Cambium Networks™

ePMP Certification Training – 10.1

Revision

Content Added/Deleted	Slide #	Date of Change	Slide Version #
Deleted RF Basics, Wifi, Wireless Network (all of this is e-learnings)		5/8/19	2Q 2019
Updated ePMP 3000, edited down screenshots of GUI		5/29/19 & 6/20/19	2Q 2019, 10.0
Minor Edits from Translation		7/2/19	10.1

Presentation Terms and Conditions

This document is proprietary and confidential information of Cambium Networks, Inc. (“Cambium”), and is licensed to and intended to be used solely for internal, personal, use by the individual to whom this document was sold (“you” or “Student”).

These materials are licensed to the Student on a personal, non-assignable, non-transferable, non-exclusive basis to, and intended to be used by you solely for your internal, personal, use, with no right to copy, reproduce, replicate, or distribute, either physically or electronically, any part hereof. No part of these materials may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written permission of Cambium. You agree not to remove from these materials any of Cambium’s proprietary and/or copyright notice(s).

The information presented in these materials are for general information and training purposes only, and are updated by Cambium on a regular basis. However, the information contained herein is provided by Cambium on an "as is" and "as available" basis, and Cambium makes no (and has not authorized any other party to make on its behalf any) representations or warranties of any kind, express or implied, about these materials or any information contained herein being accurate, complete, reliable, suitable, current, or error-free, or that you will pass any certification exam as a result of your use of these materials. Any reliance you place on these materials is therefore strictly at your sole risk. In no event will Cambium be liable for any loss or damage including without limitation, indirect or consequential loss or damage, or any loss or damage whatsoever arising out of, or in connection with, the use of, reference to or reliance on these materials.

Course Outline and Modules

DAY 1

- Introduction and Objectives
- ePMP Solutions Overview
  - Business Challenge
  - Business Solutions
  - Real World Applications
- ePMP Products
  - Planning an ePMP Link
- ePMP Hardware Installation
  - AP and SM Unboxing
  - Class Lab
  - Installation Best Practices
  - Lab Exercise – Software upgrade
- ePMP Basic Configuration
  - Class Lab– Basic Configuration

DAY 2

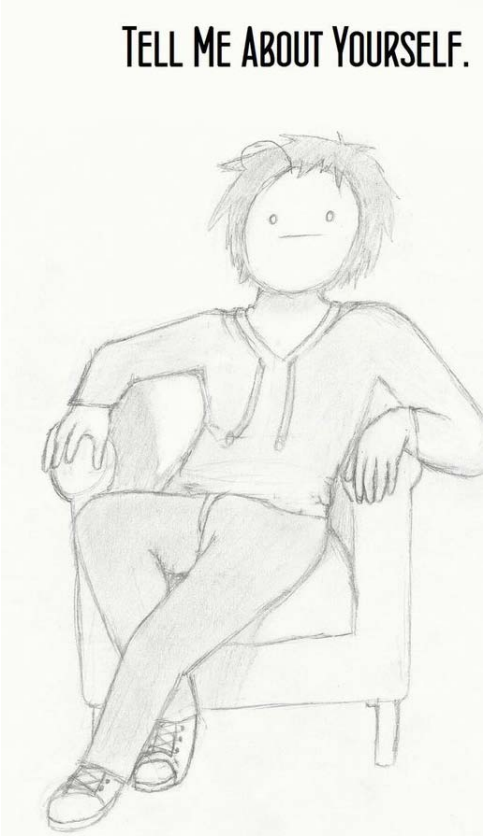
- ePMP Management
  - Standalone device Management
  - CnMaestro Management and Demo
- ePMP In-Depth Configuration
  - Primary AP Parameter
  - Primary SM Parameters
- ePMP Monitoring

  Individual/Group Lab Exercise – In Depth Configuration
- ePMP Tools and Troubleshooting

  Class Lab Exercise – Troubleshooting
- ePMP Optimization

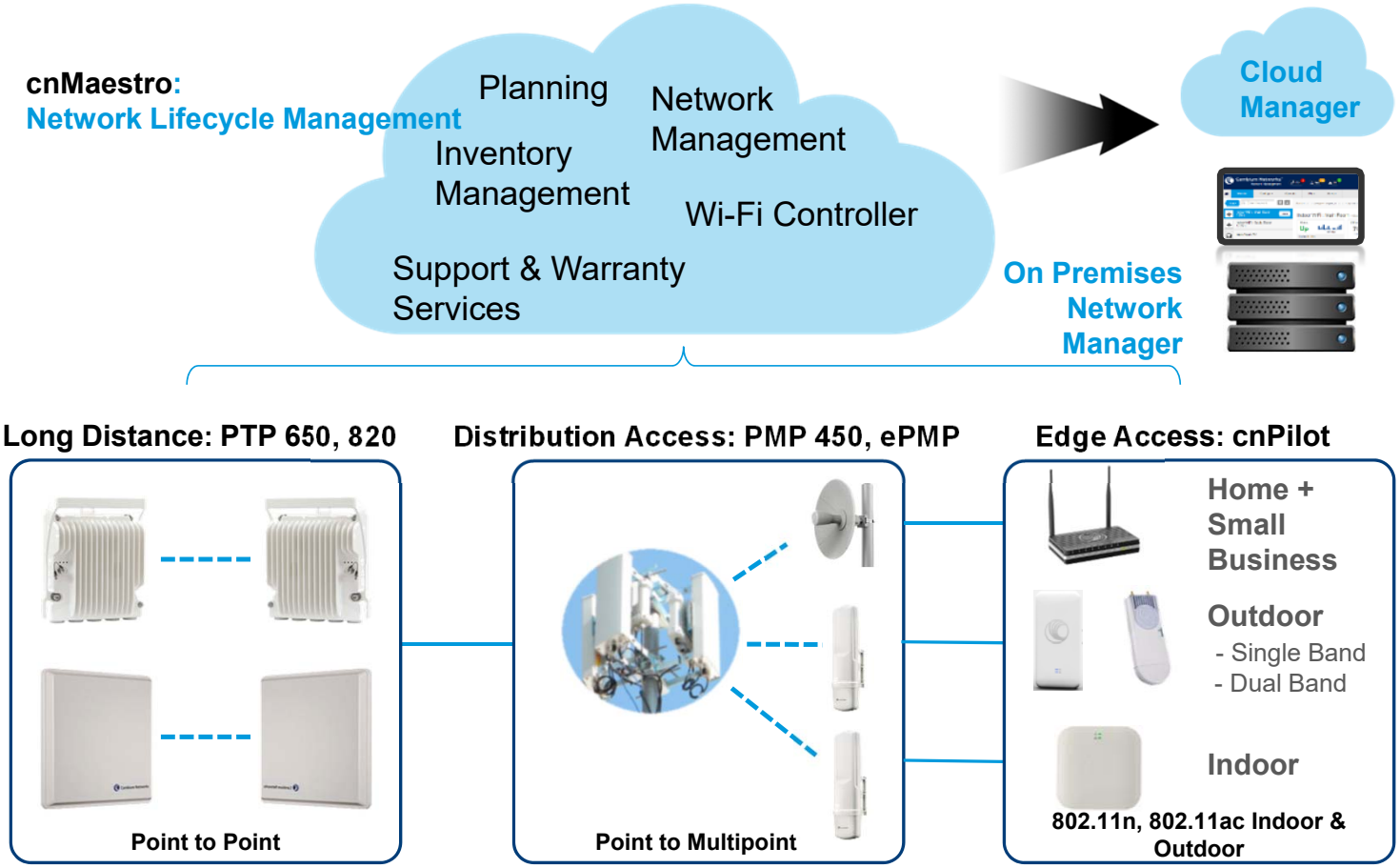
Introduction and Objectives

Introduction



- Please tell us **who you are**
- Please tell us the **size of your network**, your **growth plans**, what **technology you use** today
- Please tell us about your **biggest challenges** – we're here to help!

Cambium Networks Wireless Fabric – 2 m to 245 km



Overall Training Objectives

At the end of this session, participants should be able to understand:

- RF principles
- Interference
- Network planning
- ePMP product specifications
- ePMP system architecture
- Advantages of frequency reuse and GPS synchronization for self interference
- ePMP 3000 MU-MIMO
- Managing, monitoring and configuring ePMP with cnMaestro
- Basic configuration options
- Common deployment options
- ePMP command tools
- eFortify and ePMP 2000 for external interference mitigation

ePMP Solution Overview

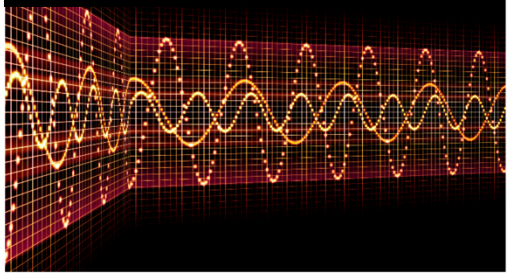
Course Introduction

- With a worldwide deployment record a decade strong, our ePMP™ fixed wireless Internet solution connects millions of people across the world.
- We enable network operators to provide high-speed wireless Internet service to businesses and residential customers supporting data, voice, streaming video, and video surveillance. These wireless broadband networks scale from small deployments that connect remote areas to community-wide deployments with thousands of subscribers.

Business Challenges

Business Challenges

Precious Spectrum



Capacity

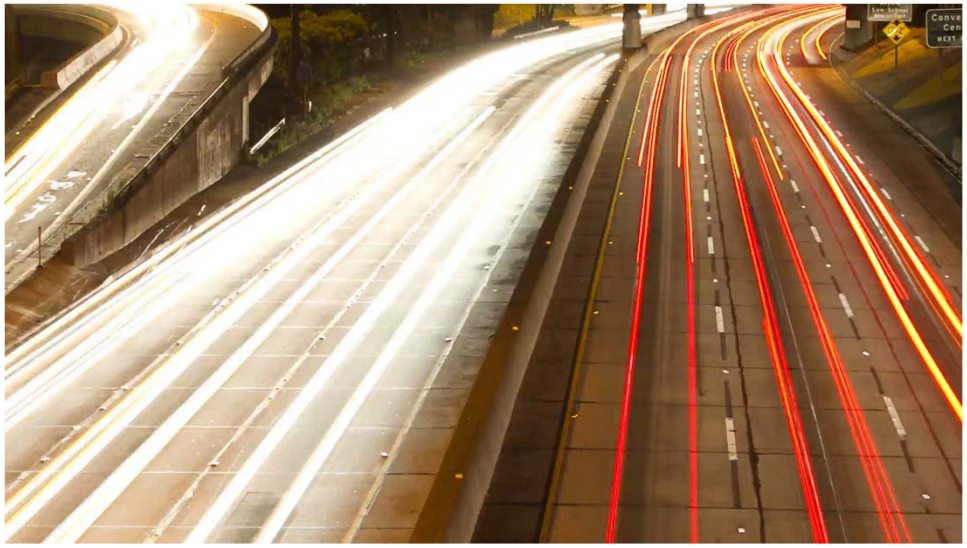
Throughput

Average Revenue Per User

Optimize Performance

Ability to Convert

Precious Spectrum



- Clean frequencies
- Usable Spectrum
- Low Interference

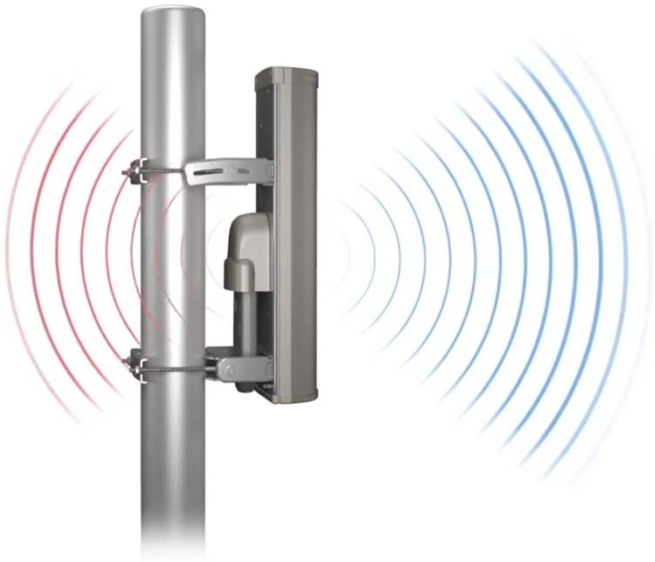
Interference

Self Interference

Interference is one of the biggest challenges for Service Providers.

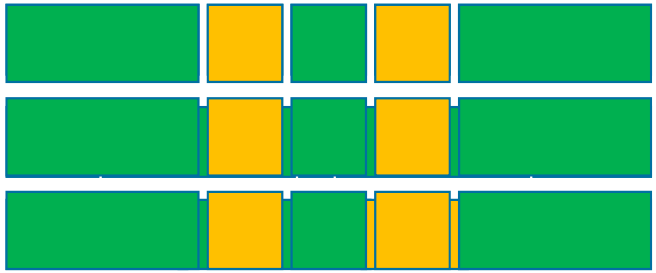
- Front-to-back ratio
- Synchronization
- Power Control

Self-Interference: Front-to-Back Ratio



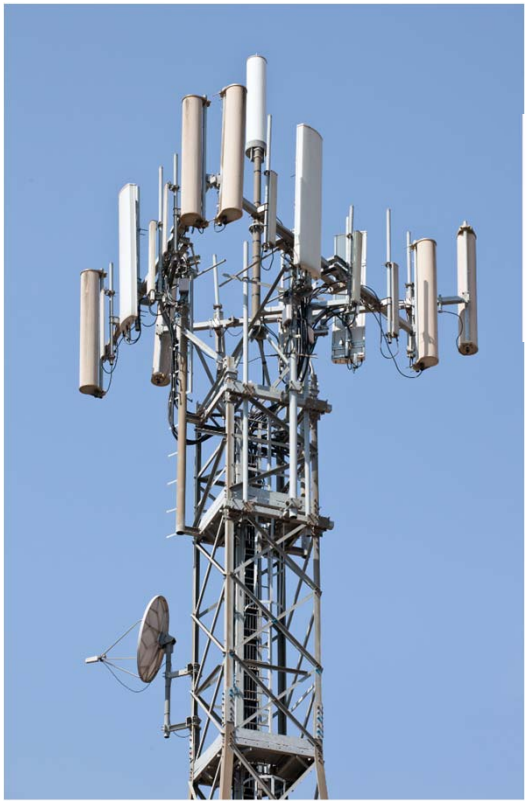
Self-Interference: Synchronization

Getting devices to transmit and receive at the same time.



Self-Interference: Power Control

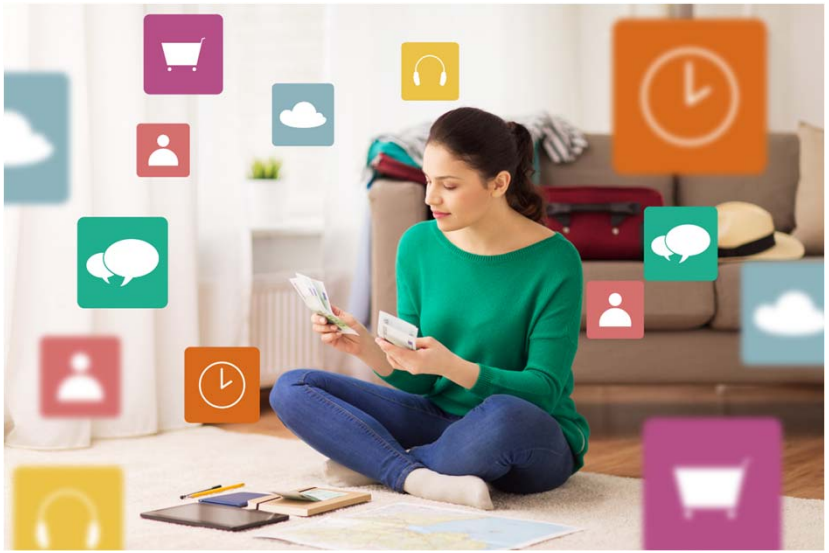
External Interference

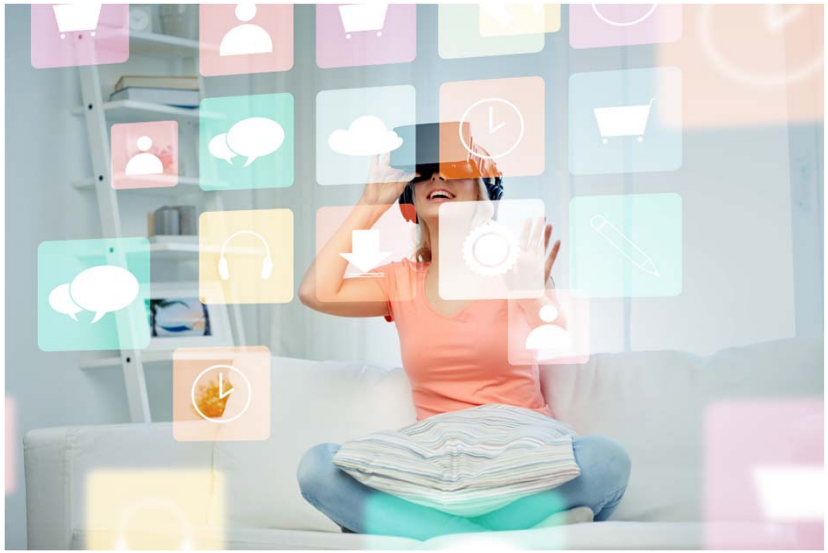


Interference can also be caused by external factor out of our control.

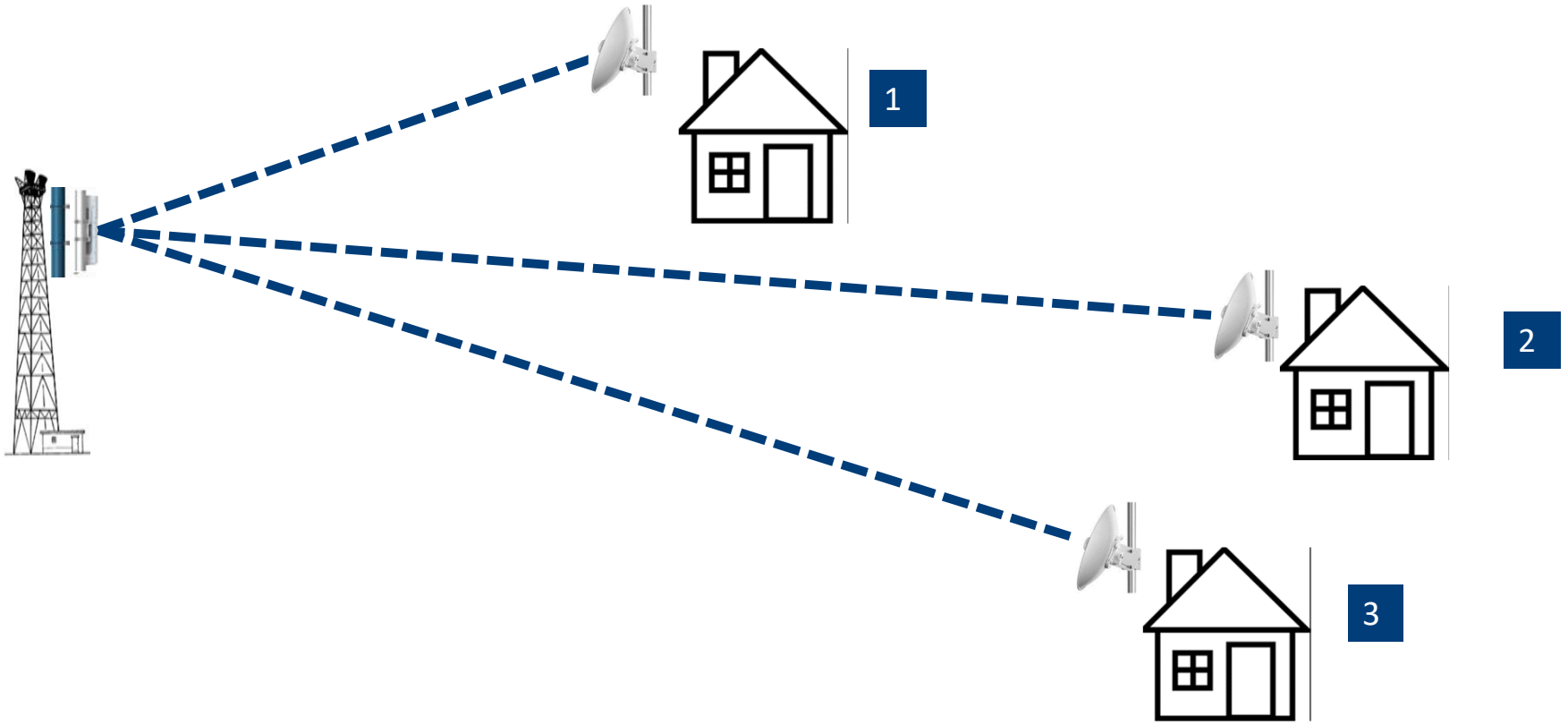
Capacity

Ever increasing demand for more customers and higher capacity without increasing costs.

