and customer feedback from more the 75,000 point-to-point links deployed worldwide over the past decade. The solutions are engineered with advanced technology that delivers a wide range of connectivity and backhaul functions, supports diverse and evolving network requirements, and empowers end customer through innovation. The following table provides a wide range of applications that can be deployed in various markets.

Wireless Service Provider Applications

- Provide 4G/LTE, 2G, 3G, macro-cell, and small-cell backhaul
- Add/overlay wireless backbone capacity
- Extend network quickly while license applications are pursued
- Provide disaster preparation with resilient links
- Supply last mile access and service extensions
- Provide backhaul to temporary deployments (Cell on Wheels)
- Eliminate backhaul bottlenecks
- Enable Wi-Fi offloading

Wireline Service Provider Applications

- Rapidly extend network without digging trenches
- Add/overlay backbone capacity
- Provide disaster preparation with resilient links
- Supply last-mile access and service extensions to high-revenue enterprise customers
- Eliminate or reduce leased-line or fiber costs

Government Public Safety Applications

- Eliminate or reduce leased lines
- Backhaul traffic from surveillance cameras and Land Mobile Radios (LMRs)
- Supply rapid-response emergency preparedness and disaster recovery for first responders
- Provide connectivity between base sites
- Enhance network redundancy

Oil and Gas Companies and Industries Such as Mining and Transportation Applications

- Backhaul Process Control Systems (PCS) and SCADA networks
- Provide video surveillance for personnel safety and asset protection
- Supply platform to shore, ship to shore, platform to ship, platform to platform broadband
- Provide communications and network redundancy in remote, hard-to-reach locations
- Extend back-office expertise and applications into field operations
- Supply network redundancy
- Rapidly deploy communications for employees and contractors during a turnaround

Utility Applications

- Supply backbone connectivity for Advanced Metering Infrastructure (AMI)
- Migrate from analog to digital communications
- Provide video surveillance for personnel safety and asset protection
- Monitor remote resources and facilities
- Establish communications and network redundancy in remote, hard-to-reach locations
- Supply communications for in-field reporting and collaboration

Enterprise Private-Network Applications

- Eliminate or reduce leased-lines
- Provide video surveillance for personnel safety and asset protection
- Providing added throughput and bandwidth for on-demand and HD video
- Enhance business continuity with disaster preparedness and recovery
- Remove network bottlenecks
- Supply communications from a headquarters locations to remote facilities

4.2 BENEFITS FOR END CUSTOMERS

PTP 650 systems include our unique combination of technologies that together deliver up to 99.999% link availability in NLOS, long-distance LOS, and high-interference environments; over water and open terrain; and through severe weather conditions. The sub-6 GHz systems are faster, more reliable, more versatile, and more secure than comparable systems with a competitive price point that makes the PTP 650 a great value, especially when considering the benefits that the PTP 650 can provide to end customers. The table below describes how a variety of organizations can benefit from a PTP 650 solution.

Key Benefits for Service Providers

- Respond quickly to market changes
- Cost-effectively capitalize on new opportunities
- Offer more profitable services
- Generate new revenue sources by extending services to underserved and remote customers
- Make needed infrastructure enhancements cost-effectively

Key Benefits for Government and Public Safety

- Reduce operating budgets by eliminating leased lines
- Increase intra- and inter-agency collaboration
- Enhance emergency response and situational awareness
- Provide anytime access to vital information
- Better utilize resources and increase productivity
- Supply ongoing communications during emergencies and special events

Key Benefits for Oil and Gas Companies and Industries Such as Mining and Transportation

- Increase personnel safety with real-time video and voice communications to remote areas
- Eliminate truck-rolls by extending expertise and information to the field
- Reduce operating budgets by eliminating leased lines and satellite communications
- Enable higher-capacity, reliable communications from an offshore platform to an onshore facility or between offshore platforms
- Supply uninterrupted communications for mission-critical operations, even in hostile environments
- Shorten turnarounds and maintenance operations by extending corporate office resources to the field
- Save on equipment and tower costs by reducing the number of hops

Key Benefits for Utilities
• Reduce operating budgets by eliminating leased lines • Provide better insight into power usage • Improve energy efficiency • Enhance access to transmission, distribution, and consumption data • Increase personnel safety with real-time video and voice communications to remote areas • Eliminate truck-rolls by extending expertise and information to the field
Key Benefits for Business Enterprises
• Reduce operating budgets by eliminating leased lines • Improve business continuity and disaster preparation • Increase intra- and inter-department collaboration • Cost-effective delivery of on-demand and HD video • Enhance physical security of personnel

4.3 FREQUENTLY ASKED PRE-SALES QUESTIONS

The following table provides several typical questions that end customers ask as they consider a PTP 650 purchase.

