Cambium Workshop

Simon Staddon
Lead Regional Technical Manager EMEA
Agenda

• Product Overview
• ePMP
• cnPilot
• CnMaestro
• PTP820
• PTP650
• PTP700
• PMP450/PMP450i/PMP450m
# Cambium Networks Portfolio

## Planning and Management System Portfolio

**LinkPlanner, CNSS**

<table>
<thead>
<tr>
<th>PMP Portfolio</th>
<th>Licensed</th>
<th>Unlicensed</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMP 450m</td>
<td>Q4 2017</td>
<td>✓</td>
</tr>
<tr>
<td>PMP 450i</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PMP 450</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ePMP1000</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PMP450i (900MHz)</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PTP Portfolio</th>
<th>Licensed</th>
<th>Unlicensed</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTP 820</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>PTP 810</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>PTP 800</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>PTP 700</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PTP650, 650S, 650L</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PTP 450i (30/40MHz2016)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ePMP1000</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PTP 450</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Cambium ePMP
ePMP Solution Overview

GPS Synchronized Radio

Unsynchronized Radios

Sector Antennas
- 90 degree Sector
- 120 degree Sector

High Performance
GPS-Synchronized MAC

- Precision Timing
- Dynamic Tx Range w/ AutoTx Power Control
- 3 Level QoS w/ Auto VoIP Prioritization

SW Platform including GUI
& Element Management System

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ePMP Competitive Advantages

• *Real* advantages as a *system solution.* *Only ePMP* has:
  – GPS Sync & Freq Reuse
  – High Scalability & Consistent Performance
  – eFortify – Mitigates Interference
  – Advanced QoS & Multicast Capabilities
    Supporting Advanced Services
  – eCommand – Tools to plan, provision & monitor
ePMP MAC Protocol Efficiency

- Efficient Use of RF Capacity – tight packing of data and reduction in overhead of propagation delays
- Allows for High SM Scalability
- Allows for Consistent Performance even in High Interference Environments
Air Fairness Adaptive Scheduler

- “Air Fairness” Scheduler Prevents a few “Bad” SMs from dragging down the entire Access Point
- Resource Allocations based on Time, not Throughput
Interference Optimized Rate Adapt Algorithms

• Adaptive Modulation Algorithms optimized to address the bursty nature of Interference

• Making the right choice between error recovery by Retransmissions or down-shifting modulations
Throughput (Mbps) vs. Interference Levels

- ePMP with eFortify
- UBNT

Interference Levels:
- LOW
- MODERATE
- HIGH
- SEVERE
5 GHz Force 180

- $99 MSRP - Integrated Radio with High Gain Patch antenna - 16 dBi Gain – added 3 dB of gain, 40% addl range
- Gigabit Ethernet Port
- Modified Industrial Design & Adjustable mount
- Horizontal Orientation for better interference rejection

<table>
<thead>
<tr>
<th>Spec</th>
<th>Integ SM</th>
<th>Force 180</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Gain</td>
<td>13 dBi</td>
<td>16 dBi</td>
</tr>
<tr>
<td>Ethernet Port</td>
<td>2 x 100Mb ports</td>
<td>1 x GigE port</td>
</tr>
<tr>
<td>Range @ MCS 9, NF = -75 dBm</td>
<td>~3 mi</td>
<td>~4.2 mi</td>
</tr>
</tbody>
</table>

- Introduction Planned in 4Q
5 GHz Force 200 – High Performance SM/PTP Radio

- High Gain SM/PTP Solution with 25 dBi gain
- **Gigabit** Ethernet Port
- Cambium or Standard PoE Pinouts

- Integrated Design & Packaging
- Easy Installation and Aiming
- Optional Radome

Available Now!
ePMP 2000 Smart Beamforming

Available June 2016
Why ePMP Elevate, Why Now?

- ePMP SW has established itself as the leading system solution with the following major differentiating factors:
  - Industries most affordable platform with Frequency re-use using GPS Sync
  - Highest scalability at a low price point
  - Industry leading interference mitigation
Why ePMP Elevate, Why Now?