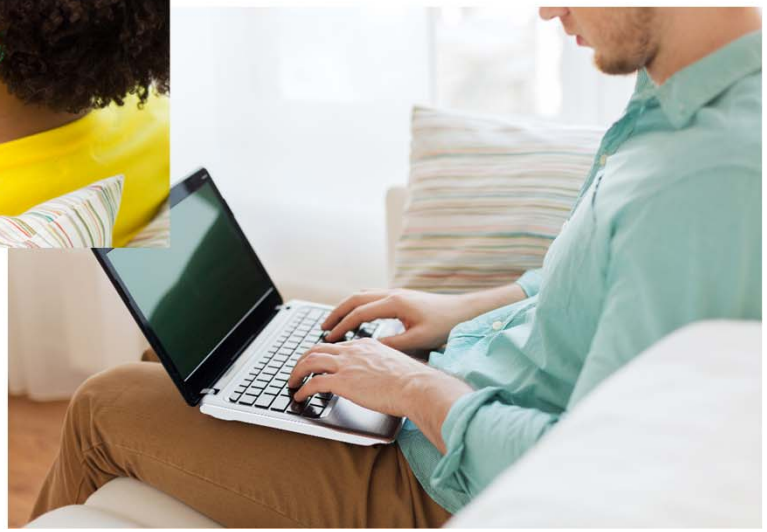




Throughput – Airtime Fairness

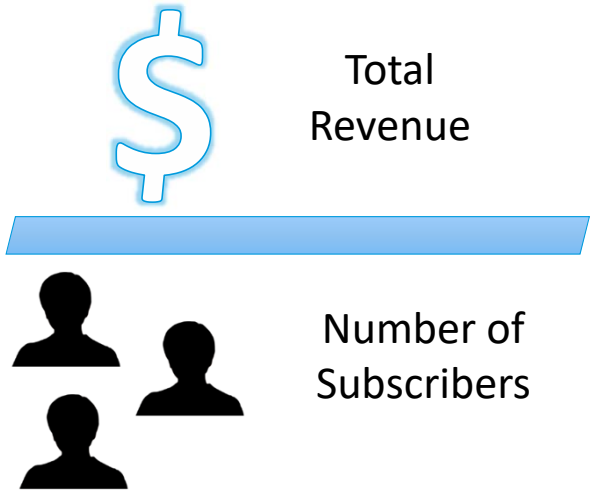


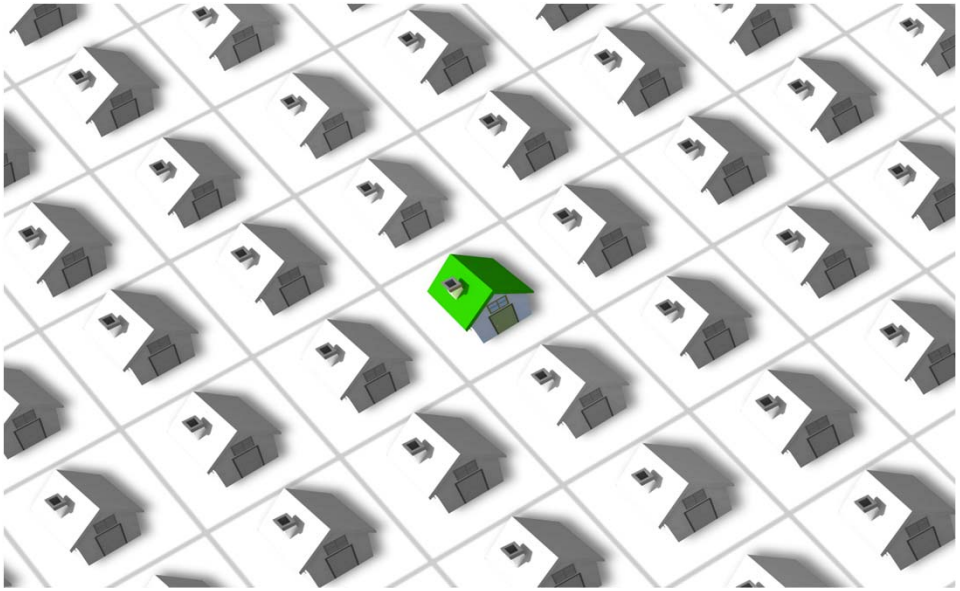
Throughput – Quality of Service (QoS)



Average Revenue Per User

ARPU is measured as the total revenue divided by the number of subscribers.

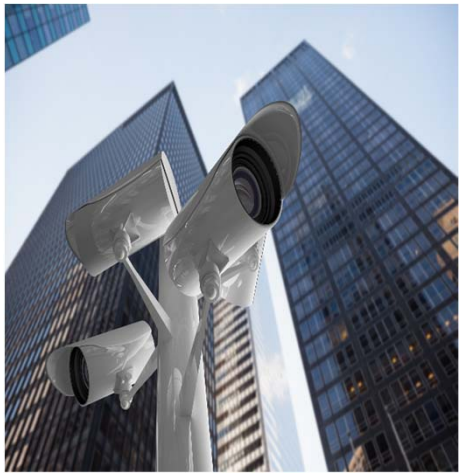




Average Revenue Per User

Management

Access to reports, analytics, and configuration data can help you decrease time managing a network and improve customer satisfaction.



Ability to Convert

Cambium Networks

Cambium Networks™

Business Solutions

Real World Applications- Which ePMP?

ePMP 1000 was introduced as an affordable way to deploy Without self-interference

ePMP 2000 was introduced to tackle the external interference side of installations

ePMP 3000 was developed to increase capacity in the downlink using Multi-User MIMO

Business Solutions: Precious Spectrum

ePMP solves the Unlicensed Spectrum Dilemma through GPS Sync.

Business Solutions: Precious Spectrum

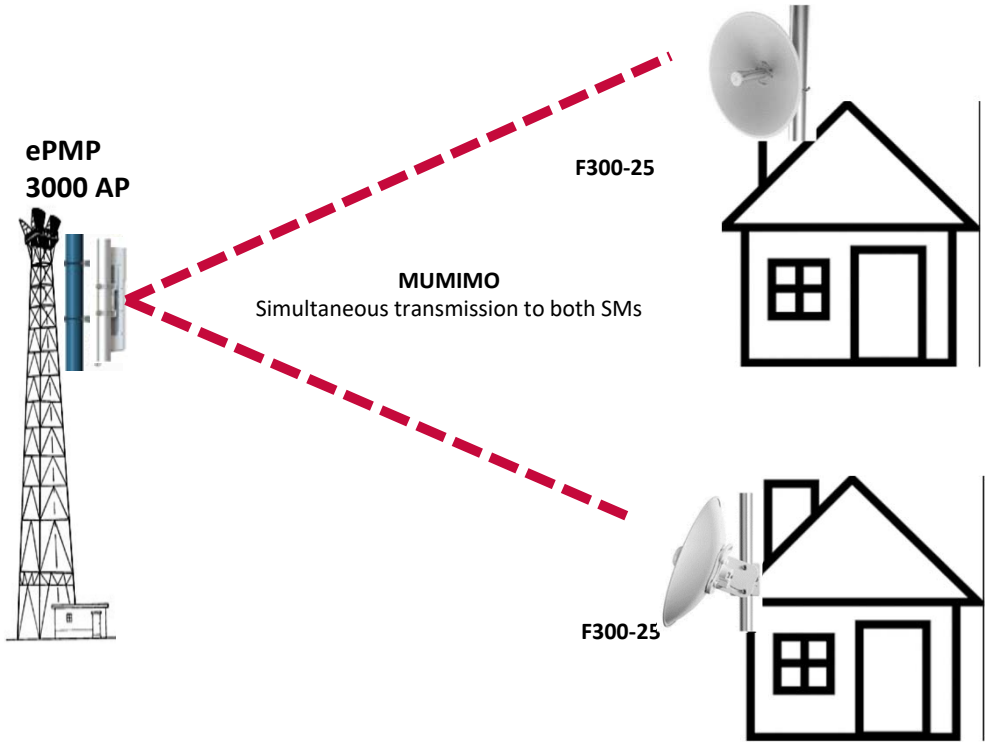
Cambium addresses Power Control by allowing the AP to direct SMs to limit their power so they are not transmitting past the intended AP. The AP can also control closer SMs to transmit less than further SMs.

Business Solution: Precious Spectrum

Multi-User MIMO (MU-MIMO)

- Achieving higher throughput in the downlink is often solved by achieving higher modulation or wider channels. In both cases, the environment and interference prevents achieving higher modulations or operating in wider channel bandwidths.

- ePMP 3000 employs Multi User Mimo technology (MU-MIMO) to simultaneously transmit to two subscribers in the downlink and thus doubling the throughput in the downlink.



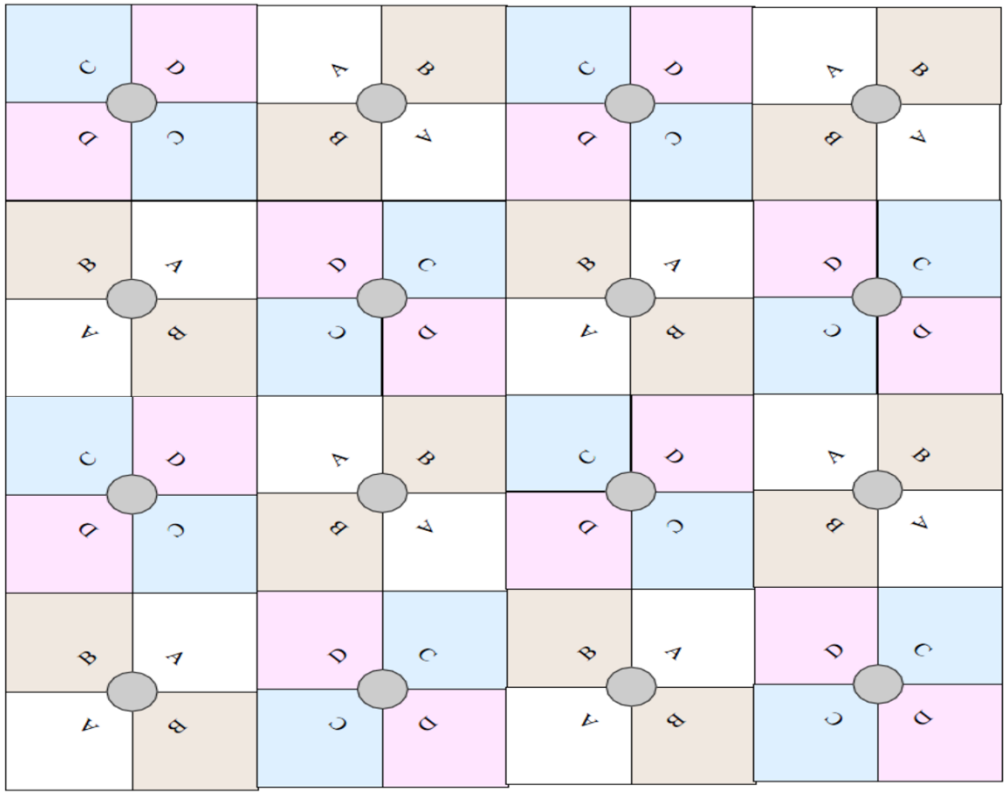
Business Solutions: Precious Spectrum

Smart Beamforming With Innovative Hypure™ Technology	Consisting of Smart Beamforming and Intelligent Filtering, Hypure Technology keeps networks operating at its best in challenging real-world conditions by blocking out multiple sources of interference in the uplink by creating narrow, targeted beams to each subscriber, rather than the former standard wide beam.
Intelligent Filtering	Automatically cleans up signals received and transmitted by the access point, optimizing the performance of each AP and the entire tower.

Business Solutions: Precious Spectrum

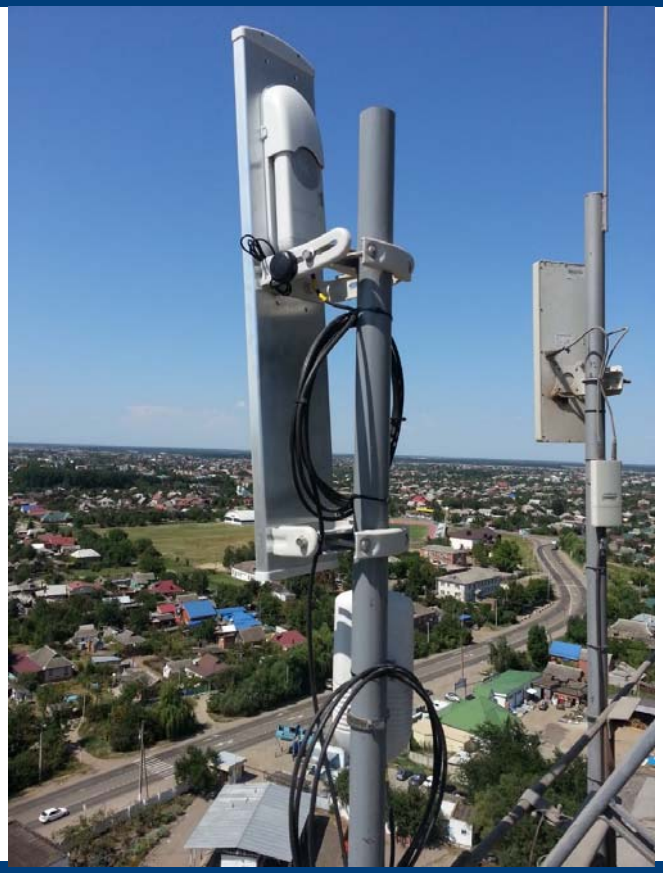
GPS Sync	It will minimize interference generated by the system onto itself, making AP collocation and frequency reuse feasible. A stable timing source is utilized by every AP in the system to precisely synchronize the start of every transmit and receive cycle within the TDD framing structure used in the ePMP solution.
Security	With 128-bit AES wireless link encryption, L2 and L3 firewall rules, different user level support, and HTTPS/SSH support, ePMP provides enhanced security to keep your network safe.
Scalability	Advanced, scalable scheduling mechanism supports up to 120 subscribers without degrading overall system performance.

Business Solutions: Precious Spectrum



Business Solutions: Capacity

- ePMP has scalable performance and spectral efficiency in the presence of interference.
  - 4X4 MUMIMO doubling sector capacity
- ePMP is designed with an advanced, scalable scheduling mechanism that supports up to 120 subscribers without degrading overall system performance.
- ePMP Is **deterministic.** The system Tx/Rxs when it needs to utilizing a Rate Adaption mechanism designed to optimize throughput.



Business Solutions: Throughput

- With Interference and Capacity solved, we now need to look at Throughput.
- With more demand for data, video, and voice, networks require airtime fairness and quality of service.
- ePMP solves this issue through advanced scheduling mechanism and various quality of service rules to prioritize traffic.

Business Solutions: Throughput

High throughput, diverse applications

Supporting 200+ Mbps throughput, the ePMP system solution provides triple-play voice, video and data services end-to-end in the most demanding networks, for an affordable price.

Long range

ePMP is optimized for outdoor applications, offering connectivity up to 40 miles with Cambium antenna accessories and further with higher gain products.

Business Solutions: Throughput

Spectral efficiency

Using the 2.4 GHz and 5 GHz frequency spectrum, the ePMP architecture covers major unlicensed global bands, making it the most effective connectivity solution for the world's under- and unconnected.

Powerful capabilities

ePMP features GPS Synchronization for seamless scalability and minimal self-interference, Quality of Service (QoS) ensures superior consistency and integrity for VoIP (Voice over IP), reliable multi-cast for IPTV, video and data services – all kept running by rigorously field tested components that minimize service requirements and maximize performance.

Business Solutions: Throughput

LINKPlanner

LINKPlanner models “what if” scenarios to optimize system performance before purchase.

LINKPlanner leads the industry as the most trusted and intuitive RF link planning tool, with tens of thousands of links deployed successfully worldwide.

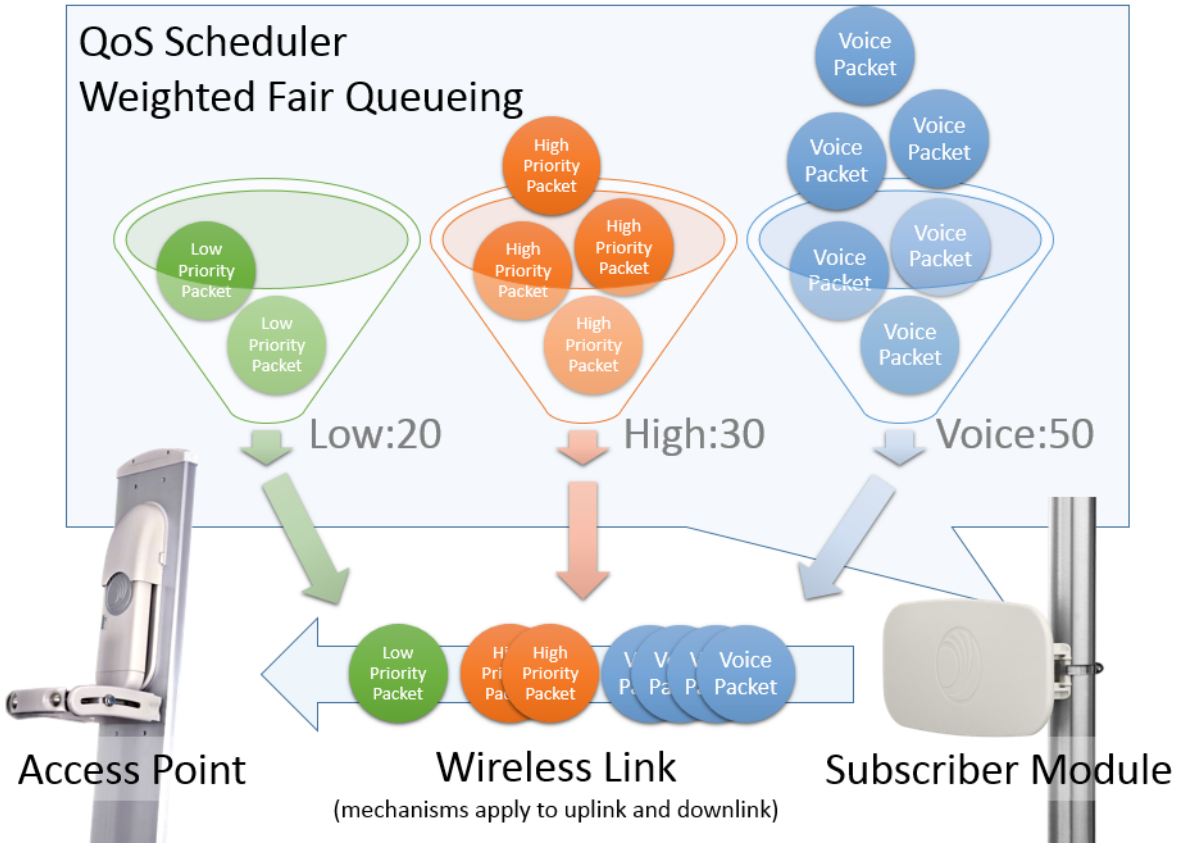
ePMP Capacity Planner

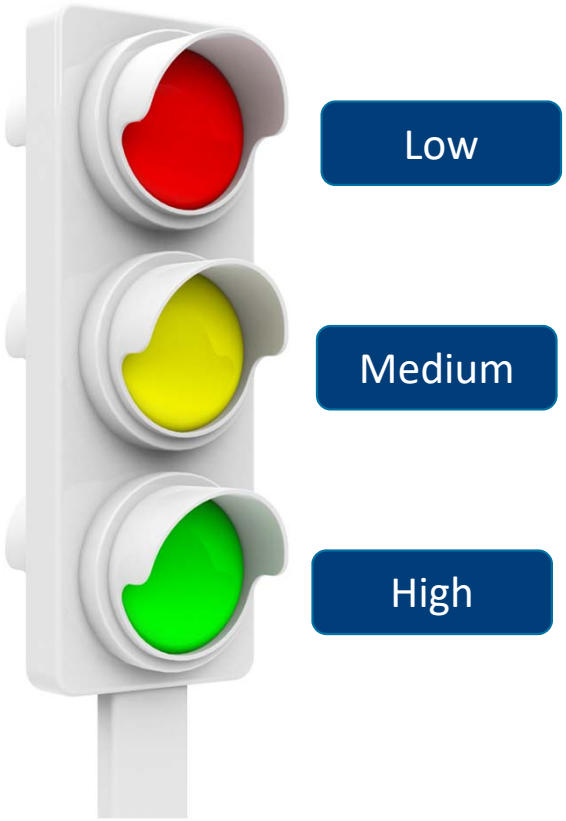
Excel-based Tool that provides a details about the performance you can expect from the ePMP and estimate the throughput and capacity based on:

- Distance of SMs from the AP
- Transmit power levels
- Antenna gains and
- Expected level of interference in the environment.