Can you meet our very demanding training needs?
We provide professional training on how to configure, install, manage and operate PTP 650 links. In addition, our User Guides offer detailed instructions with illustrations that thoroughly explain system set-up and operations.
What support does Cambium Networks provide during and after the sales process?
Our global sales and support teams provide unmatched assistance throughout the sales process, system design and deployment, operations, and management. Because Cambium Networks focuses on wireless broadband exclusively, we have the experience and expertise to help you optimize your network infrastructure and achieve your communication goals.
Can a PTP 650 solution be deployed without adding great cost or burden to my IT resources?
Audio and graphical deployment-assistance features make deploying a link easy and fast, with most installations completed in a day or less. The intuitive user interface makes the systems easy to learn and use. The User Guide provides detailed images and instructions for configuration, deploying, and operating the systems. Plus, PTP 650 systems are supported and backed by a 24x7 global technical support network.
Can a PTP 650 solution give me a lot of bandwidth and speed with low latency?
Our unique combination of technologies uses bandwidth very efficiently, resulting in significantly higher throughput than comparable systems. In addition, PTP 650 solutions offer more bandwidth options than comparable systems. PTP 650 systems deliver throughput speeds up to 450 Mbps (aggregate) over channel widths ranging from 5 to 45 MHz. Latency rates average from 1 to 3 ms each way, depending on the model, range, bandwidth, and modulation mode. The Cambium PTP LINKPlanner tool can provide precise throughput and latency rates for any given configuration prior to purchase.

Can a PTP 650 solution effectively connect with my long-distance users?

The PTP 650's high link budget and high transmit power enable your links to get more capacity at all ranges up to 450 Mbps. In typical applications, PTP 650 systems support a link budget that provides more than twice the range of comparable systems. With up to 27 dBm transmit power and up to 23 dBm at 64 and 256 QAM, the radios can push even the highest performing links to longer distances. PTP 650 systems can reliably communicate across distances up to 124 miles (200 km) in a single hop using Connectorized models equipped with external antennas.

How can a PTP 650 system maximize transmission quality and minimize downtime?

Cambium technologies are designed and engineered with one goal – to provide the most reliable, most flexible, highest performing point-to-point solution in the market.

- 2x2 MIMO with *intelligent* OFDM transmits multiple signals over multiple frequencies, resulting in higher channel bandwidth and greater resistance to signal fading.
- Fast, preemptive Adaptive Modulation offers 13 modulation/coding levels. Modulation modes automatically up-shift and down-shift without dropping packets. These fast adjustments greatly increase link reliability and efficiency.
- Our unique Dynamic Spectrum Optimization (DSO) capability automatically self-optimizes each link for maximum reliability and performance. PTP 650 links use an in-band, online spectrum analyzer to continually scan the entire operational band, seeking channels that may offer higher performance and reliability without impacting the operational link. If the higher-performance channel offers 3 dB or better, DSO will automatically jump to the optimal channel without operator intervention.
- The PTP 650 also supports split-frequency operation, allowing each direction of a link to operate on a different channel. This feature mitigates the negative impact of situations where the interference environment is different at each end of the link.

Will network management be complicated with a PTP 650 solution?

Versatility and ease of use are key characteristics of PTP 650 systems. The systems contain embedded web servers to manage a link either locally or remotely. The servers easily integrate with Web or SNMP-based management systems as well as the Cambium Wireless Manager software, version WM4.0/SP4 or higher.

- Access the Web via a browser using HTTP or HTTPS/TLS.
- Easily integrate with your existing network management systems via SNMP v1, v2c, and v3: MIB-II; and our proprietary PTP MIB.
- PTP 650 systems support in-band and out-of-band (OOBM) management. In-band management gives you the convenience to manage the far end of a link from the near end and imposes virtually no performance restrictions on customer or user traffic. OOBM lets you manage the radios over a separate local-area-network (LAN) connection from either end of the link. With OOBM, you can separate the management traffic from customer/user traffic. Both options can help you quickly troubleshoot links and reduce the need to travel to individual radio sites.
- PTP 650 systems also support IPv6/IPv4 dual-stack management.
- The online spectrum analyzer displays information to help you manage and troubleshoot frequency, power, distortion, bandwidth, and other elements of the wireless signal.