• Customers recognize the value but the biggest impediment to growth continues to be the need to forklift existing subscriber base

• WISP operators face the following challenges with forklifting
  – Lost revenue associated to downtime
  – Customer satisfaction issues
  – Last but not least, actual truck roll costs
ePMP Elevate: The Concept

- Allow ePMP SW to be loaded onto 3rd party SMs with similar architecture as ePMP.
- Allow inter-operation of 3rd party SMs to ePMP access points.
- Create a network with virtual ePMP SMs or a hybrid network and provide similar performance as a native all ePMP HW network.
ePMP Elevate: The Concept

- All licensing is managed at the AP (ePMP2000 & ePMP1000)
- Actual SM SW is free to download and installable to as many units
- AP controls how many “non ePMP” devices are allowed connection to a particular AP
- This allows all control to remain within Cambium’s secure licensing infrastructure
- Licensing at $35MSRP per non ePMP SM connecting to an ePMP AP
Support

• Support of 3rd party SM designs based on Atheros chipsets.
• Only 11n is supported, no 11AC. (11AC from UBNT has digitally signed SW)
• Release 1.0 Support entails
  – *5GHz UBNT support only
  – XW based UBNT hardware (built 2013 to current)
  – XM based UBNT hardware (2013 and before)
  – 17 UBNT models combined. Each identified as an unique SKU in SW and tested individually

*Please pay attention to release notes for FCC/ETSI DFS band constraints
## Support

<table>
<thead>
<tr>
<th>Device Name</th>
<th>UBNT Firmware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loco M5 XW</td>
<td>XW</td>
</tr>
<tr>
<td>NanoBeam M5 XW 16</td>
<td>XW</td>
</tr>
<tr>
<td>NanoBeam M5 XW 19</td>
<td>XW</td>
</tr>
<tr>
<td>NanoStation M5 XW</td>
<td>XW</td>
</tr>
<tr>
<td>Powerbeam M5 XW</td>
<td>XW</td>
</tr>
<tr>
<td>Powerbeam M5 XW 22</td>
<td>XW</td>
</tr>
<tr>
<td>Loco M5</td>
<td>XM</td>
</tr>
<tr>
<td>Loco M5 (Hitachi FEM)</td>
<td>XM</td>
</tr>
<tr>
<td>NanoStation M5</td>
<td>XM</td>
</tr>
<tr>
<td>NanoStation M5 (Hitachi FEM)</td>
<td>XM</td>
</tr>
<tr>
<td>Airgrid M5HP XW</td>
<td>XW</td>
</tr>
<tr>
<td>Airgrid M5</td>
<td>XM</td>
</tr>
<tr>
<td>Airgrid M5</td>
<td>XM</td>
</tr>
<tr>
<td>Airgrid M5HP</td>
<td>XM</td>
</tr>
<tr>
<td>NanoBridge M5</td>
<td>XM</td>
</tr>
<tr>
<td>NanoBridge M5</td>
<td>XM</td>
</tr>
<tr>
<td>NanoBridge M5 (New HW revision)</td>
<td>XM</td>
</tr>
</tbody>
</table>
## Scope of the Solution

### Development Roadmap

(please not roadmap dates are not confirmed)

<table>
<thead>
<tr>
<th>Development Milestone</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Release 1.0</strong></td>
<td></td>
</tr>
<tr>
<td>UBNT XM + XW model – Official release post date</td>
<td>Nov 28\textsuperscript{th}, 2016</td>
</tr>
<tr>
<td>Rocket M5 support as a SM</td>
<td>Dec 28\textsuperscript{th}, 2016</td>
</tr>
<tr>
<td><strong>Release 2.0</strong></td>
<td></td>
</tr>
<tr>
<td>Mikrotik Support</td>
<td>End of Q1, 2017</td>
</tr>
<tr>
<td>RB911G5HPnDQRT</td>
<td>Alpha engagement in Q4, 2016</td>
</tr>
<tr>
<td>RBSXT5nDr2</td>
<td></td>
</tr>
<tr>
<td>RB912UAG5HPnDOT</td>
<td></td>
</tr>
<tr>
<td>UBNT 2.4 XW + XM Models</td>
<td>End of Q1, 2017</td>
</tr>
</tbody>
</table>
Summary of Elevate

- 3rd Party hardware with ePMP Firmware gives:
  - Frequency re-use (4 Radios = 45MHz with 20MHZ channels)
  - Higher scalability up to 40 SM
  - Higher throughput on AP’s with more that 15 SM’s
Cambium WIFI
Cambium Wi-Fi for:

SP Managed Enterprises

SP Managed Home

Enterprise

Service Provider

Home WiFi

Target Market
Service Provider Managed Homes, Small Enterprises, Public Hotspots, Industrial

Solutions in the Market Today
1. Expensive and Complex: large enterprises
2. Inexpensive: lacking in scalability, manageability and reliability

Need for Svc Provider
- Easy to Manage
- Scalable
- Quick to Deploy
- Reliable and Affordable

Cambium’s WiFi Solution
- Zero Touch Deployment
- Easy Remote Manageability
- Cloud Managed with Very High Scalability
- Reliable and Affordable End to End Wireless
Cambium’s WiFi Differentiation

Frictionless Deployment
- Eliminate digging trenches
- Auto configuration

Scalable
- Grow your network and business easily as customer demand increases

Easy Cloud Management
- Single pane of glass – wireless backhaul and access products
- Quick Remote Troubleshooting

Support, Reliable, Affordable
- Strong global 24x7 support
- 4.5 M CPEs shipped to date.
  Over two decades of proven track record on quality
Cambium WiFi Portfolio

**cnMaestro™ WiFi Controller and Network Manager**

- Planning
- Client Management
- AP Management
- WiFi Controller

**Restful APIs**
Analytics, Monitoring, Configuration, Policy Management

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**cnPilot™ Family of WiFi Access Points**

- **cnPilot™** R200, R201
- **ePMP™** 1000 Hotspot
- **cnPilot™** Indoor E400
- **cnPilot™** Outdoor E500

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cnMaestro – Simplified Network Management

• Available in the cloud and will be deployable on premise
• Built from the ground up for secure, end-to-end network lifecycle management
  – inventory management
  – onboarding devices
  – daily operations
  – maintenance

By offering full visibility across the entirety of a network, cnMaestro™ greatly simplifies management of all network devices.
cnMaestro - Architecture

New UI Architecture
• Support of Various Devices

Instant Discovery of APs
• Traditional SNMP Discovery is Slow and Requires Firewall Configuration
• Cambium Devices Instantly Discovered Communicating over HTTPS

Multi-Tenancy
• Cambium Cloud Serves Multiple ISPs Securely
• ISPs can Serve Multiple Networks and Customers with Privacy and Security

Highly Scalable Architecture
• Distributed Processes, Message-bus, Database
• Redundancy
Benefits

• Easy to get started
  – Just create you cloud account and start onboarding your devices
  – No servers to purchase and setup

• Access from anywhere with a standard web browser
  – No need to VPN
  – No need for Java web-clients

• Scalable
  – Platform supports individual cnMaestro accounts up to 10,000 devices
  – Leverage the cloud to manage 100,000s devices

• Rich feature set
  – Designed for wireless networks
  – End-to-end management of your Cambium network
Easy Operation: Troubleshooting is a breeze...

Preloaded Status of all the component of end to end network - from mobile device having problem to the backhaul

Remote Packet Capture and RF analysis tools

Easily identify the mobile device through their names and manufacturer
Cambium
Point to Point
# PTP 820 Portfolio

<table>
<thead>
<tr>
<th>PTP 820S</th>
<th>PTP 820C</th>
<th>PTP 820G</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-outdoor</td>
<td>All-Outdoor Dual-Core</td>
<td>Split-Mount or All-Indoor Multi-Core</td>
</tr>
<tr>
<td>Single-Core</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![PTP 820S](image1)

![PTP 820C](image2)

![PTP 820G](image3)
PTP 820 Characteristics
A Single Platform Serving All Radio Transport Technologies

- **Multi-Gigabit with High Spectral Efficiency**
- **Any Radio Transmission Technology Mix**
  - MIMO, XPIC, 1+1 HSB, SD, FD, etc.
- **Multi-Purpose Configurations**
  - All packet and hybrid (Ethernet & TDM)
- **High Service Granularity**
  - Multi-tenant networks (H-QoS)
  - Enable shared networks
- **Common OS & Software Defined Engine**
  - Single OS platform across PTP 820
Show Me The Numbers
- Ethernet Throughput (Layer 2) - Mbps