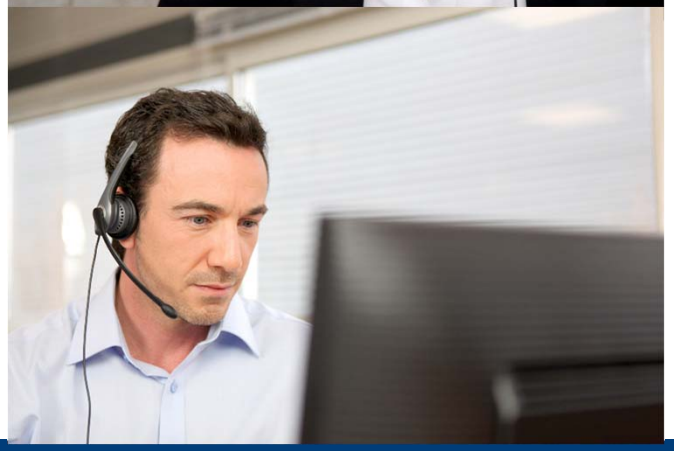
Click here to download the LINKPlanner and ePMP Capacity Planner from Cambium Support

Business Solutions: ARPU



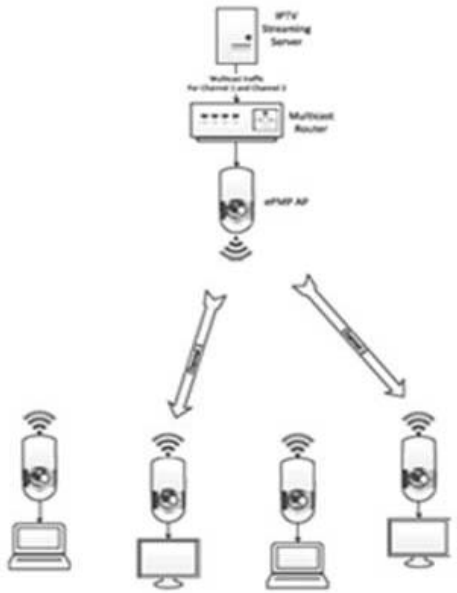


Business Solutions: ARPU



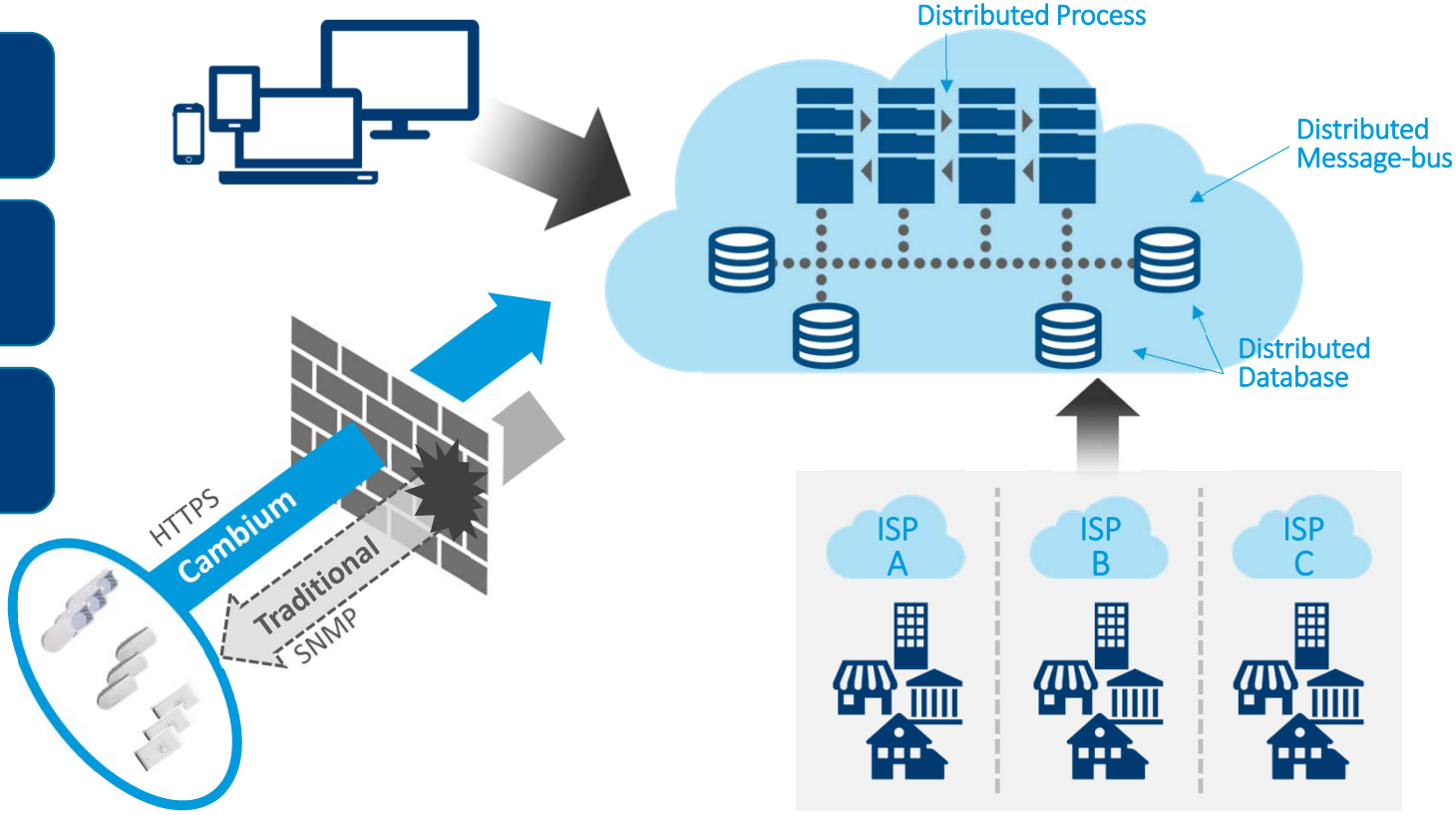
Business Solutions: ARPU

With IGMP Snooping IPTV is sent only to customers subscribed to specific channels



Business Solutions: Optimize Performance

- Zero Touch Provisioning
- Highly Scalable Architecture
- Multi-Tenancy



Business Solutions: Optimize Performance

Zero Touch Provisioning

Highly Scalable Architecture

Multi-Tenancy

Zero Touch Provisioning

- Traditional SNMP Discovery is Slow and Requires Firewall Configuration
- Cambium Devices are Instantly Discovered communicating over HTTPS

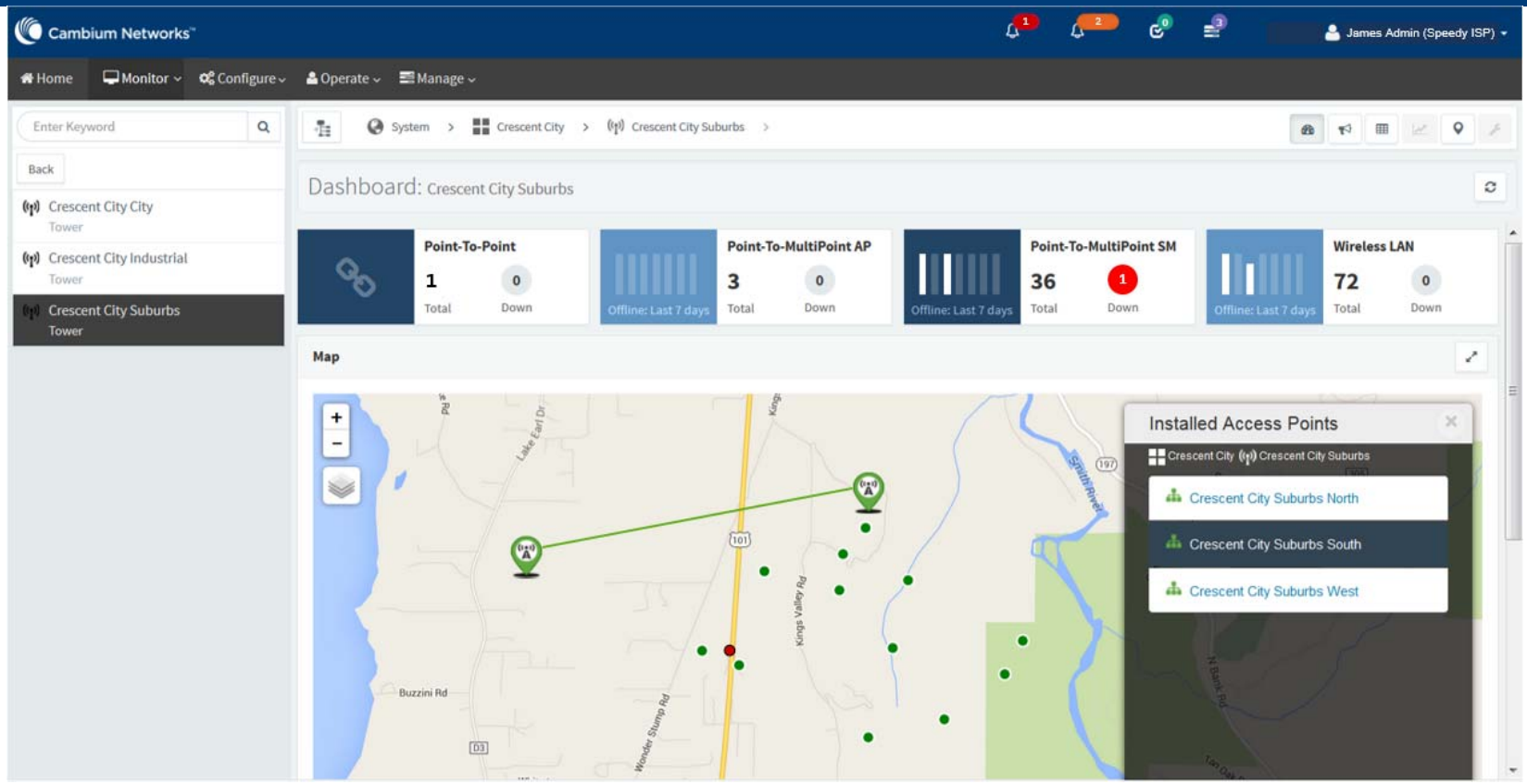
Highly Scalable Architecture

- Distributed Processes, Message-bus, Database
- Redundancy

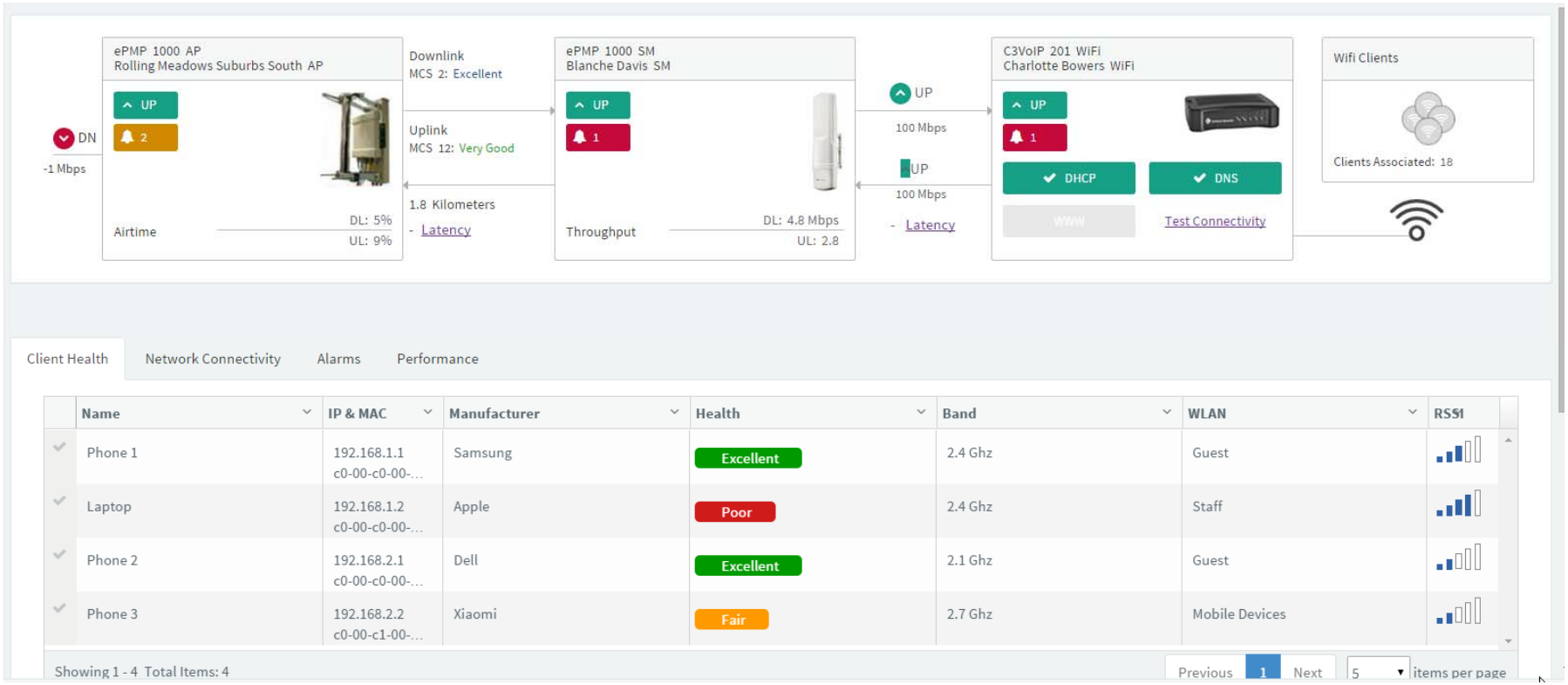
Multi-Tenancy

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

Business Solutions: Optimize Performance

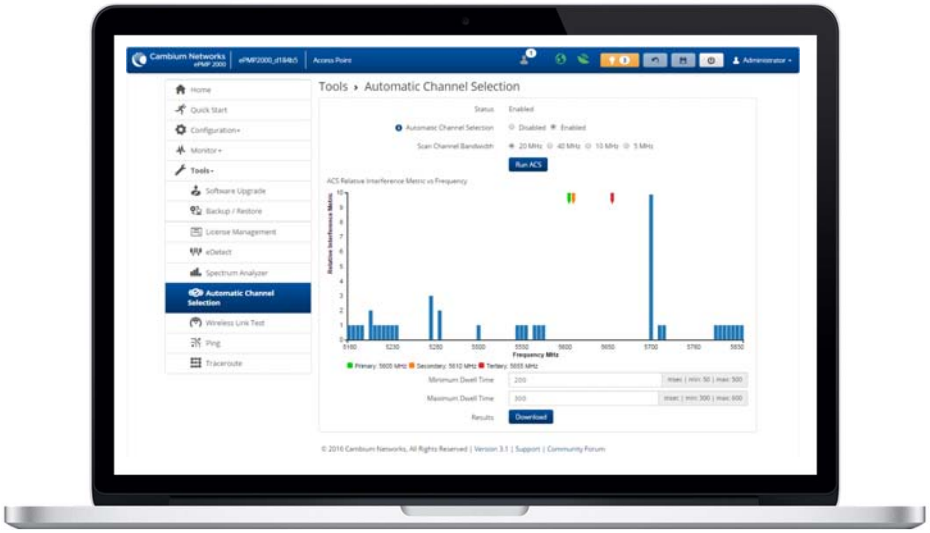


Business Solutions: Optimize Performance

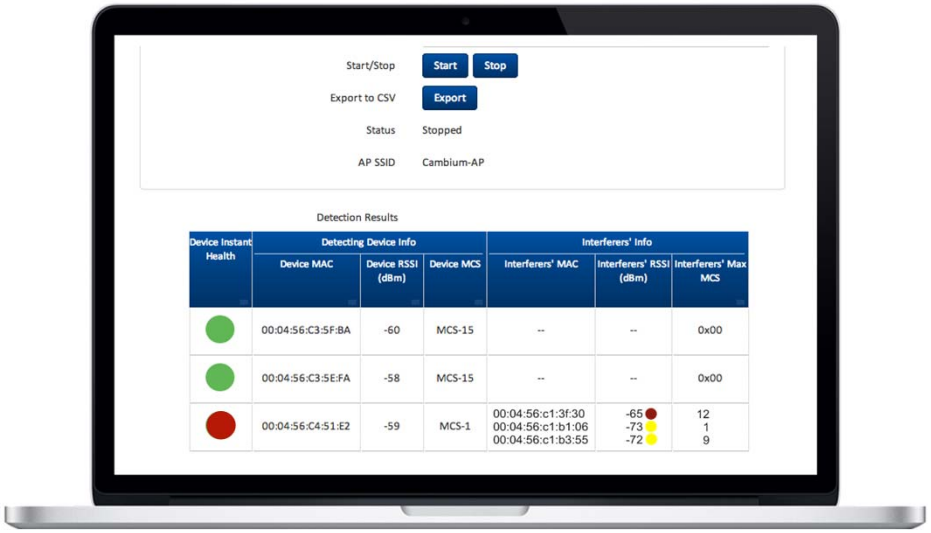


Business Solutions: Optimize Performance

Automatic Channel Selection (ACS)



eDetect (AP plus SMs)



Business Solutions: Ability to Convert

"I don't have the resources to replace all subscriber modules to upgrade to ePMP"

"Upgrading to an entirely new system will introduce too much downtime to our customers"

"Our business needs to get more out of our current subscriber installations"

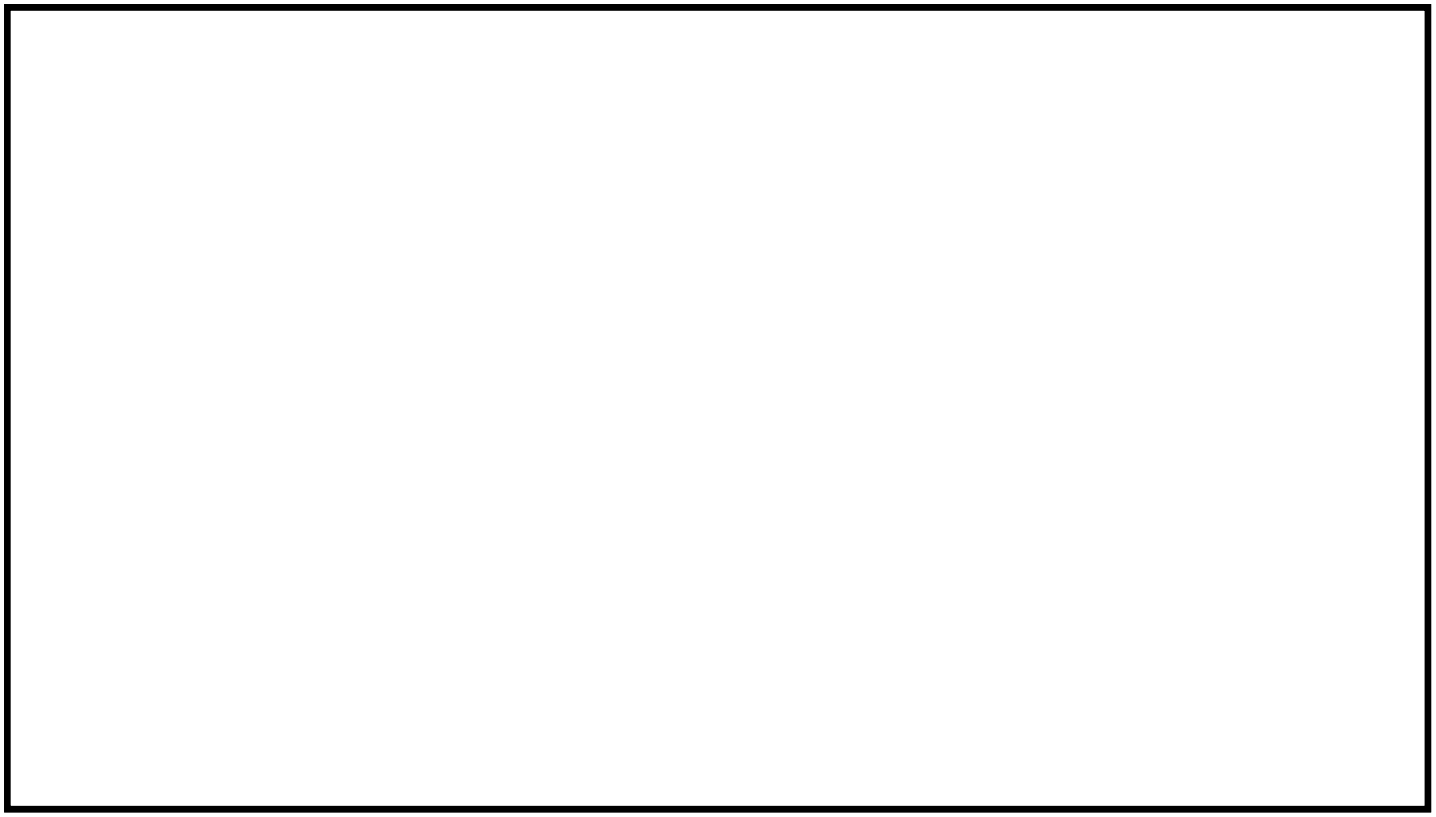
Cambium Networks

Business Solutions: Ability to Convert

Saving the cost and time of a total network replacement, an operator can simply:

- ❑ Install an ePMP Access Point and
- ❑ Load ePMP Elevate software onto their deployed subscriber modules.
- ❑ Apply connectivity licenses for Elevate subscribers per AP

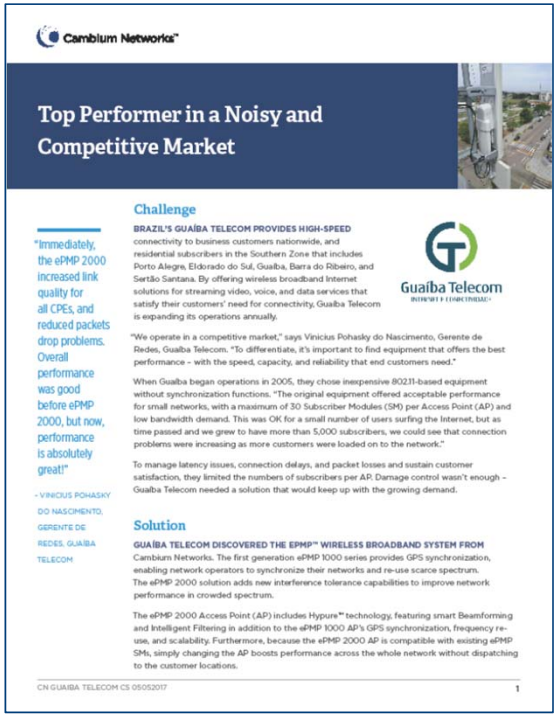
Content



Cambium Networks™

Real World Application

Real World Applications



Cambium Networks

Top Performer in a Noisy and Competitive Market

"Immediately, the ePMP 2000 increased link quality for all CPEs, and reduced packets drop problems. Overall performance was good before ePMP 2000, but now, performance is absolutely great!"