Will I be able to manage my limited bandwidth?

PTP 650 radios provide as much as 60 percent higher spectral efficiency than comparable systems. This means you can deliver higher throughput with minimal spectrum usage. As an example, a PTP 650 system can deliver 200 Mbps in a 20 MHz channel versus the typical 100 Mbps offered by other technologies such as 802.11n. In addition, PTP 650 systems monitor all available channels and dynamically select the optimal channel to sustain the highest data rate with the greatest reliability. As a result, PTP 650 links are always self-optimizing without operator intervention. However, you also have the option to manually lock the frequency in either direction and restrict each link to specified frequencies.

How can I secure my network from rogue users and malicious attacks?

Today, all network operators have to ensure the confidentiality of over-the-air transmissions and secure access to the management interfaces. For that reason, Cambium has deployed significant financial and manpower resources to provide the highest level of information security and protect your wireless communications from malicious attack. PTP 650 systems support:

- FIPS-197 compliant 128-bit and 256-bit AES encryption via an optional software license upgrade
- Management interface protection, including HTTPS/TLS, the secure version of HTTP; installation of user-provided X.509 digital certificates; and SNMPv3 which adds security to SNMP.
- Identity-based user accounts with configurable password rules to control user access to the radios
- Remote Authentication Dial In User Service (RADIUS) for remote user authentication and their levels of access based on network policies
- Local logging of security-related and other events such as successful and failed log-in events and changes to the security configuration. Events can also be sent to a centralized logging server using syslog.
- "Save and restore" feature that allows you to back up a radio's operating configuration file. Then that file can be restored quickly and easily if a unit must be reset or replaced.
- Vulnerability scanning to probe for vulnerabilities. Those that pose risk are resolved.
- FIPS 140-2 validation is in process. Since the PTP 650 is based on previously validated software in the PTP 600, many of the FIPS-required features are available now.

4.4 OVERCOMING OBJECTIONS

PTP 650 solutions are too expensive.

In reality, PTP 650 solutions are competitively priced and have a very low cost-of-ownership. With a typical ROI of a year or less, a link can pay for itself by reducing operating costs or implementing revenue-producing applications such as:

- Future-proof expandability via software – no hardware change required
- Replacing leased-lines to reduce or eliminate recurring fees
- Greater range per link to reduce the number of hops – up to 124 miles (200 km)
- Establishing communications in areas that were previously unreachable
- Removing network bottlenecks with high-speed backhaul
- Enhancing the safety of people and facilities by extending video surveillance wirelessly
- Supplying cost-effective network redundancy
- Enabling high-capacity communications to support requirements such as HD video, video conferencing, VoIP, IP gaming, distance learning and telemedicine
- Reducing troubleshooting man-hours, travel and equipment costs with fast, easy installations and online analysis and performance-boosting tools
- Extend service to underserved and remote customers

Switching to a PTP 650 solution is too risky.

In fact, just the opposite is true. PTP 650 systems are designed and engineered with the same industry-vetted, field-proven Cambium technology that made our PTP 600 solution the best in its class. More than 75,000 systems utilizing this technology have been deployed worldwide. Our global sales and support teams can assist you throughout the sales process, system configuration and deployment, operations, and management. In addition, PTP 650 systems are backed by our extended warranties, training, and 24x7 technical support.

My overburdened IT staff will have to learn something new.
We have taken special efforts to make deployment and operations as easy and efficient as possible. With audio and graphical installation-assistance features, deploying a link is easy and fast. Prior to deployment, systems can be designed and optimized using our easy-to-use PTP LINKPlanner tool. Most installations can be completed in a day or less, using the performance and configuration details provided by PTP LINKPlanner reports. The intuitive systems integrate seamlessly with existing networks and management tools. Additionally, PTP 650 User Manuals provide step-by-step instructions with illustrations for configuring, deploying, operating and managing a system.