2 Gbps in-a-box in licensed Microwave

---

Payload Compression +38%

L2 Compression +14%

Radio Throughput

Without Any Compression

- 1 Gbps
- 1.2 Gbps
- 1.7 Gbps

XPIC

527 Mbps (2048 QAM)

486 Mbps (1024 QAM)

391 Mbps (256 QAM)

- +500 Mbps
- +200 Mbps
- Doubled
- +136 Mbps

60 MHz
Sub-6 GHz
High-Capacity NLOS Solution

Integrated - Back
Connectorized
Small Form-Factor

4.9 to 6.05 GHz
PTP 650 PLATFORM FEATURES

- 4.9 to 6.05 GHz wide-band operation
- User-configurable channel widths
  - 5, 10, 15, 20, 30, 40, 45 MHz
- Up to 450 Mbps aggregate throughput
- Low latency – 1 to 3 ms one way
- 10 bps/Hz spectral efficiency
- Integrated and Connectorized models
- Up to 124 mi (200 km) range
- TDD Synchronization
- Ethernet and TDM traffic
- Symmetric and asymmetric TDD configurations
- Jumbo frame support – up to 9600 bytes
- IPv4/IPv6 management
- Extensive quality-of-service (QoS) supporting up to 8 queues
- In-band and out-of-band management
- Synchronous Ethernet / IEEE 1588-2008 Precise Timing
PTP 650S/L

- **Applications**
  - 2G/3G/LTE Small Cell Backhaul
  - Video Surveillance
  - Anywhere Short-range NLOS/LOS links are needed

- **High Performance Sub-6GHz PTP**
  - 450/300 Mbps throughput

- **Interference Mitigation & Avoidance**
  - Dynamic Spectrum Optimization (DSO)
  - TDD Synchronization for high frequency-reuse

- **4G/LTE-capable backhaul feature set**
  - IEEE 1588-2008 (Option on S)
  - Synchronous Ethernet (Option on S)

- **Optimized for Street-Level Deployments**
Always-on Wide-band Spectrum Analyzer

- Real-time and historical analytics
- Find available channels; identify sources of interference
- Scans all bands and channels from 4.9GHz to 6.05GHz
- Data available in GUI and exportable via SNMP
Spectrum Expert Management

Spectrum Management - Radar Avoidance with Dynamic Spectrum Optimization

Local Receive Spectrum (last 20 minutes) 5785 MHz State=INTERFERENCE, Mean=-38 dBm, 99.9%= -56 dBm, Peak=-53 dBm

Local Timeseries 5785 MHz

-40 | -50 | -60 | -70 | -80 | -90 | -100

25 32 22 19 16 13 10 7 4 1

 Histogram: 5785 MHz between 0:01 and 0:21

Local Interference Waterfall

Histogram measured over 20 minutes at 5785 MHz

Show Channel Change History

Show Channel States

Interference Threshold: -85 dBm
Next Generation: PTP 700

COTS+ High-Capacity, Ultra Wide-Band NLOS Solution (Up to 450Mbps)

4.4 to 5.925 GHz

Connectorized

Connector grated
Applications

• Border Security
• Situational Awareness
• Force Protection
• Rapid Tactical Response
• Video Surveillance
• Off-shore Connectivity
• Test Range Connectivity
<table>
<thead>
<tr>
<th>Applications</th>
<th>Deployments</th>
<th>Differentiating Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Surveillance</td>
<td>Tactical – short-term rapid deployments</td>
<td>• Very Wide-band (4.4 to 5.85 GHz)</td>
</tr>
<tr>
<td>Leased line replacement</td>
<td></td>
<td>• Ruggedized (IP66/67 and MIL-STD)</td>
</tr>
<tr>
<td>Base Modernization</td>
<td>Fixed – permanent backhaul</td>
<td>• Secure (FIPS 140-2, SNMPv3 / HTTPS / RADIUS)</td>
</tr>
<tr>
<td>Situational Awareness</td>
<td></td>
<td>• Lower power consumption; back-to-back architectures (PoE AUX Port)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduced SKU count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Connectorized or Connectorized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Interference tolerant; wide-band DSO; Superhet receiver</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Roadmap (UC-APL, OTAR, NSA Suite B, ...)</td>
</tr>
</tbody>
</table>