- VINICIUS POHASKY DO NASCIMENTO, GERENTE DE REDES, GUAÍBA TELECOM

Challenge

BRAZIL'S GUAÍBA TELECOM PROVIDES HIGH-SPEED connectivity to business customers nationwide, and residential subscribers in the Southern Zone that includes Porto Alegre, Eldorado do Sul, Guaíba, Barra do Ribeiro, and Sertão Santana. By offering wireless broadband Internet solutions for streaming video, voice, and data services that satisfy their customers' need for connectivity, Guaíba Telecom is expanding its operations annually.

Guaíba Telecom

"We operate in a competitive market," says Vinicius Pohasky do Nascimento, Gerente de Redes, Guaíba Telecom. "To differentiate, it's important to find equipment that offers the best performance – with the speed, capacity, and reliability that end customers need."

When Guaíba began operations in 2005, they chose inexpensive 802.11-based equipment without synchronization functions. "The original equipment offered acceptable performance for small networks, with a maximum of 30 Subscriber Modules (SM) per Access Point (AP) and low bandwidth demand. This was OK for a small number of users surfing the Internet, but as time passed and we grew to have more than 5,000 subscribers, we could see that connection problems were increasing as more customers were loaded on to the network."

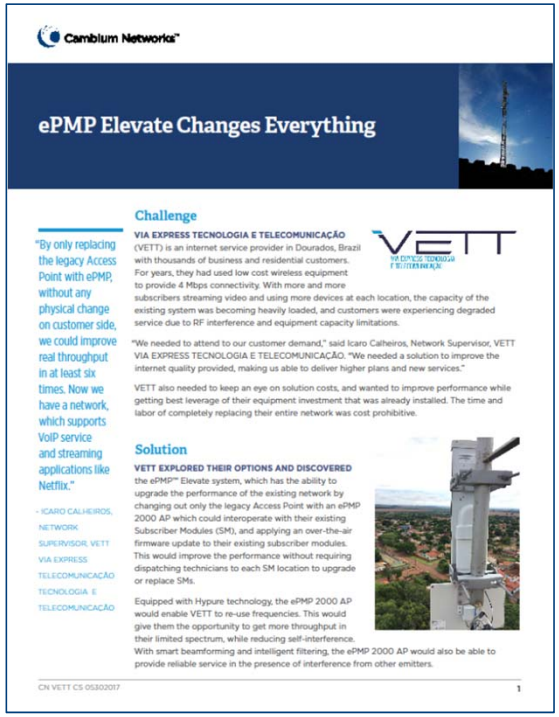
To manage latency issues, connection delays, and packet losses and sustain customer satisfaction, they limited the numbers of subscribers per AP. Damage control wasn't enough – Guaíba Telecom needed a solution that would keep up with the growing demand.

Solution

GUAÍBA TELECOM DISCOVERED THE EPMP™ WIRELESS BROADBAND SYSTEM FROM Cambium Networks. The first generation ePMP 1000 series provides GPS synchronization, enabling network operators to synchronize their networks and re-use scarce spectrum. The ePMP 2000 solution adds new interference tolerance capabilities to improve network performance in crowded spectrum.

The ePMP 2000 Access Point (AP) includes Hypure™ technology, featuring smart Beamforming and Intelligent Filtering in addition to the ePMP 1000 AP's GPS synchronization, frequency re-use, and scalability. Furthermore, because the ePMP 2000 AP is compatible with existing ePMP SMs, simply changing the AP boosts performance across the whole network without dispatching to the customer locations.

CN GUAIBA TELECOM CS 05052017 1



Cambium Networks

ePMP Elevate Changes Everything

"By only replacing the legacy Access Point with ePMP, without any physical change on customer side, we could improve real throughput in at least six times. Now we have a network, which supports VoIP service and streaming applications like Netflix."

- ICARO CALHEIROS, NETWORK SUPERVISOR, VETT VIA EXPRESS TELECOMUNICAÇÃO TECNOLOGIA E TELECOMUNICAÇÃO

Challenge

VIA EXPRESS TECNOLOGIA E TELECOMUNICAÇÃO (VETT) is an internet service provider in Dourados, Brazil with thousands of business and residential customers. For years, they had used low cost wireless equipment to provide 4 Mbps connectivity. With more and more subscribers streaming video and using more devices at each location, the capacity of the existing system was becoming heavily loaded, and customers were experiencing degraded service due to RF interference and equipment capacity limitations.

VETT

"We needed to attend to our customer demand," said Icaro Calheiros, Network Supervisor, VETT VIA EXPRESS TECNOLOGIA E TELECOMUNICAÇÃO. "We needed a solution to improve the internet quality provided, making us able to deliver higher plans and new services."

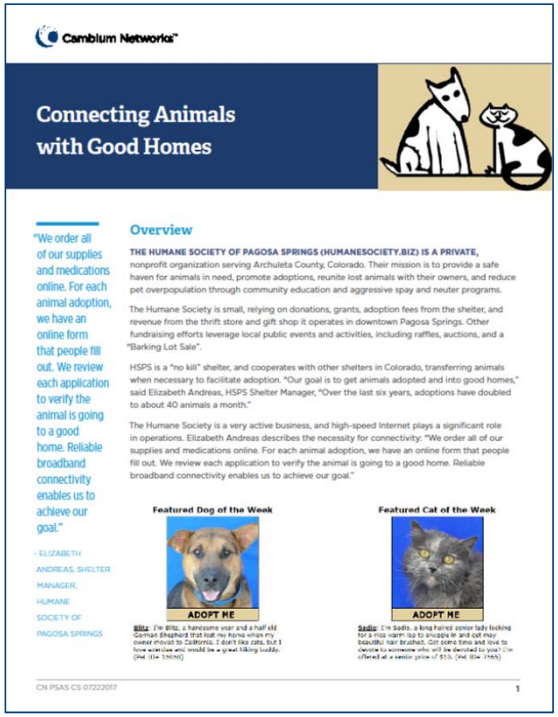
VETT also needed to keep an eye on solution costs, and wanted to improve performance while getting best leverage of their equipment investment that was already installed. The time and labor of completely replacing their entire network was cost prohibitive.

Solution

VETT EXPLORED THEIR OPTIONS AND DISCOVERED the ePMP™ Elevate system, which has the ability to upgrade the performance of the existing network by changing out only the legacy Access Point with an ePMP 2000 AP which could interoperate with their existing Subscriber Modules (SM), and applying an over-the-air firmware update to their existing subscriber modules. This would improve the performance without requiring dispatching technicians to each SM location to upgrade or replace SMs.

Equipped with Hypure technology, the ePMP 2000 AP would enable VETT to re-use frequencies. This would give them the opportunity to get more throughput in their limited spectrum, while reducing self-interference. With smart beamforming and intelligent filtering, the ePMP 2000 AP would also be able to provide reliable service in the presence of interference from other emitters.

CN VETT CS 05302017 1



Cambium Networks

Connecting Animals with Good Homes

"We order all of our supplies and medications online. For each animal adoption, we have an online form that people fill out. We review each application to verify the animal is going to a good home. Reliable broadband connectivity enables us to achieve our goal."

- ELIZABETH ANDREAS, SHELTER MANAGER, HUMANE SOCIETY OF PAGOSA SPRINGS

Overview

THE HUMANE SOCIETY OF PAGOSA SPRINGS (HUMANESOCIETY.BIZ) IS A PRIVATE, nonprofit organization serving Archuleta County, Colorado. Their mission is to provide a safe haven for animals in need, promote adoptions, reunite lost animals with their owners, and reduce pet overpopulation through community education and aggressive spay and neuter programs.

The Humane Society is small, relying on donations, grants, adoption fees from the shelter, and revenue from the thrift store and gift shop it operates in downtown Pagosa Springs. Other fundraising efforts leverage local public events and activities, including raffles, auctions, and a "Barking Lot Sale".

HSPS is a "no kill" shelter, and cooperates with other shelters in Colorado, transferring animals when necessary to facilitate adoption. "Our goal is to get animals adopted and into good homes," said Elizabeth Andreas, HSPS Shelter Manager, "Over the last six years, adoptions have doubled to about 40 animals a month."

The Humane Society is a very active business, and high-speed Internet plays a significant role in operations. Elizabeth Andreas describes the necessity for connectivity: "We order all of our supplies and medications online. For each animal adoption, we have an online form that people fill out. We review each application to verify the animal is going to a good home. Reliable broadband connectivity enables us to achieve our goal."

Featured Dog of the Week

Blitz: I'm Blitz, a handsome year and a half old German Shepherd that lost my home when my owner moved to California. I don't like cats, but I love everyone who will be a great hiking buddy. (Ref ID# 17690)

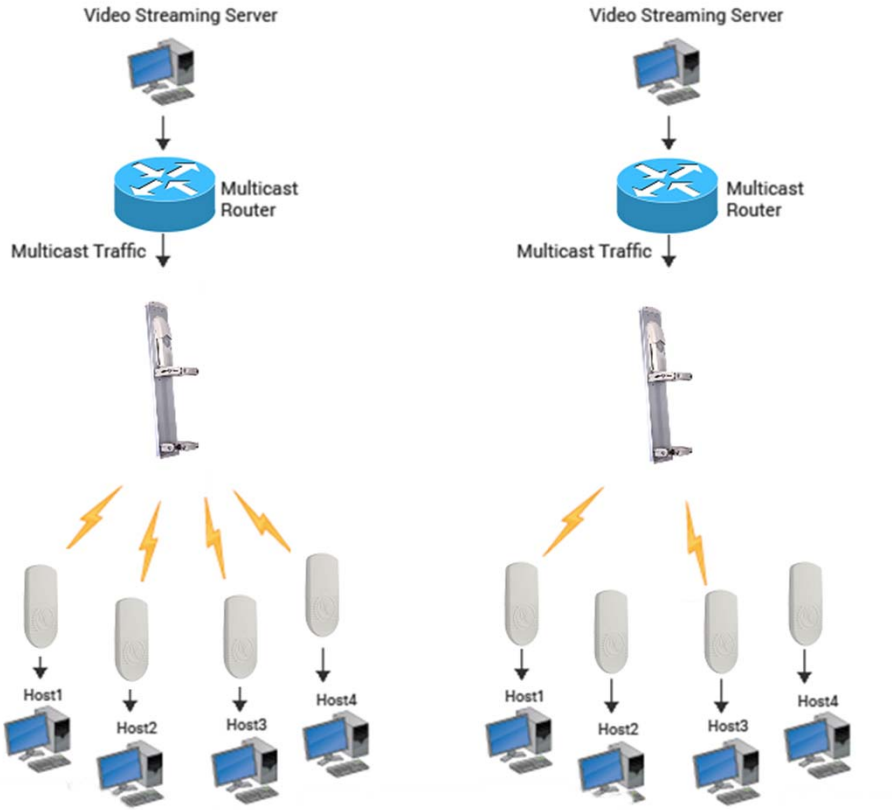
Featured Cat of the Week

Sadie: I'm Sadie, a long haired senior lady looking for a nice warm lap to snuggle in and get my beautiful hair brushed. Got some time and love to devote to someone who will be devoted to you? I'm offered at a senior price of $15. (Ref ID# 2765)

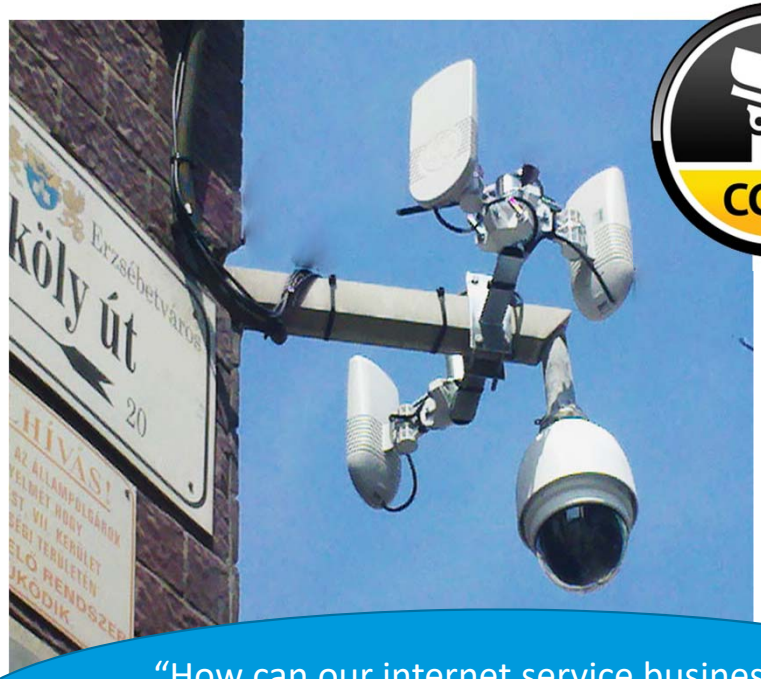
CN PSAS CS 07222017 1

Reliable Application Delivery

- ePMP Solution provides so much consistent performance that operators are planning IPTV deployments over wireless!
- New ePMP Feature provides for reliable Multicast over wireless



Reliable Application Delivery



"How can our internet service business tap into the video surveillance market?"
SOLVED

Best in class CCTV performance from:

- Advanced over the air QOS
- Adaptive modulation targeting zero packet loss
- Low CAPEX deployment model with built in switch – connect the camera directly to the ePMP subscriber unit to establish connectivity

ePMP Products

ePMP Solution

ePMP 1000
5 GHz & 2.4 GHz
GPS Sync
QoS
Proven reliability up to 120 SM per sector
Pair with Force 180, 16 dbi
Enhances high noise environments

ePMP 2000
5 GHz
GPS Sync
Intelligent Filtering
Smart Beam Forming
Supporting up to 120 SM
Pair with Force 200, 25 dbi
Enhances high noise environments

ePMP Solution

Force 180
4910 MHz - 5970 MHz
2x2 MIMO/OFDM
Wind Survival - 145 km/hr
Peak Gain - 16 dBi
Azimuth – 15 degrees
Elevation – 30 degrees

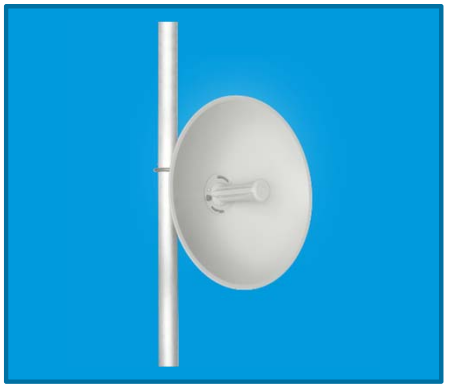
Force 190
4910 MHz - 5970 MHz
2x2 MIMO/OFDM
Wind Survival - 125 km/hr
Peak Gain - 22 dBi
Azimuth – 10-11 degrees
Elevation – 10-11 degrees

Force 200
4910 MHz - 5970 MHz
2x2 MIMO/OFDM
Wind Survival - 145 km/hr
Peak Gain - 25 dBi
Azimuth – 7 degrees
Elevation – 7 degrees
Front-To-Back Isolation >25 dB
Cross Polarization >15 dB

ePMP Solution

ePMP 3000
5 GHz
Frequency Reuse
Dynamic Filtering
Uplink Beam steering
4x4 MU-MIMO doubling
sector capacity
Enhances high noise environments

Force 300-16
4910 MHz - 5970 MHz
2x2 MIMO/OFDM
Wind Survival - 180 km/hr
Peak Gain - 16 dBi
Azimuth – 15 degrees
Elevation – 30 degrees



Force 300 - 25
4910 MHz - 5970 MHz
2x2 MIMO/OFDM
Wind Survival - 180 km/hr
Peak Gain - 16 dBi
Azimuth – 6-10 degrees
Elevation – 6-10 degrees
Front-To-Back Isolation 25 dB
Cross Polarization 20 dB

Portfolio Overview

ePMP™ Portfolio Overview

Cambium Networks™

	Connectorized | Integrated	GPS Sync Radio	Bridge-in-a-Box	Force 180	Force 190	Force 200	Force 130	Access Point w/ Intelligent Filtering	Force 300-16 Force 300-25 CSM 300	4x4MUMIMO Access Point & 2X2 MIMO AC AP
Frequency Band(s)	2.4 GHz, 5 GHz 2.4/2.5 GHz (Brazil, NZ) 6.4 GHz (Russia)	2.4 GHz, 5 GHz	5 GHz	5 GHz	5 GHz	2.4 & 5 GHz	2.4 &, 5 GHz (not available in North Am)	5 GHz	5 GHz	5 GHz
Channel Size	5|10|20|40 MHz	5|10|20|40 MHz	5|10|20|40 MHz	5|10|20|40 MHz	5|10|20|40 MHz	5|10|20|40 MHz	20|40 MHz	5|10|20|40 MHz	20 | 40 | 80 MHz	20 | 40 | 80 MHz
Physical Layer	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11n – 64QAM	2 x 2 MIMO / OFDM 802.11ac Wave 2 256QAM	4 x 4 MIMO / OFDM 3000l is 2 x 2 MIMO 802.11ac Wave 2 256QAM
Interface	100 Mbit - 2nd Ethernet port PoE out	Gigabit	Gigabit	Gigabit	100 Mbit	Gigabit	Gigabit	Gigabit	Gigabit	Gigabit/SFP
Environmental	IP55	IP55	IP55	IP55	IP55	IP55	IP55	IP55	IP55 CSM 300 is IP67	IP55 3000L is IP67
Latency	15~17ms	5~7ms	15~17ms	5~7ms	2~3ms	2~3ms	15-17 ms	5~7ms	5~7ms	5~7ms
Performance	200+ Mbps	200+ Mbps	200+ Mbps	200+ Mbps	200+ Mbps	200+ Mbps	200+ Mbps	200+ Mbps	600+ Mbps	1+ Gbps 3000L is 600 Mbps
Powering Methods	30V PoE Cambium Proprietary	30V PoE 802.3af	30V PoE Cambium Proprietary Standard PoE Pinouts	30V PoE Cambium Proprietary Standard PoE Pinouts	30V PoE Cambium Proprietary Standard PoE Pinouts	30V PoE Cambium Proprietary Standard PoE Pinouts	24V Passive PoE	56V PoE 802.3at	30V PoE	56V PoE, 802.3at 3000L is 30V POE
Power Consumption	7 W max, 5 W typical	10 W max, 7.5 W typical	10 W max, 5 W typical	10 W max, 5 W typical	8 W max, 5 W typical	10 W max, 5 W typical	5 W typical	20 W max	12 W	21 W max 3000L is 12W typical
Max Tx Power	+30 dBm	+30 dBm	+30 dBm	+30 dBm	+27 dBm	+30 dBm	+28dBm – 5 GHz +31 dBm – 2.4 GHz	+30 dBm	+27 dBm CSM 300 is+29 dBm	MCS0, VHT80: +25 dBm MCS9, VHT80: +21 dBm
Antenna	Integrated: 2.4 GHz – 11 dBi 5 GHz – 14 dBi Connectorized: 3rd party	90°/120° Sector: 18 dBi or 3rd party antenna	Integrated: 16 dBi	Integrated: 16 dBi	Dish: 22 dBi	Dish: 2.4 GHz - 17 dBi 5 GHz – 25 dBi	Integrated: 14 dBi @ 5 GHz,12 dBi @ 2.4 GHz	90/120° Sector: 17dBi Optional Beamforming	300-16: Integrated 16 dBi 300-25: Dish 25 dBi CSM 300: RP-SMA	90/120° Sector: 17 dBi 4 x 4 MU-MIMO Optional Beamforming 3000L is connectorized
Modes	AP: 120 Subscribers SM PTP	AP: 120 Subscribers PTP	Bridge-in-a-Box: PTP	SM PTP	SM PTP	SM PTP	SM PTP	AP: 120 Subscribers PTP	SM PTP	AP: 120 Subscribers 3000L AP: 64 Subscribers PTP

cambiumnetworks.com

ePMP Key Differentiators

- Superior performance in interference compared to other affordable options
- Deploy with confidence in today's crowded radio environments
- Scalability without sacrifice
- Frequency reuse enabled by GPS synchronization
- Advanced QoS and multicast capabilities supporting advanced services
- cnMaestro end-to-end management

ePMP 1000 AP

Access Point available in **FULL** (up to 120 Subscriber Module) or **LITE** (up to 10) version, as well as **with or without GPS Synchronization**

Access Point without GPS Synchronization same as connectorized Subscriber Module

Up to 220 Mbps of throughput per sector

GPS Synchronization enables frequency re-use

Frequency Bands/Channels
- 2.4 GHz; 5 GHz
- 5 | 10 | 20 | 40 MHz

Interfaces
- Physical layer 2x2 MIMO A and B / OFDM
- Ethernet 100/1000 BaseT

Adaptive Modulation
- BPSK to 256QAM

Aggregate Capacity
- Up to 220 Mbps
- Up to 120 Subscribers per AP
- AP Lite supports up to 10 Subscribers
- Processing power of 25k pps

Maximum Power & Antenna Gain
- 30 dBm transmit power
- Panel Antenna 15dBi (90°), 14dBi (120°)

Latency
- 3 – 5ms typical (one way)

Physical
- Connectorized AP with or without GPS Sync
- Environmental IP55
- Power consumption 7.5 W typical

ePMP 2000

Consisting of Smart Beamforming and Intelligent Filtering, Hypure is innovative technology to keep your network operating at its best in challenging real-world conditions.