4.5 COMPETITION

Key PTP 650 Competitive Advantages	
Highest Throughput	With up to 450 Mbps, the PTP 650 offers the highest throughput relative to comparable sub-6 GHz systems.
Highest Spectral Efficiency	PTP 650 radios have the highest spectral efficiency in the sub-6 GHz category with 10 bps/Hz in contrast to 5 bps/Hz from comparable systems.
Lowest Latency	Averaging 1 to 3 ms latency, PTP 650 systems outperform comparable systems with 5+ ms.
Greatest Range and Link Budget	• Range: PTP 650 systems provide twice the range at the highest modulations – 12 mi (20 km) versus 6 mi (10 km). • Link Budget: With 23 dBm transmit power at 256 QAM, PTP 650 systems can achieve a 133 dB link budget versus 17 dBm transmit power with 64 QAM and 132 dB link budget on typical 802.11n systems.
Most Powerful Interference Mitigation and Channel Optimization	Our unique Dynamic Spectrum Optimization (DSO) has several capabilities that enable our PTP 650 radios to offer the best interference mitigation and channel optimization in the sub-6 GHz category. DSO accomplishes this by: • DSO uses an in-band, online spectrum analyzer to continuously scan the band. In comparison, OTHER systems require that the network be taken out of service to perform manual spectrum analysis operations. • Taking hundreds of measurements per second and performing ongoing statistical evaluation of all channels • Automatically changing channels to avoid interference without dropping the link – if the optimal channel indicates a 3 dB-or-greater performance • Split-frequency operation which allows each direction of a link to operate on a different channel. This mitigates the negative impact where the interference environment is different at each end of the link. • The time-stamped database tracks events, alerts the operator of any interference that triggers channel changes, and provides statistics that help to pinpoint the channels with the clearest data paths. The result is that PTP 650 links are optimizing themselves to operate on the best available channel at all times.

Key PTP 650 Competitive Advantages	
Best Non-Line-of-Sight Performance	The PTP 650's best-in-class NLOS performance is accomplished through a combination of features, including a unique adaptive frame structure, fast adaptive modulation, 1024-subcarriers, split-frequency operation, and spatial diversity. PTP 650 systems can reliably operate in environments where comparable systems cannot even make a connection.
Multi-Level, Robust Security	PTP 650 radios offer more information security features than comparable systems with 128/256-bit AES encryption, HTTPS and SNMPv3, identity-based user accounts, configuration password rules, user authentication and RADIUS support, event logging and management, syslog support, and vulnerability management.
Excellent Line-Rate PPS	PTP 650 radios support full line-rate performance regardless of the mix of traffic size or traffic patterns with more than 900,000 packets per second processing power.
Multi-Band and Multi-Bandwidth	• PTP 650 radios support multi-band functionality with 4.9 to 6.05 GHz in a single SKU. • Operating over narrow channels, PTP 650 systems provide superior multi-bandwidth flexibility, operating in 5, 10, 15, 20, 30, 40 and 45 MHz channels.
Carrier/Enterprise Features and Certifications	PTP 650 systems offer 128/256-bit AES, IPv6/IPv4 dual-stack management, MEF 9 certification, and IEEE 1588v2 and SyncE frequency and timing. Comparable systems offer fewer features. The PTP 650 can be used to deploy MPLS networks to the edge with 9600-byte jumbo frame support.
Flexible Input/Output	With PoE output, Fiber, GigE, OOBM, and an 8-port T1/E1 module, PTP 650 systems offer more flexibility than comparable systems
Third-Generation Mechanics	PTP 650 ODUs are lighter and smaller. They have improved glands and weather proofing and are IP66/IP67 rated against dust and water intrusion.
Industry-Leading Link Planning Tool	Our PTP LINKPlanner tool is the most easy-to-use, accurate, and time-saving link planner in the market. We offer PTP LINKPlanner at no charge to customers to give them the ability to plan and optimize their PTP 650 system prior to purchase. Most comparable systems require the customer to purchase a link planning tool, and most of those link planners are complicated and time-consuming tools.
High Value	PTP 650 systems are competitively priced, have an exceptionally low-cost-of ownership, and are more feature-rich than comparable systems. As a result, PTP 650 systems offer the highest performance and value in sub-6 GHz, point-to-point wireless broadband connectivity.