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ATEX/HAZLOC Oil/Gas Applications

- **Target Markets:**
  - PetroChem
  - Utility (Generation and Transmission)
  - Defence

- **Solution:**
  - 4.9 to 5.925 GHz
  - ATEX/HAZLOC Compliant
  - Dedicated SKUs

**ATEX**
(Atmospheres Explosibles) Equipment Group II
Category 3 / Zone 2
Gas Group IIC
Temperature Class T4

**HAZLOC**
(Hazardous Locations)
Class 1 Location
Division 2
Gas Groups A, B, C, D
Cambium
Point to MultiPoint
## PMP450

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>More Frequency Bands</strong></td>
<td>2.4 GHz, 3.5 GHz, 3.65 GHz, 4.9-5.9 GHz, 900 MHz</td>
</tr>
<tr>
<td><strong>256 QAM, MIMO-A modulations</strong></td>
<td>90 =&gt; 125 Mbps Throughput</td>
</tr>
<tr>
<td><strong>Processing Improvements</strong></td>
<td>Higher PPS, Optimized performance</td>
</tr>
<tr>
<td><strong>Larger MTU Size</strong></td>
<td>1700 Byte MTU</td>
</tr>
<tr>
<td><strong>Feature Rich QoS</strong></td>
<td>Strict Priority Support / Flexible QoS methods and bandwidth mgmt</td>
</tr>
<tr>
<td><strong>Spectrum Agile Architecture</strong></td>
<td>Enhanced Area-Averaged Capacity, Better link stability</td>
</tr>
<tr>
<td><strong>Introduction of 450i – Advanced Radio Hardware</strong></td>
<td>MPLS Tag-Friendly</td>
</tr>
<tr>
<td><strong>Controllable, Predictable Performance</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Image of PMP450 equipment.*

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# PMP 450: Subscriber Module Options

## Antenna Options

<table>
<thead>
<tr>
<th>Integrated Antenna</th>
<th>CLIP (5 GHz only)</th>
<th>Reflector Dish</th>
<th>Connectorized SM</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="PMP 450d Antenna" /></td>
<td><img src="image2" alt="CLIP Antenna" /></td>
<td><img src="image3" alt="Reflector Dish" /></td>
<td><img src="image4" alt="Connectorized SM" /></td>
</tr>
<tr>
<td><strong>PMP 450d</strong></td>
<td><strong>450i Connectorized</strong></td>
<td><strong>450i Integrated High Gain</strong></td>
<td></td>
</tr>
</tbody>
</table>
# PMP 450 Advantages

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Cambium PMP</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Access</td>
<td>Scheduled TDD – Deterministic and Scalable regardless of load</td>
<td>Without scheduled TDD, users will complain about availability as subscribers are added.</td>
</tr>
<tr>
<td>Latency and QoS</td>
<td>Consistent and Deterministic – critical for voice and video and T1 replacements</td>
<td>Without consistent latency, network users will complain about delays and poor performance.</td>
</tr>
<tr>
<td>GPS Synchronization</td>
<td>Supported -&gt; Efficient Channel Re-use / Easy Deployment. in Multi-Sector / Multi-Site systems</td>
<td>Unsynchronized systems perform inconsistently and poorly as subscribers are added. Use more channels to serve the same # of users.</td>
</tr>
<tr>
<td>Throughput and System Capacity</td>
<td>High ability for frequency reuse. Higher aggregate real user throughput and system capacity for given channel width and available spectrum.</td>
<td>Competitive systems require more AP towers to be added to meet demand – but this adds interference.</td>
</tr>
</tbody>
</table>

Select a solution that meets today’s needs and supports growth
PMP 450i/PTP700 Dynamic Interference Filtering

Spectrum

Traditional Fixed Filter
Makes Radio Susceptible to Neighboring Channel Interference

Cambium’s Dynamic Filtering
Wraps around selected channel, Filtering out Interference from Neighboring Channels
**PMP 450d - Integrated Dish SM**

- 25 dBi Integrated dish
- Works with existing power supplies
- Compatible with C3VoIP
- Extremely easy to assemble and deploy
- Reduce total cost of ownership:
  - Single supplier
  - Speed of installation
  - Improved first install rates
Introducing **PMP 450i and PTP 450i**