Innovative GPS Synch Technology enables unparalleled spectrum efficiency

Advanced, scalable scheduling mechanism supports up to 120 subscribers without degrading overall system performance.

Provides more than 200 Mbps of real user throughput per sector

Frequency Bands/Channels
- 5 GHz
- 5 | 10 | 20 | 40 MHz

Interfaces
- Physical layer 2x2 MIMO A and B / OFDM
- Ethernet 100/1000 BaseT; 802.3at compliant

Adaptive Modulation
- BPSK to 256QAM

Aggregate Capacity
- Up to 220 Mbps
- Up to 120 Subscribers per AP
- AP Lite supports up to 10 Subscribers

Maximum Power & Antenna Gain
- 30 dBm transmit power
- Sector Antenna 18 dBi

Latency
- 3 – 5ms typical (one way)

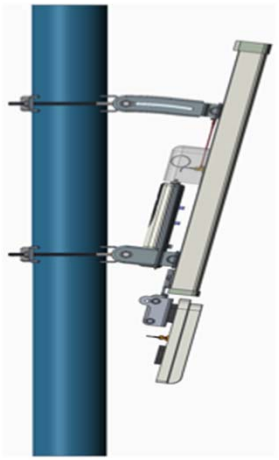
Physical
- Connectorized AP with GPS Synch
- Environmental IP55
- Power consumption 20 W maximum

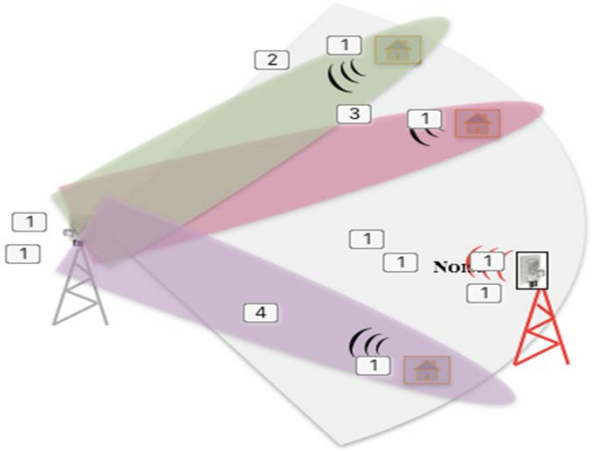
Why ePMP 2000?

ePMP Generation II

ePMP2000 – Reduces self interference and mitigates the impact of external interference in an affordable solution.

- All the scalability, capacity benefits of ePMP1000
- Dynamic filtering to battle neighboring channel interference
- Beam Steering in the uplink to fight the most common source of co-channel interference





ePMP 3000

Up to 5X performance with Gen3 Technology

Double sector throughput with the same channel bandwidth by serving two subscribers at the same time with MU-MIMO

The ePMP 3000 is the third generation access point (AP) that carries on the interference tolerance mechanisms from ePMP 2000 but adds the power of Multi-User MIMO (MU-MIMO)

Peak throughput of 1.2 Gbps

Frequency Bands/Channels
- 5 GHz
- 20 | 40 | 80 MHz

Interfaces
- Physical layer 4x4 MU-MIMO / OFDM
- 100/1000BaseT, rate auto negotiated, 802.3at compliant
- SFP

Adaptive Modulation
- BPSK to 256QAM

Aggregate Capacity
- Up to 1.2 Gbps
- Up to 120 Subscribers per AP

Maximum Power & Antenna Gain
- 32 dBm transmit power
- Sector Antenna 17 dBi

Physical
- Connectorized AP with GPS Synch
- Environmental IP55
- Power consumption 25 W maximum

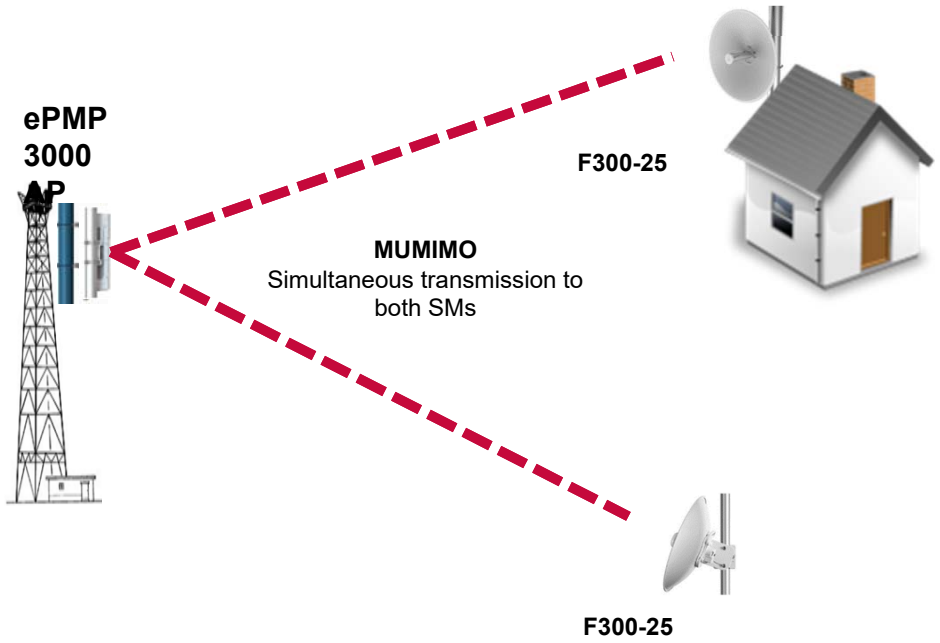
Why ePMP 3000?

ePMP Generation III

ePMP 3000 – All the powers of previous generations plus affordable MU-MIMO

- Frequency re-use, Dynamic Filtering, Uplink Beamsteering
- 4X4 MUMIMO doubling sector capacity
- 256QAM Modulation, 80MHz channel support, higher packets per second
- Improved radio performance (reduced C/I requirements)
- Add more subscribers to the AP

MU-MIMO: How Does it Work?



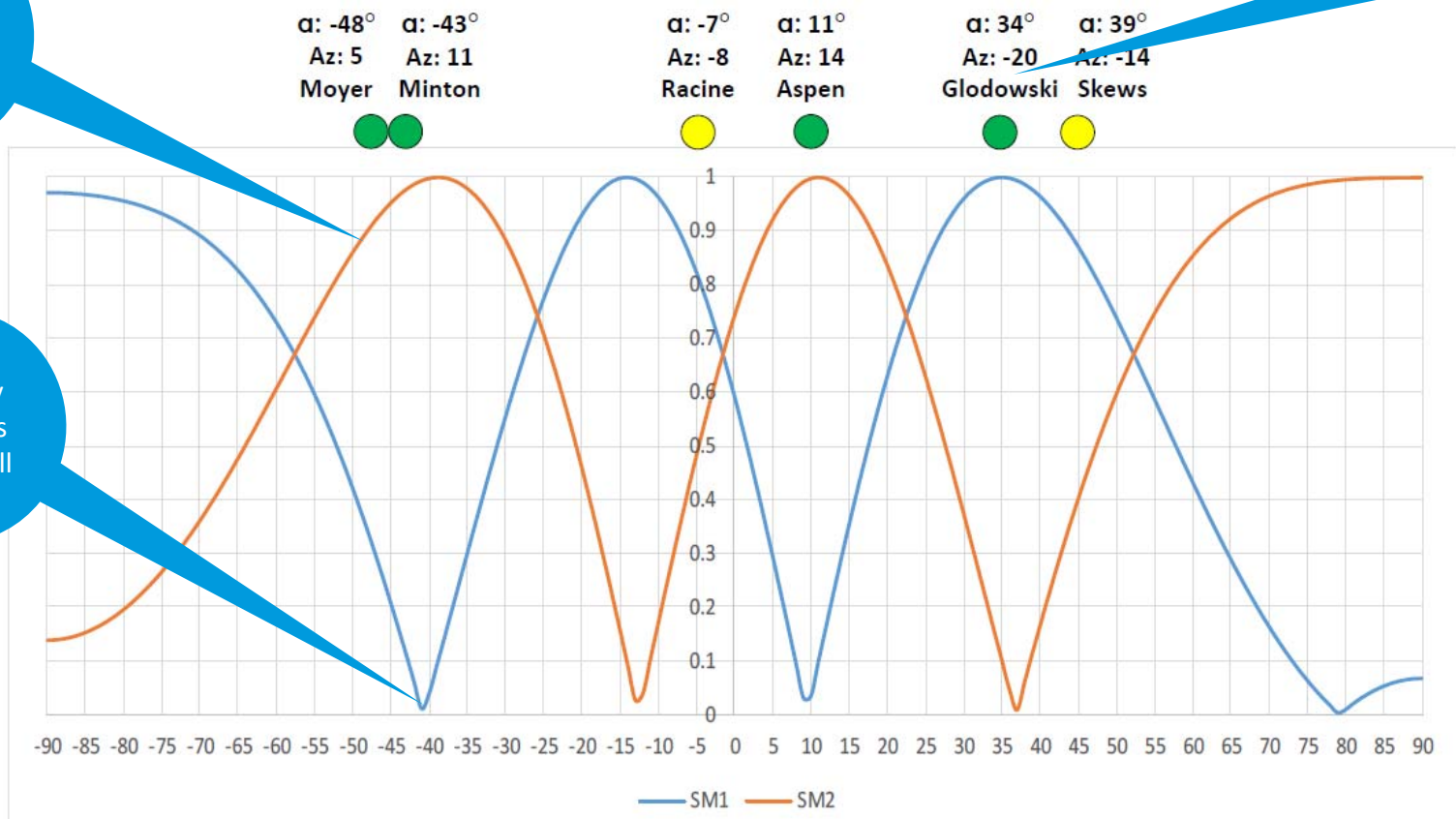
In a 4X4 system, 2 SMs can be grouped for MUMIMO gain with as little as 6 SMs in the network

MU-MIMO: How Does it Work?

SM at this azimuth can be grouped

Primary SM1

Primary SM1 has deep null

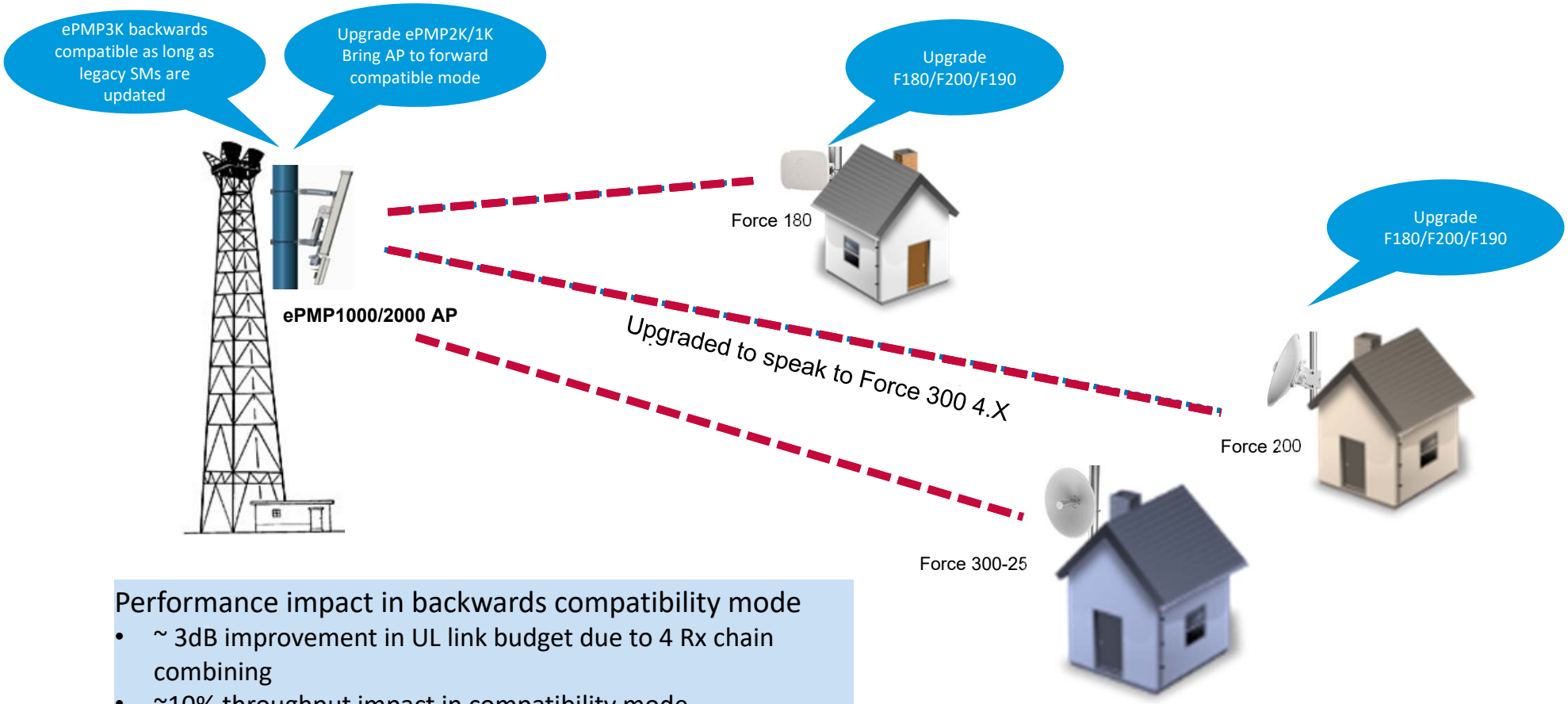


Glodowski can be grouped with 3 other green SMs

Key foundations for grouping:

- Sounding
- Azimuth metric
- Traffic pattern

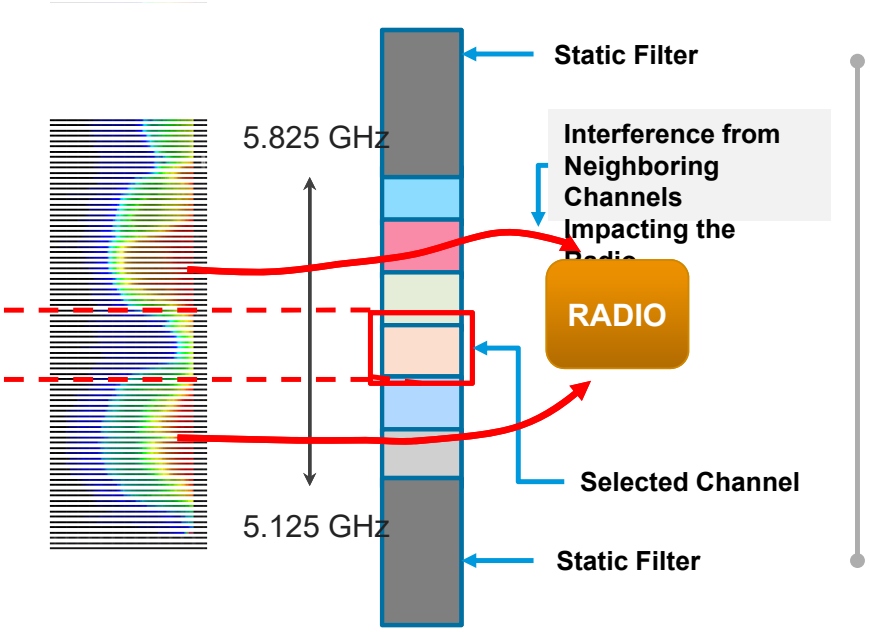
ePMP 3000 Compatibility Modes

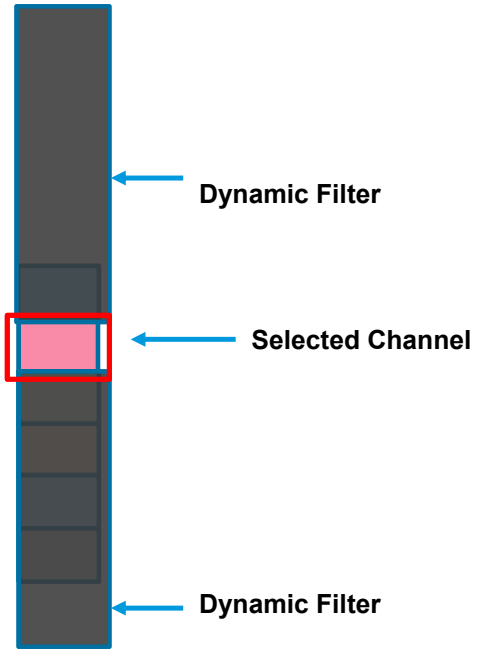


Performance impact in backwards compatibility mode

- ~ 3dB improvement in UL link budget due to 4 Rx chain combining
- ~10% throughput impact in compatibility mode

Intelligent Filtering

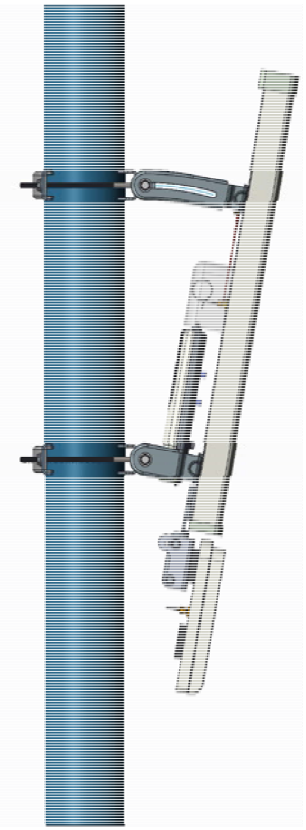


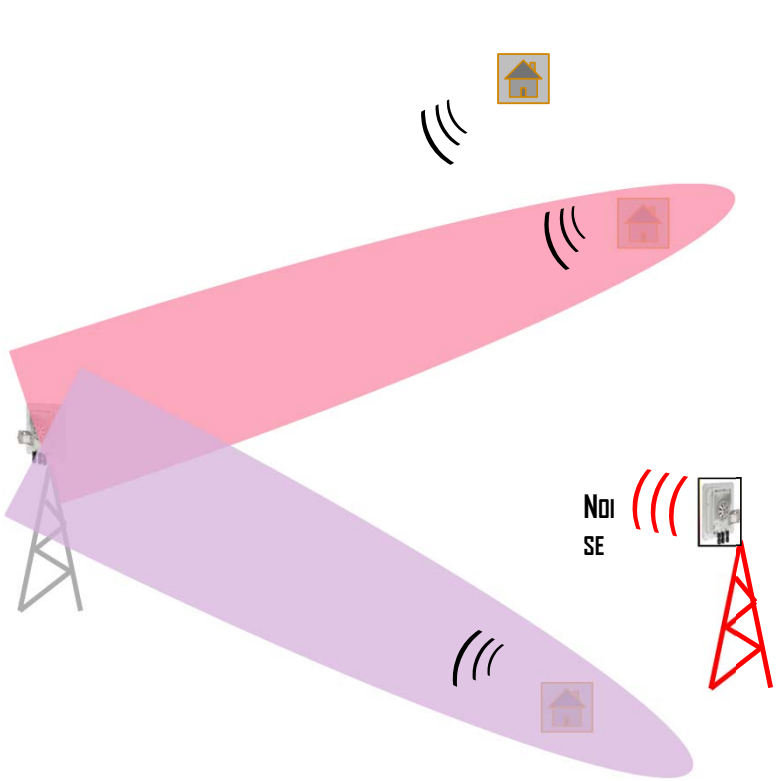


Spectrum Traditional Fixed Filter
Makes radio susceptible to neighboring channel interference