5.0 FREQUENTLY ASKED OPERATIONAL QUESTIONS

1. What is the data throughput of a PTP 650 radio?

PTP 650 systems will deliver up to 450 Mbps (with maximum conditions – 2x2, 45 MHz channel, and 256 QAM). The flexible capacity licensing model:

- Lite Capacity – Up to 125 Mbps
- Mid Capacity – Up to 250 Mbps
- Full Capacity – Up to 450 Mbps

2. How does the PTP 650 compare to the PTP 600?

The following table shows the key features of the PTP 650 Series solutions as compared to the PTP 600 Series. This list represents the status of features at the PTP 650 launch date. However, this is an ever-evolving list and will change as new releases of the PTP 650 are planned and delivered. For features such as 4.5 and 4.8 GHz frequencies and UC-APL which exist in the PTP 600 but not in the PTP 650, you can continue to deploy the PTP 600 models that meet your needs until the PTP 650 offers the same capabilities.

FEATURE	PTP 600	PTP 650	NOTE on PTP 650
4.9 GHz band	Y	Y	
5.4 GHz band	Y	Y	Awaiting FCC authorization
5.8 GHz band	Y	Y	
2.3, 4.5, 4.8 GHz bands	Y	N	Future releases
Max throughput	300 Mbps	450 Mbps	
Channel bandwidths (MHz)	5, 10, 15, 20, 30	5, 10, 15, 20, 30, 40, 45	5, 15, 30 available in future release
Tiered capacity (125, 250, 450 Mbps)	Y	N	
Spectral efficiency – 10 bp/Hz	Y	Y	Based on max. throughput and channel width
Line rate - >900K PPS	Y	Y	
Fast Adaptive Modulation	Y	Y	Including 256 QAM
Low, consistent 1-3 ms latency	Y	Y	
Dynamic UL/DL ratio	Y	Y	In PTP 650 Full Capacity only
nLOS and NLOS performance	Y	Y	
IPv6/IPv4 dual-stack management	Y	Y	
TDD-SYNC	Y	Y	Future release
T1/E1 TDM	2	8	External module; future release
Type approval	Y	Y	FCC and EU at launch; ROW expected by 12-2013
128/256-bit AES encryption	Y	Y	
HTTPS & SNMPv3	Y	Y	
Role-based security	Y	Y	
RADIUS authentication	Y	Y	
Password complexity	Y	Y	
Syslog	Y	Y	
OOBM	Y	Y	
Remote password maintenance	Y	Y	
FIPS 140-2	Y	N	
MEF9	Y	Y	
IP66/67-rated protective aluminum radio enclosures	Y	Y	
ATEX/HAZLOC	Y	N	Not planned to date
Multi-PTP	Y	N	Not planned to date

:

3. What are the key advantages that the PTP 650 offers?

While PTP 650 systems are engineered with the same industry-vetted and field-proven technology as the PTP 600, the technology has been elevated to provide several performance differentiators, including:

- Highest aggregate throughput – up to 450 Mbps in a 45 MHz channel
- Highest spectral efficiency – up to 10 bps/Hz
- Line rate – >900K PPS
- Increased link budget at 64/256 QAM
- Best channel optimization
- Fast adaptive modulation – BPSK to 256 QAM
- Low-consistent latency – averaging 1 to 3 ms each direction
- Dynamic upload/download ratio
- Best nLOS and NLOS performance
- Excellent interference mitigation
- Robust, multi-level security
- Industry-leading link planning tool – PTP LINKPlanner

4. What throughput do I get at maximum range?

Operating range and data throughput of wireless communications are dependent on conditions. The unique design of our PTP 650 radios combats interference (leading to higher throughput) while maximizing signal range (through high system gain). PTP 650 Series systems can support up to 5 miles (8 km) non-line-of-sight, up to 20 miles (32 km) near-line-of-sight and up to 124 miles (200 km) line-of-sight. Maximum data rates for the PTP 650 vary between 125 Mbps and 450 Mbps based on the tiered capacity selected. To best estimate throughput and range incorporating topographic variances and obstructions, use our PTP LINKPlanner tool.

5. How can I manage a PTP 650 solution?

You have the flexibility to choose the management option that best meets your needs.

Option 1 – Remote management via Web browser using HTTP or HTTPS/TLS

Option 2 – Existing NMS Systems:

- IPv6 or IPv4 dual-stack
- SNMP v1, v2c and v3 (v3 is available on AES-enabled radios)
- MIBs – MIB-II plus our proprietary PTP MIB
- Email alerts

Option 3 – Cambium Wireless Manager software, WM 4.0/SP4 or higher

6. Can I source and use my own PoE adapter with PTP 650 radios?

No. PTP 650 systems use a non-standard PoE configuration, and failure to use one of the following two power injectors could result in equipment damage, will invalidate the safety certification, and may cause a safety hazard. **NOTE**: The Point-to-Multipoint Cluster Management Module (CMM) cannot be used to power PTP 650 radios.