- **New Radio Design**
  - Ultra Wide-band radio – 4900 to 5925 MHz support
  - Opens up new frequency bands (4.9, 5.1 and 5.2)
  - Includes Dynamic Interference Filtering
  - Improved Radio Characteristics
    - Increased Transmit Power
    - Better Receive Sensitivity

- **New FPGA / SoC architecture**
  - Platform evolution to new generation processor
  - Expect to triple processing power of radio at launch with path to >75k PPS
  - Allows for wider channel support leading to more throughput

- **Ruggedized, IP66/67**
  - Visually similar to PTP 650
  - All metal construction
  - Increased Reliability in harsh environments
  - Optional ATEX/HAZLOC certified models available

- **New Power scheme**
  - 802.3at PoE compatible
  - Aux port with PoE Output
    - Allows direct connection of camera or other equipment

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PMP 450i – High Gain Directional SM and BH

• Integrated Flat Panel Antenna
  – 23 dBi Gain
  – 12” x 12” panel
  – 11° azimuth and elevation
  – Compact design
  – Easy Alignment and Installation

• New Tilt Bracket Assembly
  – Sturdy mounting bracket
  – Reasonably priced
  – Reduce installation time and effort
PMP 450i – Connectorized Radio

• Connectorized Radio
  – Access Point
    ▪ with current PMP 450 Sector Antenna
    ▪ Same mounting points at PMP 450 AP, so can replace that radio on same antenna if necessary
  – Connectorized SM or BH
    ▪ Pair with any dual pol antenna to maximize gain
ATEX and HAZLOC Certified

PMP 450i will also be available with ATEX / HAZLOC Certification

**ATEX** (Atmospheres Explosibles)
- Equipment Group II
- Category 3 / Zone 2
- Gas Group IIC
- Temperature Class T4

**HAZLOC** (Hazardous Locations)
- Class 1 Location
- Division 2
- Gas Groups A, B, C, D

---

COMPLIES WITH UL1604, CSA C22.2 No. 213
UL60950-1 / CSA C22.2 No. 60950-1
LISTING No. E113068
CLASS 1, DIV 2, GROUPS A,B,C,D
OPERATING TEMPERATURE CODE T4

II 3 G Ex ic IIC T4
Tamb = -40°C to +60°C
TRAC09ATEX31224X
Cambium 5GHz Sector Antenna

• Performance Differentiation
  – Will replace Integrated Access Point
  – Integrated 2x2 Dual-Pol Sector
  – Optimized for ABAB channel re-use
  – Null-fill
  – Improved gain response across frequency and azimuth
  – Easy to install

• Key Specifications
  – 17 dBi gain
  – 4.9 to 6.1 GHz
  – 90 degree (3 dB beam width)
  – 120 degree (6 dB beam width)
  – Front/Back Ratio: > 32 dB
Introducing *cnMedusa™*

- **Increase Capacity for Tomorrow’s Media Rich Applications**
  - Over 400 Mbps today, roadmap beyond 1 Gbps per sector

- **Do More with the Same Spectrum**
  - Over 400 Mbps in a 20 MHz channel
  - 20 bps/Hz, over 40 bps/Hz with frequency re-use

- **Protect your Investment**
  - Use existing Subscriber deployments in the enhanced network
**cnMedusa - Ground Breaking Innovation**

- Truly Massive, going beyond standards of LTE
  - 14 x 14 Massive MU-MIMO

- Beamforming sector array antenna system
  - Integration with radio eliminates points of failure
  - Dramatically lowers product cost
  - Reduces installation costs and installation time

- Enables operation in high-noise environments, in narrower channels, to a higher density of customers
**cnMedusa - Just the Beginning**

- **cnMedusa** is more than just a product
  - It represents the technology that enables “5G-like” capacities and provides the platform for innovation
  - Combining innovation in radio design, antenna technology and extreme RF engineering allows Cambium to unleash this first-of-its-kind performance engine

- **PMP 450m** is the first product powered by **cnMedusa**... but it won’t be the last
  - Created to leverage the power of the 450 platform
  - Yet allow capacities to reach levels beyond expectations
PMP 450m

• More than 3x Capacity vs. 450/450i
  – cnMedusa™ Massive MU-MIMO technology allows simultaneous communication with multiple SMs in a sector