Cambium's Intelligent Filtering
Wraps around selected channel, filtering out interference from neighboring channels

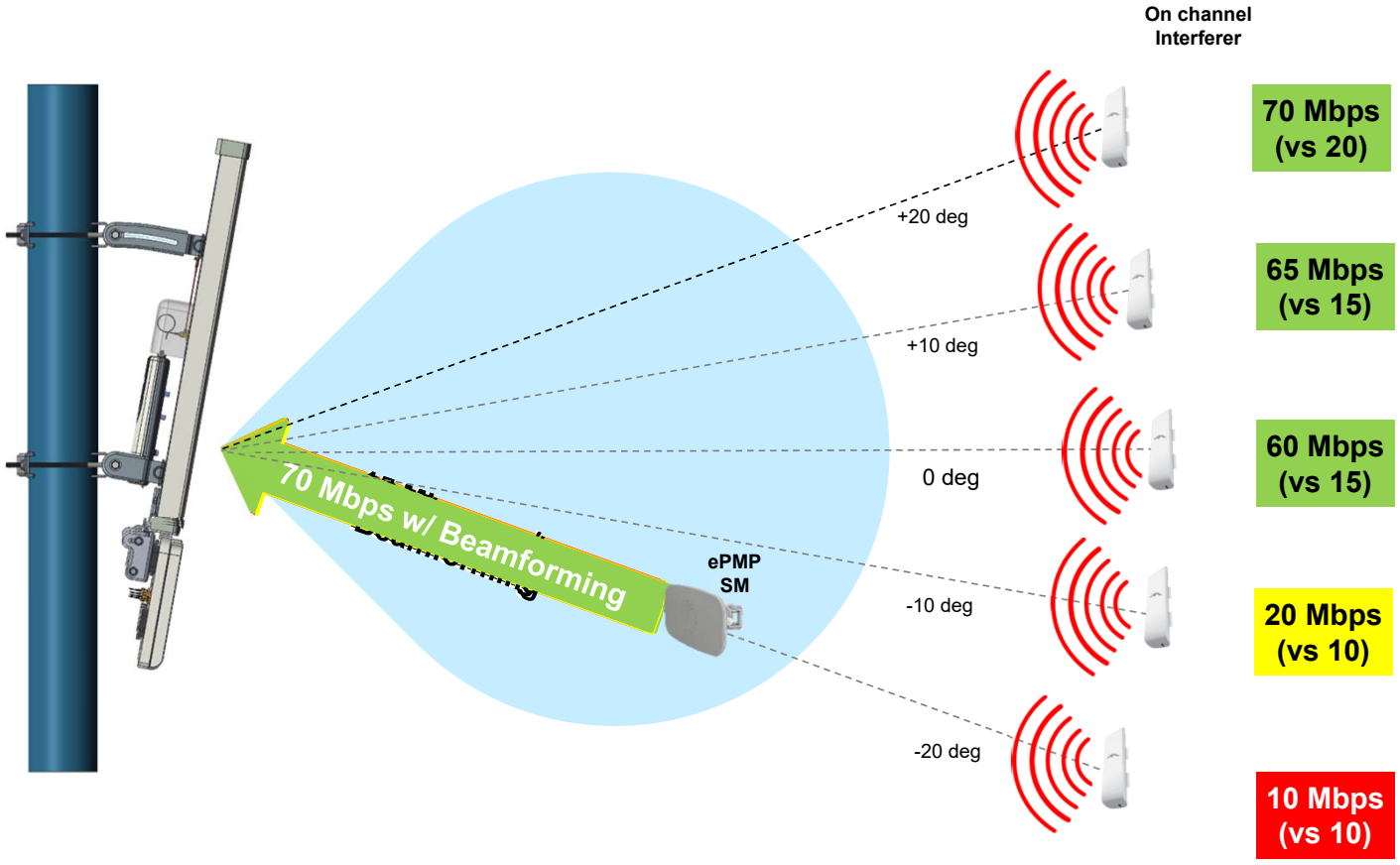
Smart Beamforming





- Co-channel interference is typically more damaging to a network than adjacent channel interference.
- Filtering not possible as the interferer is transmitting on the same channel as the access point.
- Sector antenna means the access point must ‘listen’ to any co-channel interference in its azimuth, limiting network performance.

Smart Beamforming

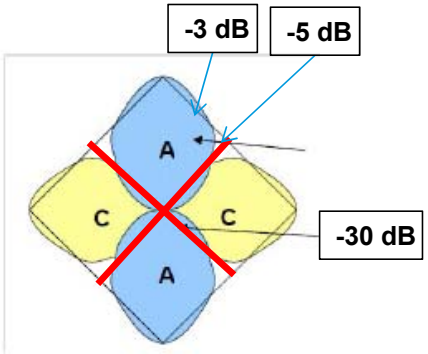


ePMP

ePMP 1000 / 2000 Sector Antenna – 18 dBi

- **Frequency Reuse:** Designed for ABAB channel re-use (two channels covering four sectors), the sector antenna has a 35 dB front to back ratio.
- **Channel Flexibility:** Consistent gain from 4.9 to 6.0 GHz.
- **Consistent Coverage:** Excellent **null fill**.
- **Designed for the Installer:** Small compact design, integrated ePMP 1000 and 2000 radio mount and GPS antenna integration.
- **Predictable Performance:** The sector antenna is integrated into Cambium Networks LINKPlanner. The 3D model shows coverage at all elevations and across the azimuth.
- **ePMP 1000 / 2000 Application**

ePMP 1000 / 2000 Sector Antenna



Sector Size	Antenna 3-dB Beamwidth
120°	90°
90°	60°
60°	45°

- In the past, Cambium recommended antennas to have 3 dB roll off at < sector width for:
  - For 90 degree sector
  - For 120 degree sector
- Now with improved Antenna technology employed on the new ePMP Antenna
  - Improvement in the roll off beyond the 90 degree point
  - Allow for frequency reuse
  - Meets our requirements for use in a 120 degree sector
  - Can be used to support either sector configuration.

ePMP 3000 Sector Antenna – 17 dBi

- **Frequency Reuse:** Designed for ABAB channel re-use (two channels covering four sectors), the sector antenna has a 30 dB front to back ratio.
- **Channel Flexibility:** Consistent gain from 4.9 to 6.0 GHz.
- **Consistent Coverage:** Excellent **null fill**.
- **Designed for the Installer:** Small compact design, integrated ePMP radio mount and GPS antenna integration.
- **Predictable Performance:** The sector antenna is integrated into Cambium Networks LINKPlanner. The 3D model shows coverage at all elevations and across the azimuth.
- **ePMP 3000 Application – 2X Horizontal, 2X Vertical**

ePMP Force 180

The ePMP Force 180 Integrated Radio can be configured as a Subscriber Module, an unsynchronized Access Point or a Backhaul radio

This radio will function as a client (slave) to an ePMP GPS Synchronized Radio in either a PMP or PTP deployment forming a GPS Synchronized solution

Small, sleek form factor delivering high performance. 16 dBi antenna providing increased range

Frequency Bands/Channels
- 2.4 GHz; 5 GHz
- 5 | 10 | 20 | 40 MHz

Interfaces
- Physical layer 2x2 MIMO A and B / OFDM;
- Ethernet 100/1000 BaseT

Adaptive Modulation
- BPSK to 256QAM

Aggregate Capacity
- Up to 220 Mbps
- Up to 120 Subscribers per AP
- AP Lite supports up to 10 Subscribers
- Processing power of 25k pps

Maximum Power & Antenna Gain
- 30 dBm transmit power
- Panel Antenna 15dBi (90°), 14dBi (120°)

Latency
- 3 – 5ms typical (one way)

Physical
- Connectorized AP with or without GPS Synch
- Environmental IP55
- Power consumption 7.5 W typical

Bridge-in-a-Box Solution

- PTP Wireless Bridge – ePMP Bridge-in-a-Box is a pre-paired Point-to-Point (PTP) link comprised of two ePMP Force 180 devices designed to extend networks between two locations (up to 10 miles apart).
- 200+ Mbps throughput

ePMP Force 190

The **ePMP Force 190** high gain integrated design enhances range and improves throughput in high interference environments with a compact design

Designed for installations that **require a smaller on-premises footprint while enabling high gain**

Narrow beamwidth

Frequency Bands/Channels
- 5 GHz;
- 5 | 10 | 10 | 40 MHz channels

Interface:
- Physical layer 2x2 MIMO / OFDM
- Ethernet 10/100 BaseT

Adaptive Modulation
- BPSK to 64QAM depending on Nominal Receive Sensitivity

Aggregate Capacity
- 200 Mbps in 40 MHz channel

Maximum Power & Antenna Gain
- 27 dBm transmit power
- 22 dBi (5 GHz)

Latency
- Round trip latency 2-3 ms

Physical
- Environmental - IP55
- Power Consumption 5W typical

ePMP Force 200

The **ePMP Force 200** high gain integrated design enhances range and improves throughput in high interference environments

Gigabit Ethernet interface provides up to 200 Mbps of real user data throughput

Produced using off-the-shelf components

Most cost effective radio for up to 200 Mbps

Frequency Bands/Channels
- 2.4 GHz and 5 GHz
- 5 | 10 | 10 | 40 MHz channels

Interfaces
- Physical layer 2x2 MIMO / OFDM
- Ethernet 10/100/1000 BaseT

Adaptive Modulation
- BPSK to 64QAM depending on Nominal Receive Sensitivity

Aggregate Capacity
- 200 Mbps in 40 MHz channel
- Processing power of 20k pps

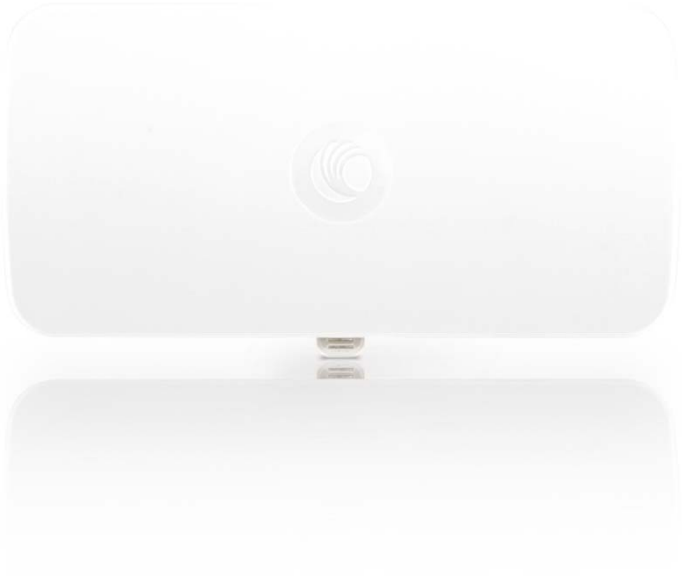
Maximum Power & Antenna Gain
- 30 dBm transmit power
- Gain 17 dBi (2.4 GHz), 25 dBi (5 GHz)

Latency
- Round trip latency 2-3 ms

Physical
- Environmental - IP55
- Power Consumption 5W typical

ePMP Force 300-16

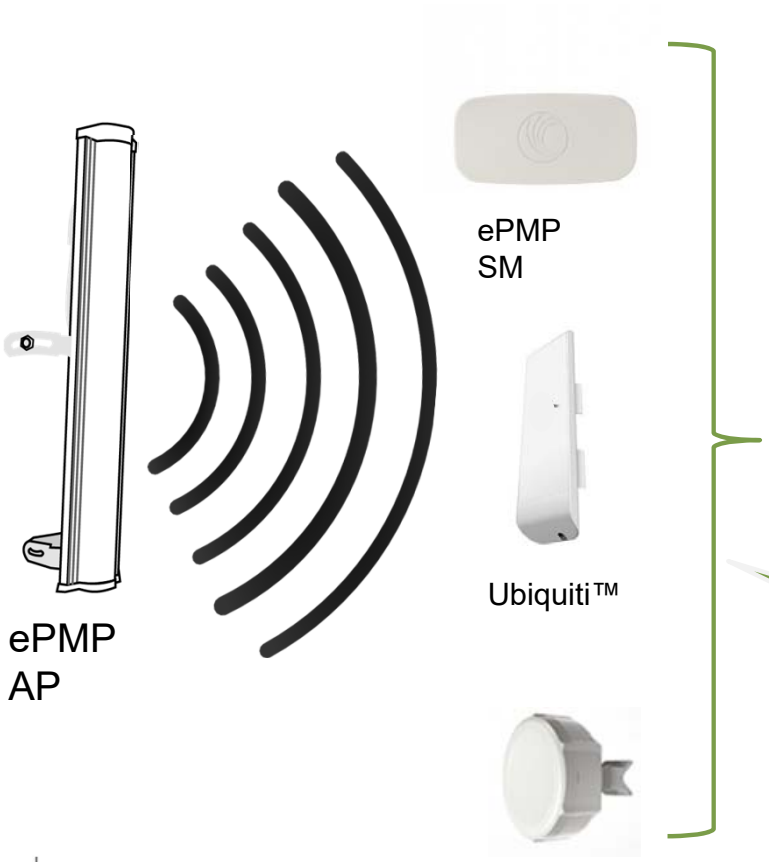
- With a horizontal orientation mount providing a 15 degree beam width and 16dBi gain, the F300-16 offers a compelling, compact subscriber or point to point solution resilient to interference.
- 500+ Mbps of throughput (256QAM, 80 MHz)
- 20/40/80 MHz channel size
- 5.1 to 5.9 GHz operation
- TDD mode of operation with sub-5ms latency in PTP mode
  - Future support for “Flexible” mode (non-synchronized, lower latency)



ePMP Force 300-25

- 500+ Mbps of throughput (256QAM, 80 MHz)
- Quad-core A7 ARM processor provides 65K PPS
- 20/40/80 MHz channel size
- 5.1 to 5.9 GHz operation
- TDD mode of operation with sub-5ms latency in PTP mode
  - Future support for “Flexible” mode (non-synchronized, lower latency)

ePMP Elevate



- Allows **ePMP Elevate** software to run on **non-Cambium Networks 802.11n-based** subscriber modules
- **ePMP Elevate** subscribers function as **ePMP** subscribers – with all the **ePMP** benefits
- Comparable performance to all-**ePMP** networks, despite different subscriber hardware; industry-first **hardware-agnostic networks**

Managed by **cnMaestro™**

ePMP | elevate

Transform your Network with ePMP Elevate

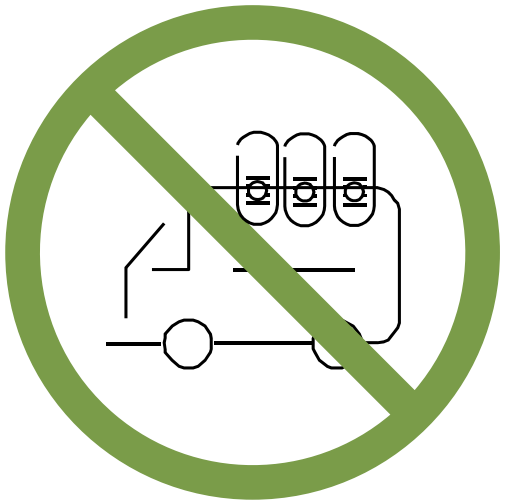
ePMP | elevate

- The hardware investment is protected, and the existing infrastructure is given a new lease of life to support revenue-generating applications for years to come.
- Elevate also provides:
  - Frequency reuse enabled by GPS Synchronization
  - Smart Beamforming
  - On non-Cambium 802.11n-based hardware
- ePMP Elevate networks can be managed by cnMaestro™

Transform your Network with ePMP Elevate

All the benefits of ePMP 1000, ePMP2000 & ePMP 3000 without a single truck roll.

- Frequency re-use
- Scalability
- Performance under interference
- Applications and greater ARPU
- NO TRUCK ROLL!



ePMP | elevate

The Next Level of Network Migration

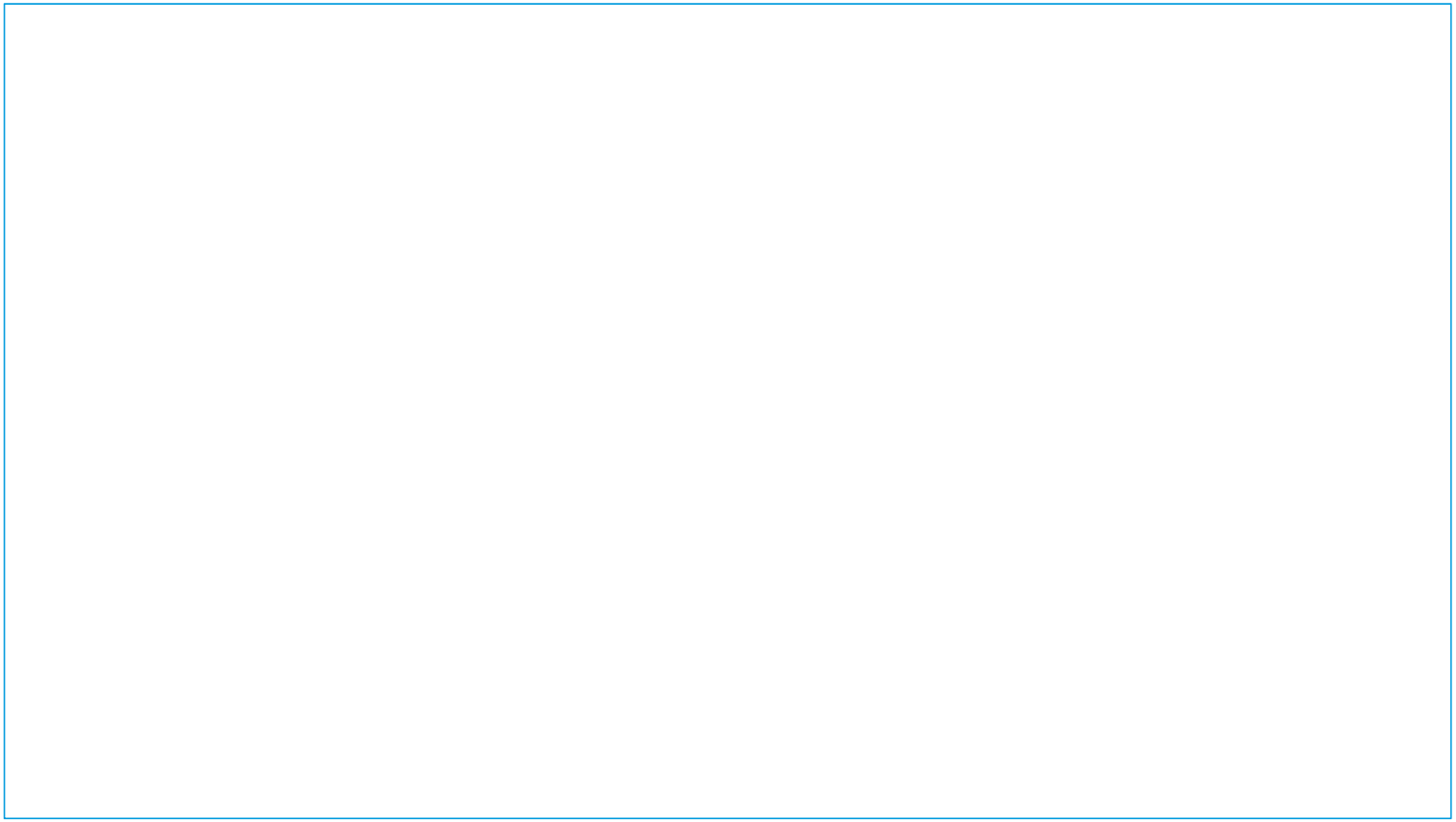
Saving the cost and time of a total network replacement, an operator simply:

1. Installs an ePMP Access Point and
2. Loads ePMP Elevate software onto their deployed subscriber modules.
3. Applies connectivity licenses for Elevate subscribers per AP

1

2

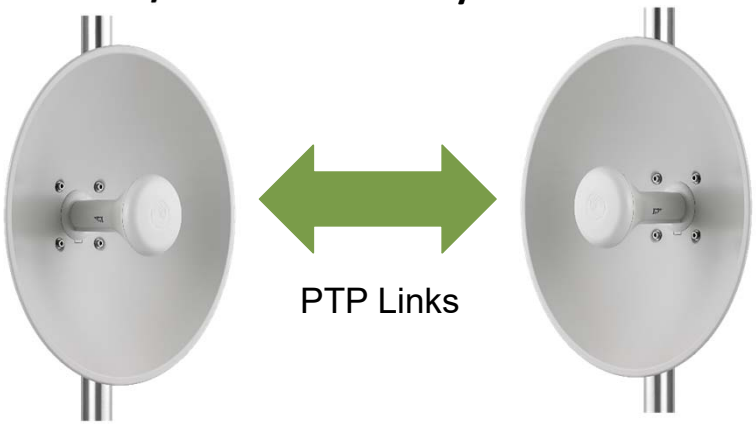
Migration Overview



Lab

Deployment Configurations

Synchronized & Unsynchronized



Unsynchronized

Synchronized & Unsynchronized PMP

ePMP Solves the Unlicensed Spectrum Dilemma

"I need to find a cleaner frequency that provides better performance"

"I can't keep adding extra hardware to keep my towers clean"

"I want to expand my network but usable spectrum is limited"

"When we add new devices, our network interference increases and disrupts performance"

ePMP Answer: Frequency re-use with GPS Sync at the most affordable price point

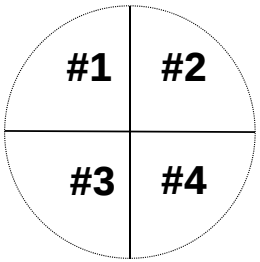
"I need to find a frequency that provides better performance"
SOLVED

A measure of how efficiently a wireless solution utilizes RF spectrum

- Advanced WiMAX/LTE like MAC layer combined with sync source from GPS allows precise control over Tx/Rx
- Back to back re-use of frequencies without Tx/Rx overlapping.
- Every AP on the network synchronized and not stepping on each other
- Find that clean chunk and re-use across your network.