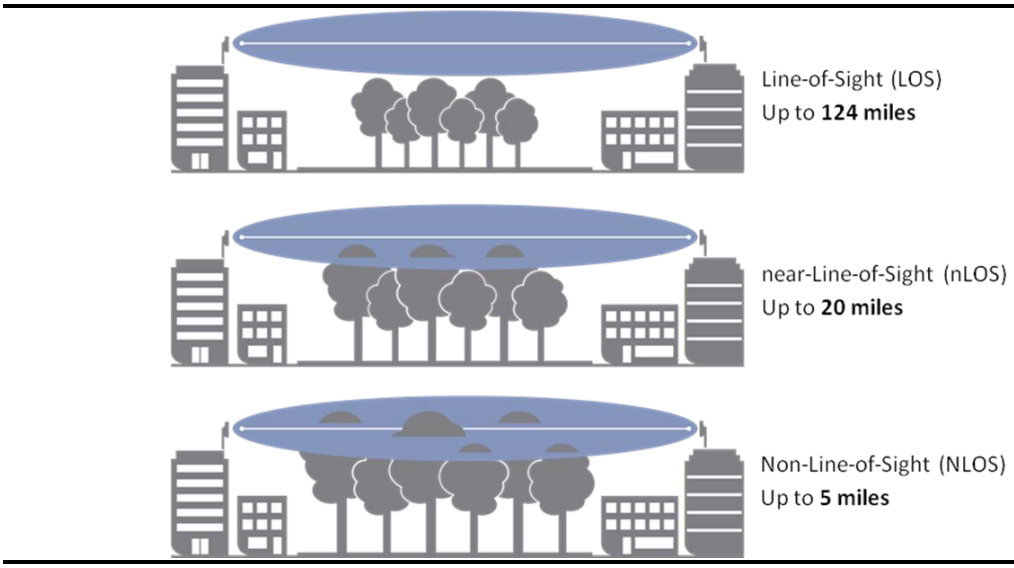
- AC Power Injector – 32° to 104° F (0° to 40° C); 35 W; 90-240 VAC, 50/60 Hz
- AC + DC Power Injector - -40° to +140° F (-40° to +60° C); 70 W; 90-240 VAC, 50/60 Hz

7. Are PTP 650 radios 802.11a devices?

No. The PTP 650 systems use a proprietary air interface in order to deliver much higher spectral efficiency and reliability than 802.11-based systems. In areas where 802.11a systems are operating, the PTP 650 will use the DSO (Dynamic Spectrum Optimization) feature to detect the 802.11a radio signals and choose a clear channel away from any interference.

8. What is meant by near-line-of-sight (nLOS) and non-line-of-sight (NLOS)?

PTP 650 radios provide a wireless connection between two points. Frequently, obstacles partially or completely block RF signals, resulting in one of three scenarios.



9. Will PTP 650 radios interfere with my Canopy® access network?

Flexibility is a key value driver of our solutions. As a result, PTP 650 systems have been designed to interoperate with Canopy AP clusters operating in the same frequency band. There are certain considerations that you need to address during installation, including frequency allocation, vertical separation, and angular direction of the modules.

10. How do PTP 650 radios avoid interference from other devices nearby?

Our unique Dynamic Spectrum Optimization (DSO) capability uses the in-band, online spectrum analyzer to continually scan the entire operational band, seeking channels that may deliver higher performance and reliability without impacting the operational link. You can configure DSO to automatically jump to the optimal channel with no operator intervention. Additionally, PTP 650 systems support split-frequency operation, allowing each direction of the link to operate on a different channel. This mitigates the negative impact of situations where the interference environment is different at each end of the link. The time-stamped database tracks events, alerts an operator of any interference that triggers channel changes, and provides statistics that help to pinpoint the channels with the clearest data paths. With DSO, you can be confident that your PTP 650 links are self-optimized to operate on the best available channel.

11. How do PTP 650 systems integrate into my data network?

The system acts as a transparent Layer-2 bridge between two segments of your network. In this sense, each point-to-point wireless system can be treated as a virtual wired connection between two points. The PTP system forwards 802.3 Ethernet packets destined for the other part of the network and filters packets that it does not need to forward. The system is transparent to higher-level management systems such as VLANs and Spanning Tree.