• One Simple device to install
  – Integrated 90° sector beam-forming array
  – Radio integrated, only a single cable necessary
  – 20” x 25” x 4” (52x65x11 cm)
  – 31 lbs. (14.1 kg)

• Supreme Spectral Efficiency
  – Achieve over 400 Mbps in a 20 MHz channel
## Cambium 450m: Key System Features

<table>
<thead>
<tr>
<th>Features</th>
<th>Customer Benefit / Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>cnMedusa™ Massive MU-MIMO</td>
<td>Combining Beam Forming and multiple RF chains yields <strong>more than 3X throughput</strong>, simply by changing the AP Hardware (in a typical deployment)</td>
</tr>
<tr>
<td>Integrated 90° Sector Antenna Array</td>
<td><strong>Leading Edge antenna innovation</strong> brings <strong>Smart Beamforming</strong> to the 450 platform, <strong>ZERO RF cables</strong> to connect or weatherproof</td>
</tr>
<tr>
<td>Multiple RF Chains</td>
<td>14 x 14 MIMO system allows simultaneous communication to up to <strong>seven SMs</strong></td>
</tr>
<tr>
<td>Utilize existing SMs</td>
<td>Realize capacity upgrade <strong>without any truck rolls</strong> to Subscriber sites</td>
</tr>
<tr>
<td>No need for Frequency Re-plan</td>
<td>Using the same 20 MHz channel, capacity enhancements are attained <strong>without any network changes</strong>, but <strong>substantial increase in spectral efficiency</strong></td>
</tr>
<tr>
<td>Multiple I/O Options</td>
<td><strong>AUX port</strong> (second Ethernet port) with multiple functions allow for greater flexibility of deployment. A <strong>SFP port</strong> also available for optical connection.</td>
</tr>
<tr>
<td>Wideband Radio 5150 – 5925 MHz</td>
<td>One SKU to allow operation in all 5 GHz unlicensed bands</td>
</tr>
</tbody>
</table>
What makes up Massive MU-MIMO?

• Massive MU-MIMO encompasses several technologies:
  – MIMO
  – MU-MIMO
  – Beamforming
  – Massive MIMO

• All of these, and their own supporting technologies working together, add up to a Massive MU-MIMO solution.
What is MIMO?

- Multiple Input Multiple Output (MIMO) is a range of technologies to:
  - Multiply wireless link capacity without using more spectrum
- Achieved by:
  - Allowing the system to transmit and/or receive more than one data signal simultaneously
- In a single polarization system, data is transmitted and received on a single polarity of the radio wave (i.e., a Vertical polarization antenna)
- In a dual polarization system, horizontal and vertical (or dual slant) polarities are used to transmit and receive data.
  - This can double the capacity, by sending two sets of data
  - Or, the same data can be sent twice, improving reliability
- A separate antenna element is used for each polarization
Multiple Antenna MIMO Techniques

- Multiple antennas, each dually polarized, can be used to multiply capacity again without requiring more spectrum
- When more antennas are added, the complexity of signal processing required to extract data from the transmissions increases
- Systems can use arrays of antennas to multiply the gains from MIMO
  - These are described as $A:B$ (or $A \times B$)
    - This refers to an array of antennas with $A$ number of Tx antenna elements with $B$ number of Rx antenna elements
- Beyond 8x8, this is considered Massive MIMO
What is MU-MIMO?

• MIMO techniques are primarily designed to increase capacity between two wireless nodes.

• Multi-User MIMO (MU-MIMO) uses the antenna array to communicate to multiple wireless nodes simultaneously.
  – The AP communicates to multiple subscribers simultaneously rather than each in serial.
  – This is done via Spatial Multiplexing.
Spatial Multiplexing

• Spatial Multiplexing is the process of using multiple radio beams to communicate to multiple subscribers, where the beams are separated by space
  – By separating the beams from each other in space, interference is avoided
  – This works most efficiently if the subscribers are separated by wide angles

• *cnMedusa* creates “groups” of SMs by determining which can be spatially multiplexed
  – Minimum separation of group members is $\sim 6.5$ degrees
  – Grouping algorithm runs every TDD frame
Channel State Information (Sounding)

MU-MIMO requires up to date CSI (Channel State Information) at the Access Point.