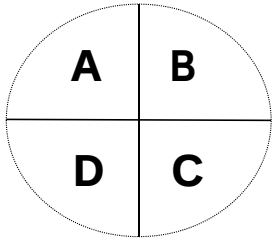
The Importance of Spectral Efficiency

- Spectral Efficiency:
  - A measure of how efficiently a wireless solution utilizes RF spectrum
    - Defined as Throughput Achieved (bps) per Spectrum Utilized (Hz) – bps / Hz
- **Clear Spectrum** is a **scarce resource**
- A solution that makes efficient use of this scarce resource provides a **superior Return on Investment** to the Network Operator
- Example for Illustration: Four Sector AP Site with 6 km coverage radius deployed in 50 MHz of available spectrum:

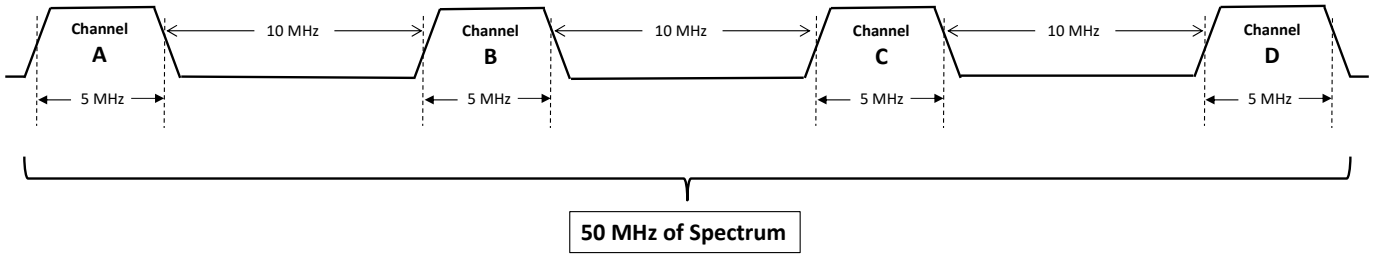


Unsynchronized Deployment in 50 MHz

- No channel reuse within the cell



- Guard Bands between channels used must be greater than or equal to 2X than channel Bandwidth

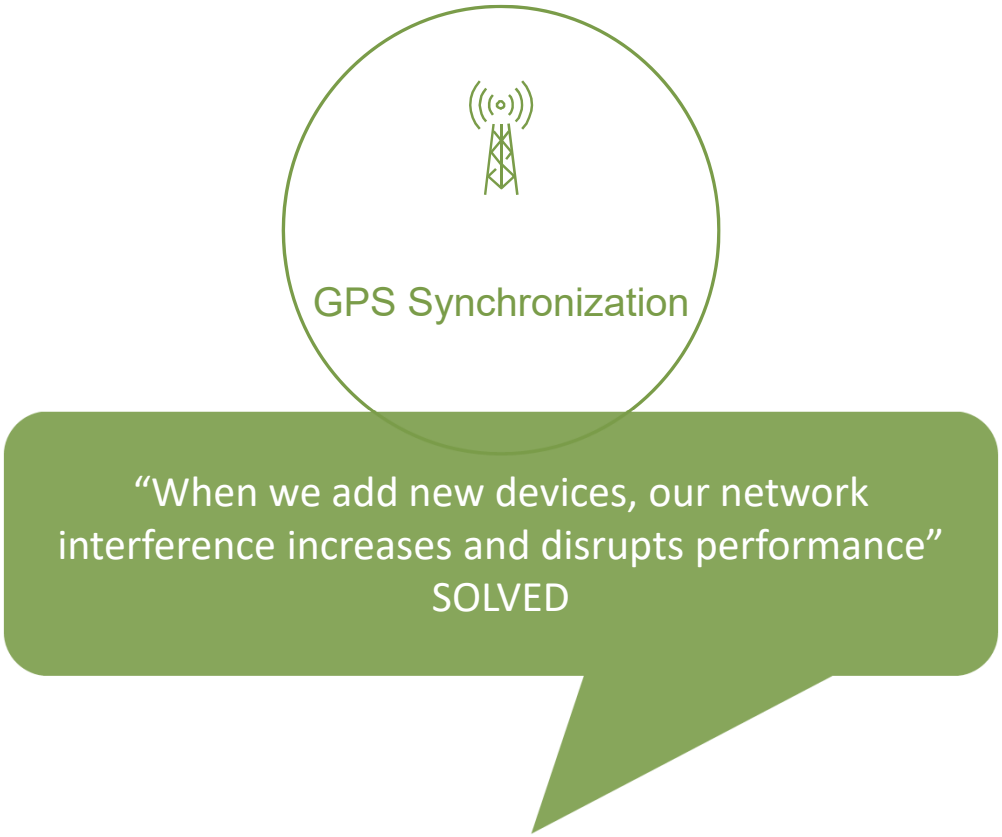


- Avg Capacity of 5 MHz channel with 6 km range = **22 Mbps**
- Spectral Efficiency of Unsynchronized Deployment:

4 x 22 Mbps = 88 Mbps / 50 Mhz = 1.8 bps/Hz

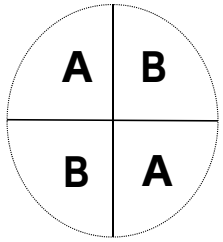
ePMP Solves interference problem #1 – Self Interference

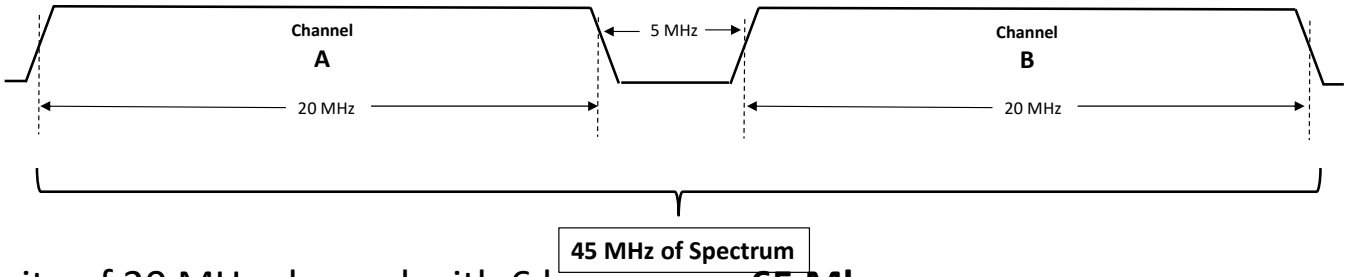
- **GPS Synchronization** is a satellite-based mechanism for precisely coordinating transmit and receive cycles of ePMP devices
- This coordination greatly reduces system self-interference, thereby allowing more efficient use of radio spectrum
- A **significant** source of interference is self interference. With synchronization, **power control**, **Front to Back Ratio** say good bye to self interference.



ePMP GPS Sync Deployment in 50MHz

- **2 channel reuse** supported within the cell
- **5 MHz Guard Bands** between channels



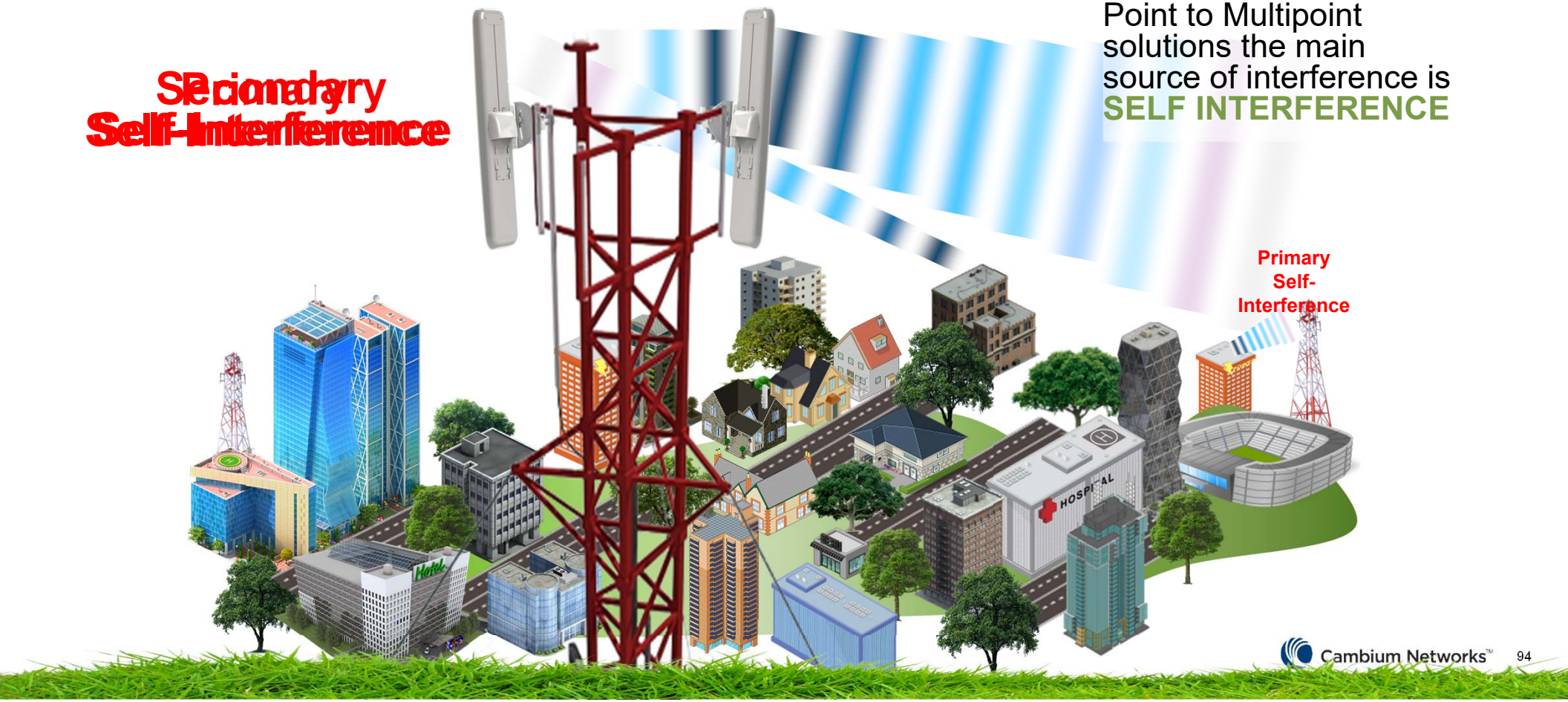


- Avg Capacity of 20 MHz channel with 6 km range = **65 Mbps**
- Spectral Efficiency of Synchronized Deployment:

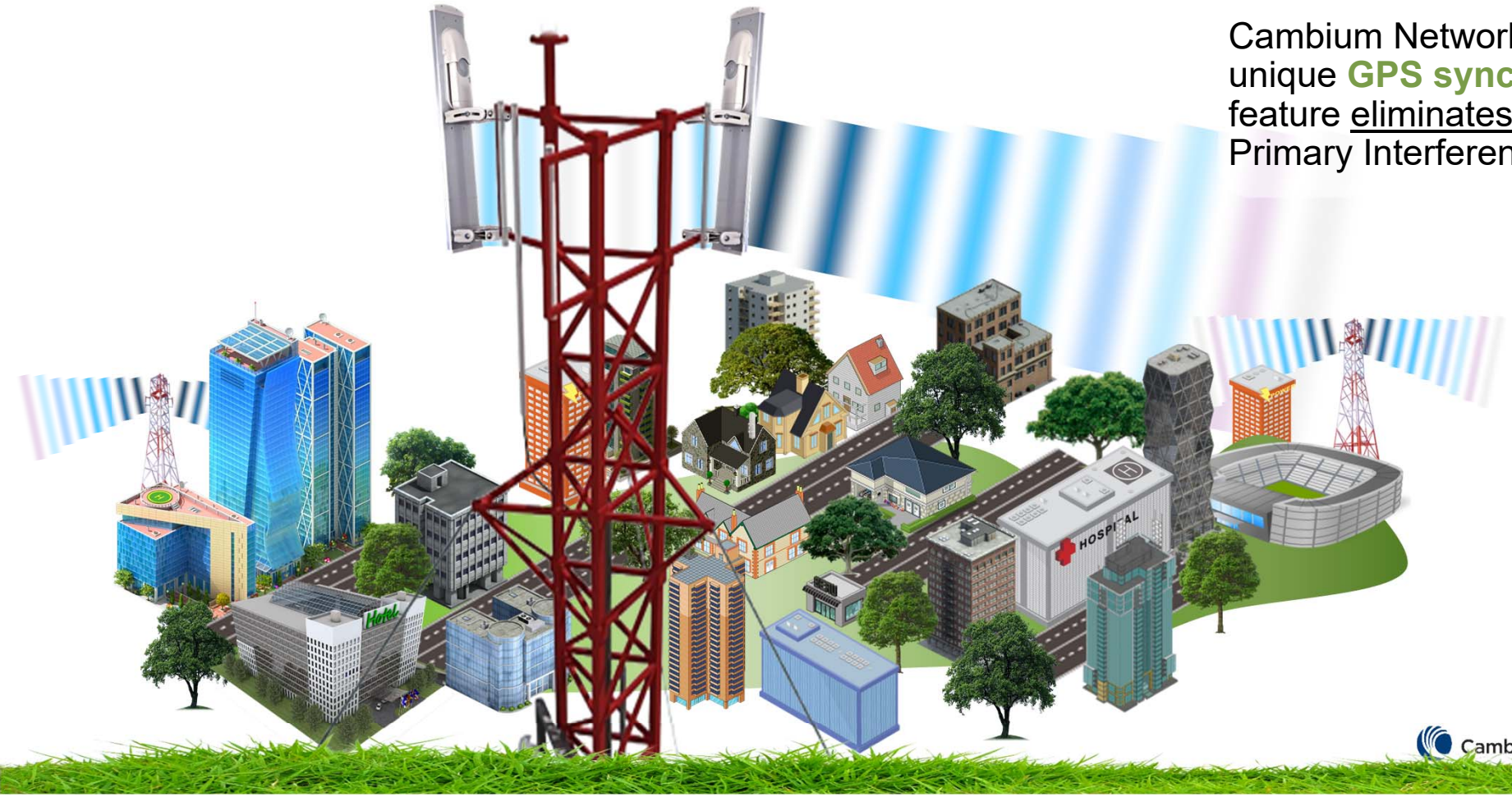
4 x 65 Mbps = 260 Mbps / 45 Mhz = 5.8 bps/Hz

> 3X Spectral Efficiency for ePMP GPS Sync Solution

Primary and Secondary Self-Interference

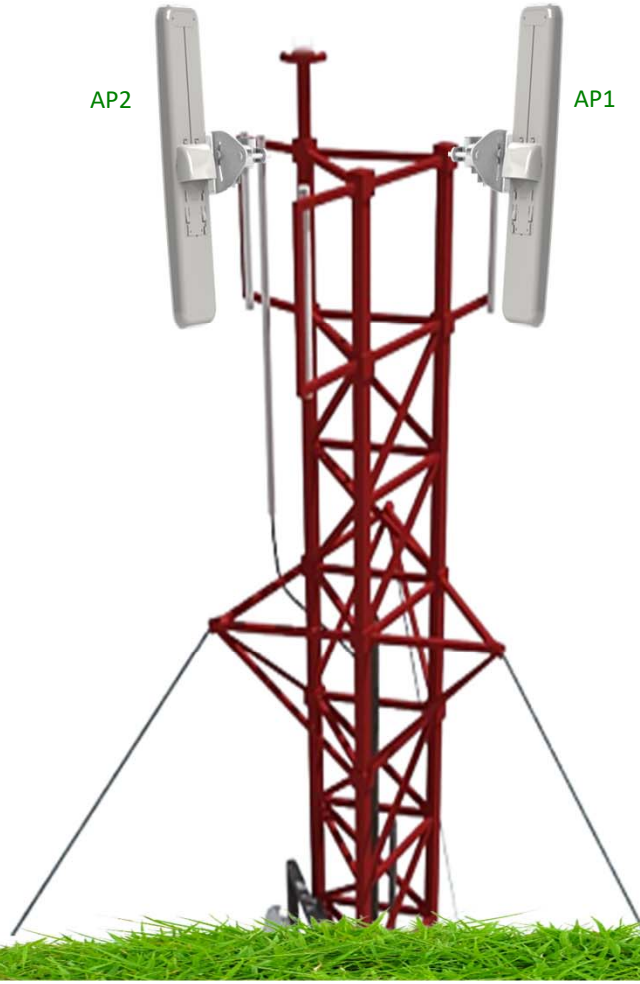


Primary and Secondary Self-Interference



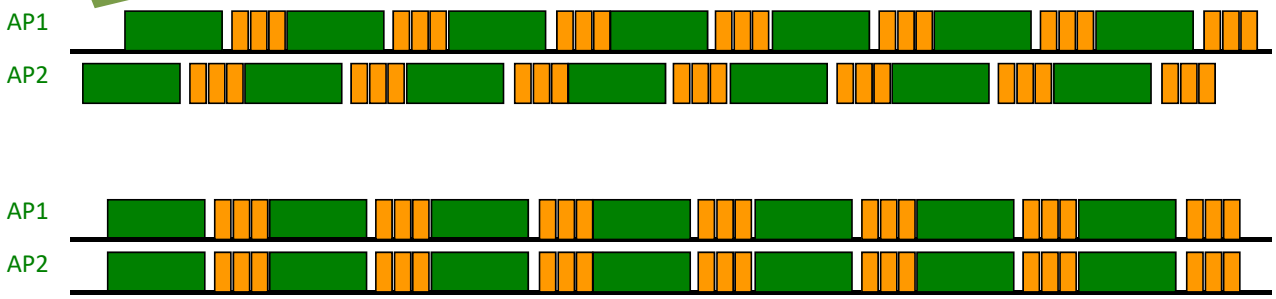
Cambium Networks unique **GPS synch** feature eliminates Primary Interference

AP Transceiver Cycles



Unsynchronized

Each AP is transmitting at a different time



GPS-Synchronized

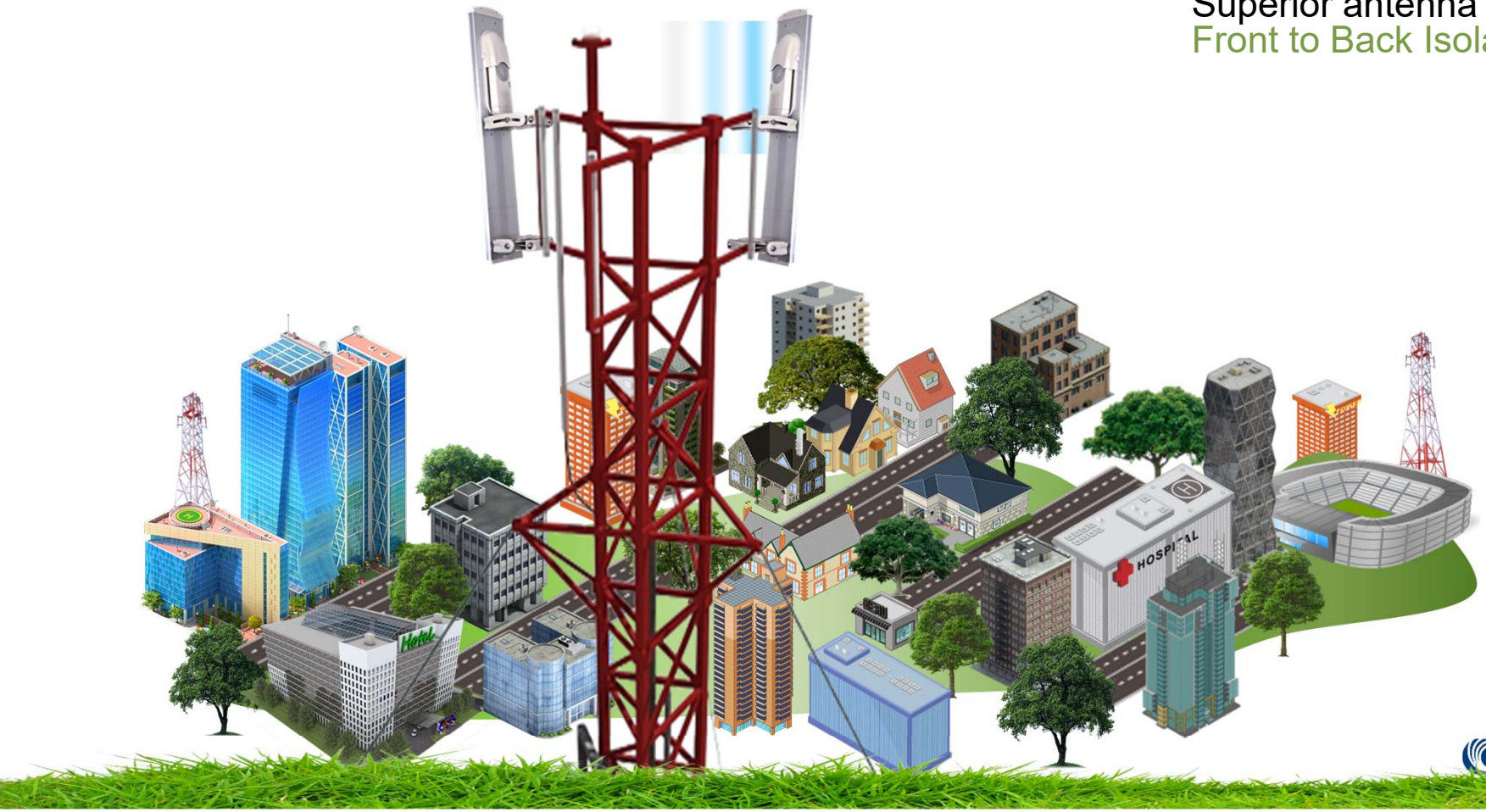
Each AP is transmitting and receiving at the same time, reducing self-interference