12. Do PTP 650 systems support Virtual LANs (VLANs)?

Yes. All Ethernet frames tagged with a VLAN priority greater-than or equal-to a system-administrator-configured threshold (set on the VLAN Configuration web page) will be prioritized for transmission over the wireless link.

13. Can I use the current PTP 600 accessories with PTP 650 systems?

Because some accessories have changed, you cannot use all PTP 600 Series accessories with the PTP 650. The PTP-SYNC module, GPS antenna, Superior Essex cable, RJ-45 plugs, and crimping tool have not changed. As a result, you can use these accessories with both the PTP 600 and 650. The following accessories have changed, and you need to use the PTP-650-specific versions of these accessories.

Accessory	What Is Different?
LPU	Uses PG16-style glands; allows RJ-45 plug to be pre-terminated and matches the glands used on the ODU
Power supply	More capacity (100W vs. 60W) for AUX port; reset button removed; new power on/off/on method for entering recovery mode
Mounting brackets	Connectorized and Integrated brackets are different to reduce size and simplify deployment; Integrated model allows 45 degree mounting.
Spare glands	PG16-style glands for use with ODU and LPU
SFP module	Extended tube now has the new PG16-style gland; copper GigE modules now available in addition to fiber

14. Why is it important to install the PTP Lightning Protection Unit with PTP 650 radios?

PTP radio units are frequently installed on high towers and masts, often with external antennas, making them targets for nearby electro-magnetic surges (lightning) in the atmosphere. While 100% protection is neither possible nor implied, PTP Lightning Protection Units can provide the radios the best possible protection against damage resulting from sudden power surges induced in the cables by nearby lightning strikes.

15. Doesn’t the Extended Warranty with All Risks Advanced Replacement cover lightning damage to my PTP radios?

Yes, the Extended Warranty with All Risks Advanced Replacement does cover the equipment cost to replace a damaged PTP 650 radio in the event of a lightning strike. However, because the PTP-LPU can prevent the damage from occurring, you can eliminate the cost of taking down the damaged unit and installing the replacement unit, plus the downtime between the time the radio was damaged and when the replacement unit is installed. In addition, the attractive price point of the PTP-LPU means a fast return on investment, especially when you factor in higher service availability.

APPENDIX: PTP 650 SPECIFICATIONS

Radio Technology	Remarks
Radio Technology	
RF band[1]	Wide-band operation – 4.9 to 6.05 GHz (Allowable frequencies and bands are dictated by individual country regulations. The most common bands are listed here.) 4.940 – 4.990 GHz (Public Safety) 5.150 – 5.250 GHz 5.250 – 5.350 GHz 5.470 – 5.725 GHz[2] 5.725 – 5.850 GHz 5.825 – 6.050 GHz
Channel sizes[3]	5, 10, 15, 20, 30, 40, and 45 MHz channels Channel sizes depend on individual country regulations
Channel selection	By Dynamic Spectrum Optimization or manual intervention; automatic selection on start-up and continual self-optimization to avoid interference
Spectral efficiency	10 bps/Hz maximum
Max. transmit power[4]	Up to 27 dBm at BPSK; up to 23 dBm at 256 QAM
System gain[4]	Integrated: Up to 164 dB with 20 MHz channel and integrated 23 dBi antenna; varies with modulation mode, channel size, and spectrum Connectorized: Varies with modulation mode and antenna type
Receiver sensitivity	-98 dBm with 5 MHz channel
Modulation/error correction	Fast Preemptive Adaptive Modulation featuring 13 modulation/FEC coding levels ranging from BPSK to 256 QAM dual payload MIMO
Duplex scheme	Synchronized Time Division Duplex (TDD) and Half Duplex Frequency Division Duplex (HD-FDD); dynamic or fixed transmit/receive ratio; each TDD-synchronized link requires a Cambium TDD-SYNC synchronization unit[5] to provide an accurate timing reference signal
Antenna	Integrated: Flat panel – 23 dBi Connectorized: Can operate with a selection of separately-purchased single- and dual-polarity antennas through 2 x N-type female connectors (local regulations should be checked prior to purchase)
Range	Up to 124 miles (200 km)
Security	FIPS-197 compliant 128/256-bit AES Encryption (optional) HTTPS and SNMPv3 Identity-based user accounts Configurable password rules User authentication and RADIUS support Event logging and management; optional logging via syslog Disaster recovery and vulnerability management