*cnMedusa* periodically collects CSI from all SMs to evaluate channel conditions, then decides which group of SMs can simultaneously access the channel.

The channel information transmitted by the SM to the AP is used to:

- Determine if the SM is eligible for beamforming or MU-MIMO
- Calculate the PHY weights for beamforming communication
- Establishing groups of SMs in MU-MIMO mode
- Calculate the PHY weights in MU-MIMO mode
450m Integrated Antenna Array

- In conventional systems, a static sector antenna provides a wide beam, typically covering 90 to 120 degrees.
- Beamforming uses an antenna array to dynamically create a narrow beam aimed at the subscriber of interest.
  - In advanced systems these beams are moved between subscribers as the subscribers need.

**Sector Mode**
- Antenna Gain: 14.5 dBi
- Array Gain: 0 dB
- Conductive Power: 10 dBm + 8.5 dB +3 dB

**Beamforming Mode**
- Antenna Gain: 14.5 dBi
- Array Gain: 8.5 dB
- Conductive Power: 1.5 dBm + 8.5 dB +3 dB
MU-MIMO Operation

• The access point identifies which subscribers are connected

• It collects sounding information from each subscriber to determine the channel state for each subscriber and the angle the subscriber is at relative to the access point

• The access point antenna array forms a narrow beam covering the subscriber of interest and uses it to transmit and/or receive data

• This process may occur simultaneously for multiple subscribers
Example of MU-MIMO antenna pattern

Individual beams

Composite
70 SMs in Medusa AP Service Area

Sector Mode: 48 Mbps Total
MU-MIMO Mode: 89 Mbps Total

AP Capacity uplift of 1.8 w/MU-MIMO

A 25% Increase in Sector capacity while serving a 250% increase in Subscribers
108 SMs in Medusa AP Service Area

- Sector Mode: 48 Mbps Total
- MU-MIMO Mode: 96 Mbps Total

AP Capacity uplift of 2.0 w/MU-MIMO

A 35% increase in Sector capacity while serving a 440% increase in Subscribers
LinkPlanner – Planning

Link: Northern Ca to McClellan dent

Equipment

<table>
<thead>
<tr>
<th>Band</th>
<th>License</th>
<th>Product</th>
<th>Bitrate</th>
<th>TDM</th>
<th>Optimization</th>
<th>Sync</th>
<th>Summary</th>
<th>Master</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4 GHz</td>
<td>Full Power</td>
<td>PTP9460</td>
<td>30 Mbps</td>
<td>2 x T1</td>
<td>TDM</td>
<td>Enabled</td>
<td>Summary</td>
<td>Master</td>
</tr>
</tbody>
</table>

Profile

Configuration at each end

Northern Ca
- Andrew 44 ft Dual Pol Parabolic, PKNF 52 (34.7dBi)
- Antenna Height: 125 feet
- Cable Loss: 0.6 dB
- Maximum ERP: 59.1 dB
- Maximum Power: 21.8 dB
- Interference Density: -90.2 dB in 30MHz channel

McClellan dent
- Andrew 44 ft Dual Pol Parabolic, PKNF 52 (34.7dBi)
- Antenna Height: 125 feet
- Cable Loss: 0.6 dB
- Maximum ERP: 59.1 dB
- Maximum Power: 21.8 dB
- Interference Density: -90.2 dB in 30MHz channel

Performance Summary

Throughput to Northern Ca
- Mean Throughput Predicted: 127.48 Mbps
- Mean Throughput Required: 100.0 Mbps
- Percentage of Required Throughput: 127%
- Min Throughput Required: 50.0 Mbps
- Min Throughput Availability: 99.9995%

Throughput to McClellan dent
- Mean Throughput Predicted: 127.48 Mbps
- Mean Throughput Required: 100.0 Mbps
- Percentage of Required Throughput: 127%
- Min Throughput Required: 50.0 Mbps
- Min Throughput Availability Required: 99.9990%

Link Summary
- Aggregate Throughput: 254.96 Mbps
- Link Availability: 99.9999995%
Installed

- Installed and cut over additional sites, and now have more than 62 450m APs with active customers
- These units replaced more than 85 PMP 450 APs
- >3000 customers are live, with more installations being planned and executed
- Customer is quite pleased with installation, cutover process, and the performance of the product.
Questions