[1] Regulatory conditions for RF bands should be confirmed prior to system purchase. All bands use the same hardware. Individual bands and channel widths are available pending local regulatory approvals and region code licenses.
[2] Pending FCC authorization in North America
[3] 5, 15, and 30 MHz channel widths will be available in a future release,
[4] Gain, maximum transmit power and effective radiated power may vary based on regulatory domain and region code license.
[5] Available in a future release

Ethernet Bridging	
Protocol	IEEE 802.3
User data throughput	Dynamically variable up to 450 Mbps Maximum conditions – 2x2, 45 MHz channel[1], 256 QAM Flexible capacity licensing model: Lite Capacity: Up to 125 Mbps Mid Capacity: Up to 250 Mbps Full Capacity: Up to 450 Mbps
Latency	1 – 3 ms one-direction latency
QoS	8 Queues
Packet classification	Layer 2 and Layer 3 IEEE 802.1p, MPLS, Ethernet priority
Packet performance	Line rate (>850K packets per second)
Timing transport	Synchronous Ethernet, IEEE 1588v2[5]
Frame support	Jumbo frame up to 9600 bytes
Flexible I/O	2 x Gigabit Ethernet copper ports: Gigabit Port 1: Data + PoE power input Gigabit Port 2: 802.3at PoE output port SFP port (single-mode fiber, multi-mode fiber, and copper Gigabit Ethernet options available)
T1/E1 TDM support	8 x T1/E1 TDM module (optional indoor unit)[5] G.823-compliant timing DC power input (compatible with AC+DC Power Injector output)
T1/E1 Latency (one way)	1 – 3 ms typical, depending on range, bandwidth, modulation mode, and number of T1/E1 ports; accurate T1/E1 latency figures can be determined for any given configuration using the Cambium PTP LINKPlanner.
Management & Installation	
LED indicators	Power status, Ethernet link status, and activity on extended-range PoE supply
Network management	In-band and out-of-band; out-of-band management (OOBM)[5]
System management	IPv6/IPv4 dual-stack management support Web access via browser using HTTP or HTTPS/TLS[6] SNMP v1, v2c and v3, MIB-II and proprietary PTP MIB Cambium Wireless Manager, WM 4.0/SP4 or higher Online spectrum analyzer (no impact on payload traffic or network operation)
Installation	Built-in audio and graphical assistance for link optimization
Connection	Distance between outdoor unit and primary network connection is up to 330 feet (100 meters) using Power-over-Gigabit Ethernet. Longer distances up to 984 feet (300 meters) can be achieved using the fiber interface.

[6] Web access via HTTPS/TLS is available on AES-enabled radios.

Physical	
Dimensions	Integrated Outdoor Unit (ODU): Width 14.6” (371 mm), Height 14.6” (371 mm), Depth 3.2” (81 mm) Connectorized ODU: Width 8.0” (204 mm), Height 12.5” (318 mm), Depth 3.5” (90 mm)
Weight	Integrated ODU: 8.95 lbs (4.1 kg) including bracket Connectorized ODU: 6.8 lbs (3.1 kg) including bracket
Operating temperature	-40° to +140°F (-40° to +60°C) including solar radiation
Dust-water intrusion protection	IP66 and IP67
Wind speed survival	200 mph (322 kph)
Power supply	Two options: AC power injector: 32° to 104° F (0° to +40° C); 35 W; 90-240 VAC, 50/60 Hz Dimensions: Width 5.2” (132 mm), Height 1.4” (36 mm), Depth 2” (51 mm) AC+DC power injector: -40° to +140° F (-40° to +60° C); 70 W, 90-240 VAC, 50/60 Hz Dimensions: Width 9.75” (250 mm), Height 1.5” (40 mm), Depth 3” (80 mm)
Power consumption	30 W maximum (up to 70 W with 802.3at device on auxiliary port)
Regulatory	
Protection and safety	UL60950-1; IEC60950-1; EN60950-1; CSA-C22.2 No. 60950-1; CB approval for Global
Radio	4.9 GHz: FCC Part 90Y, RSS-111 5x GHz: FCC Part 15, sub-parts 15C and 15E; RSS 210 Issue 8; EN 302 502; EN 301 893 Eire ComReg 02/71R1; UK Approval to IR2007
EMC	Europe – EN 301 489-1 and -4

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