Downlink Transmission

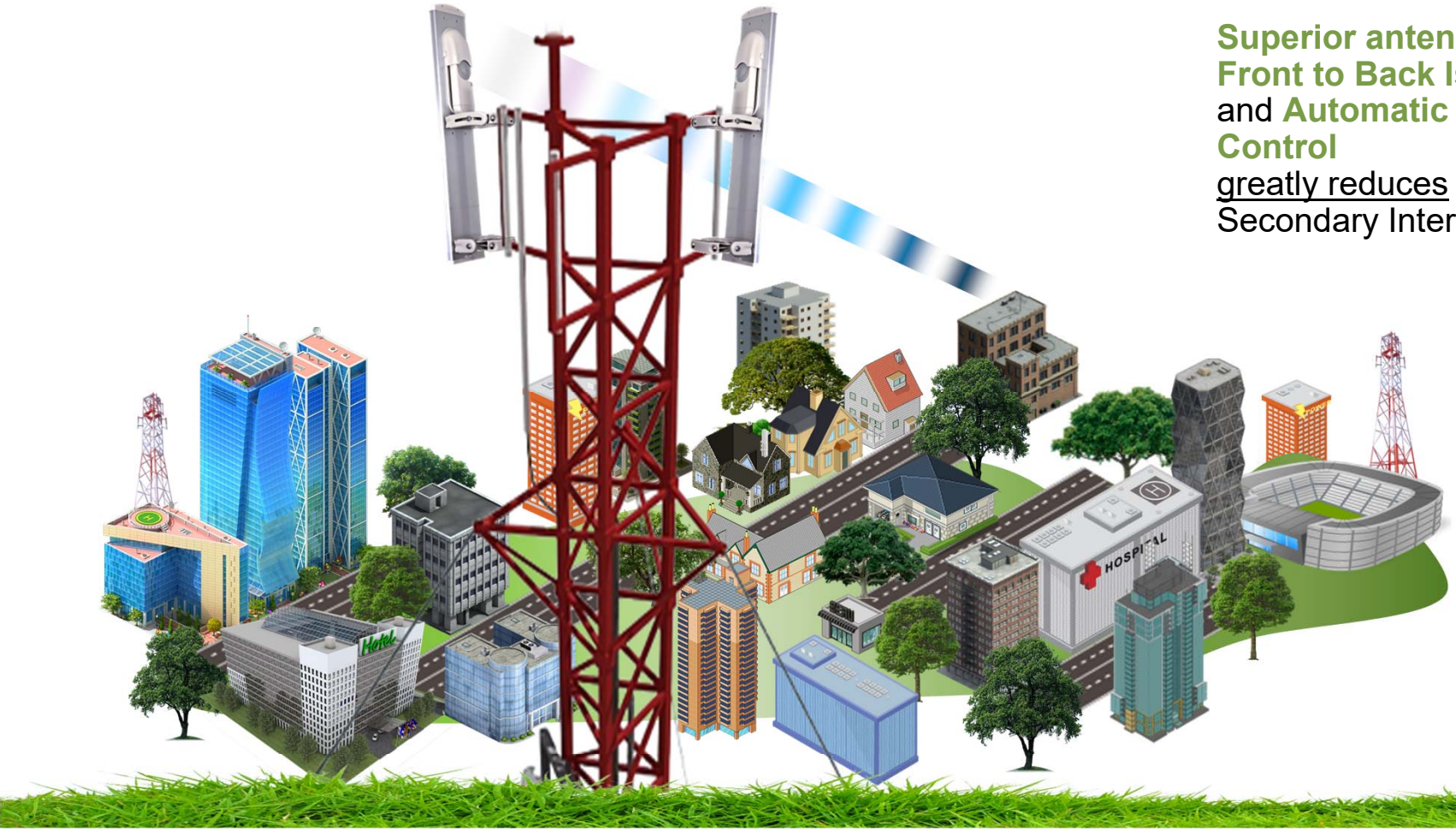
Uplink Transmission

Primary and Secondary Self-Interference

Superior antenna
Front to Back Isolation

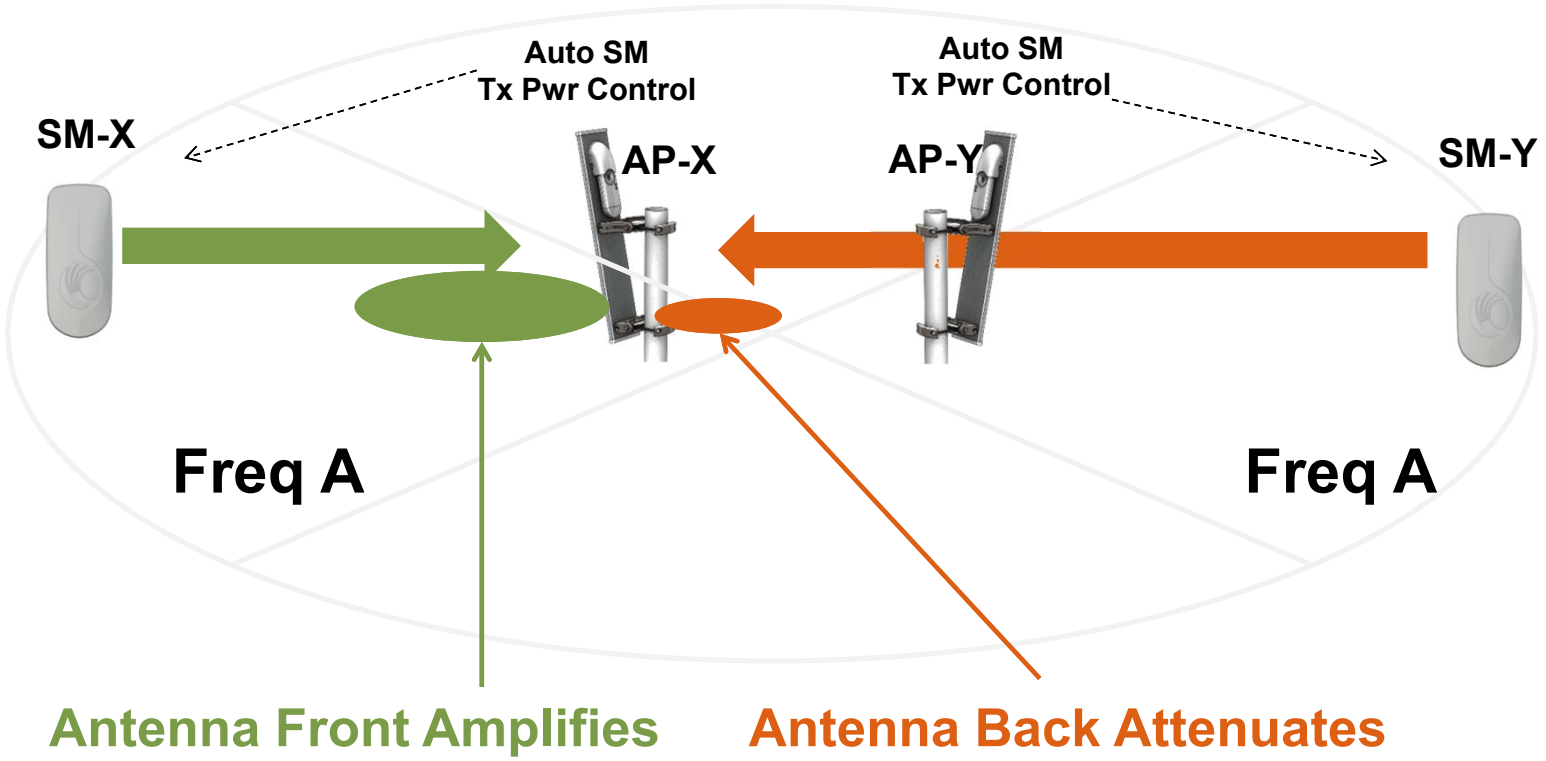


Primary and Secondary Self-Interference



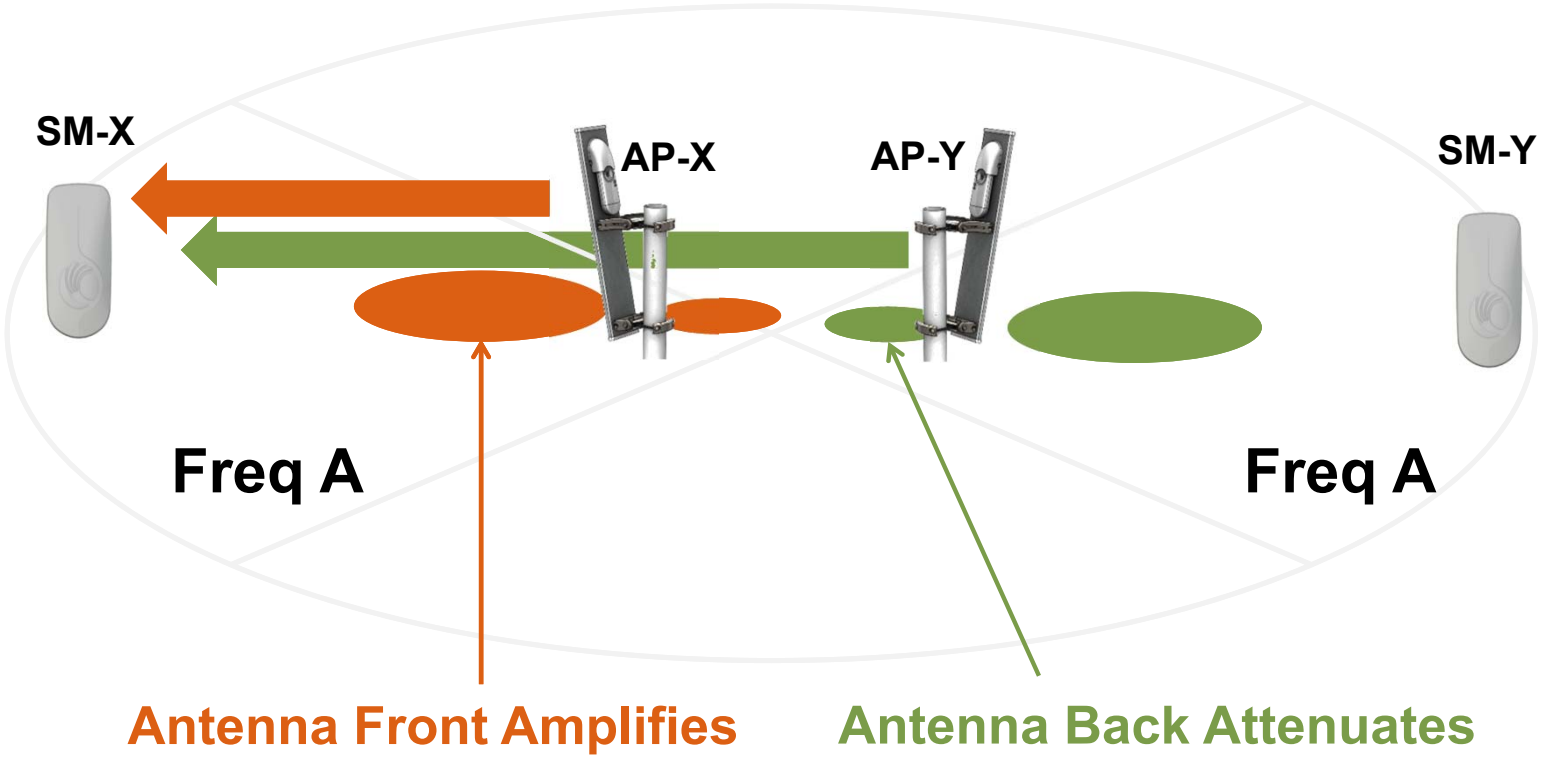
Superior antenna Front to Back Isolation and **Automatic Power Control** greatly reduces Secondary Interference

Secondary Self Interference - Uplink



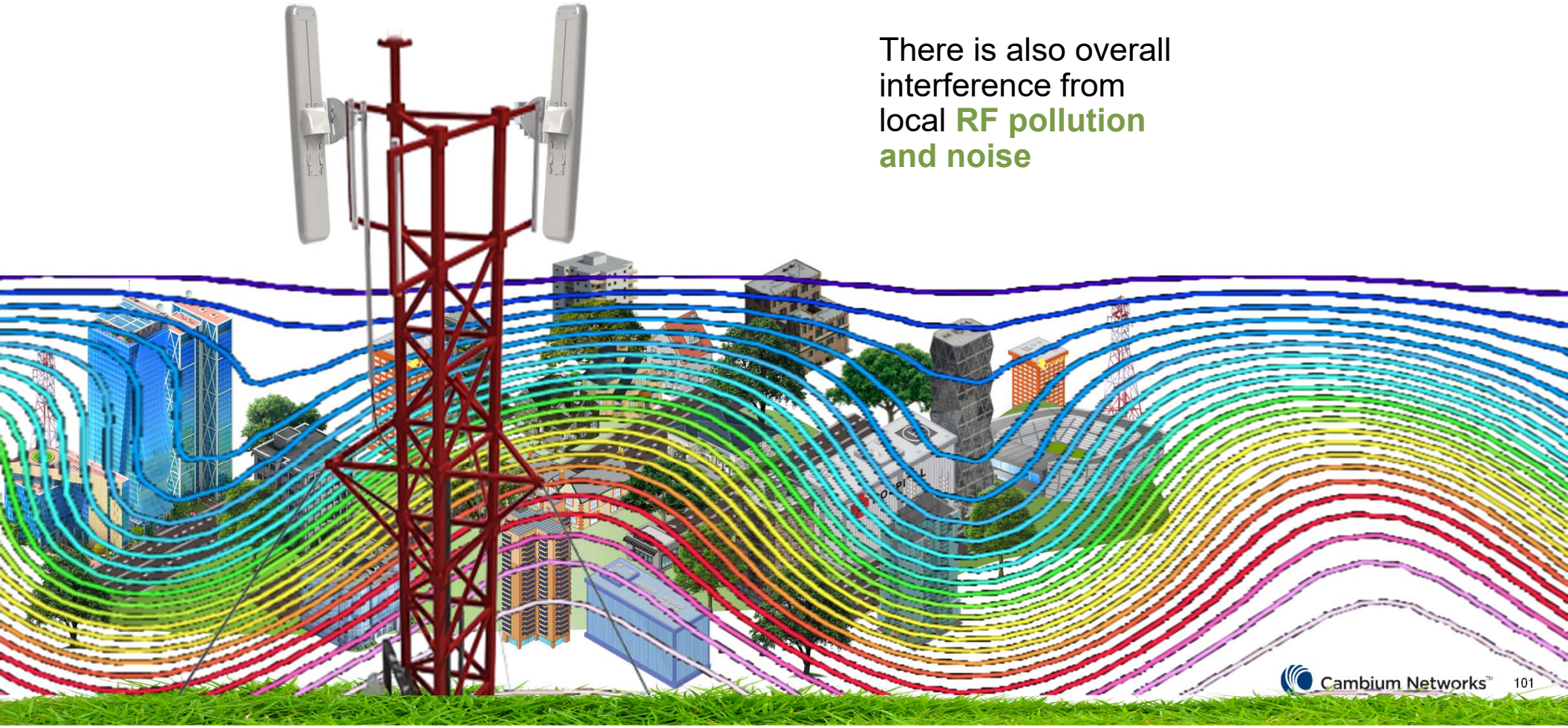
High Front Amplification and High Back Attenuation are required
Need High Front to Back (F/B) Ratio > 30 dB

Secondary Self Interference - Uplink



High Front Amplification and High Back Attenuation are required
Need High Front to Back (F/B) Ratio > 30 dB

Noise Floor

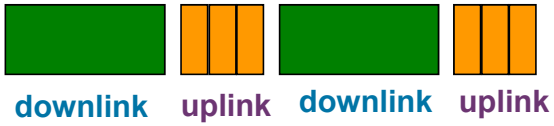


There is also overall interference from local **RF pollution and noise**

GPS Synchronization Key Components and Benefits

Key Components

- GPS-Synchronized TDD MAC



- Automatic SM Transmit Power Control (TPC)
- Front-to-Back Antenna Isolation

Benefits

Eliminates “Collision Collapse” and Primary Self Interference:

- AP to AP Interference (DL to UL)
- SM to SM Interference (UL to DL)

Allows for Reduction in Guard Bands

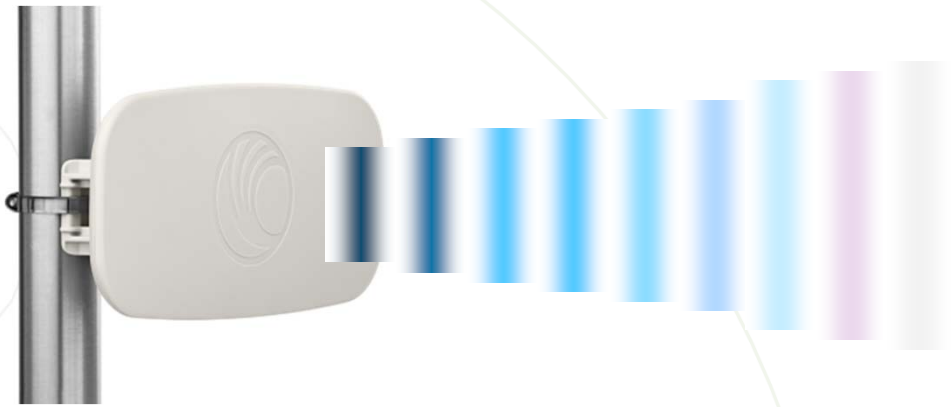
Reduces Secondary Self Interference

- SM to Other AP Interference (UL to UL)
- AP to Other SM Interference (DL to DL)

Allows for Frequency Reuse

Automatic Transmit Power Control (ATPC)

- ATPC is not supported on standard 802.11 products
- For 802.11n TDD mode, transmit power control in UL is very beneficial to avoid interference from neighboring towers specifically to support ABAB configuration
- Some proprietary information elements have been added to Beacon message to notify SMs the Target received level desired at the AP.
- SMs calculate the path loss in the link and sets the TX power such that it arrives at the AP at target level.
- If AP notices higher or lower received power level from the SM, it notifies SM to adjust power in certain steps.
- SM gets continuous transmit power feedback from AP and adjusts TX power accordingly.



Automatic Repeat Request (ARQ)

- ARQ (Automatic Repeat Request):
  - **ACK**: Handshake between transmitter and receiver to acknowledge the reception of packets.
  - **Retry**: Mechanism to retry failed transmissions to prevent packet loss.
- Always ON
- Not used for Broadcast, multicast, or Voice Priority packets

Rate Adapt

- Adjust MCS (Modulation & Coding Scheme) to achieve **0.00%** packet loss based on:
  - Channel Quality: SNR/CINR
  - ARQ ACK Feedback
- The lower the MCS the lower the throughput.
- Control subframes are fixed to MCS1 (QPSK ½)
- Data subframes (A-MPDUs) MCS will vary based on SNR & ACK feedback.
  - The transmitter decides which MCS to use for data:
    - AP decides the DL MCS for each SM
    - SM decide the UL MCS

eFortify – Recognize and React

- You are not alone out there
- Spectrum is Congested
- GPS Sync: Provides a Solid Foundation on which to build a Network
- eFortify:
  - Builds on GPS Sync
  - By providing higher performance operation in the face of External Interference
  - Maintains Consistent Latency

eFortify – How does it Work?

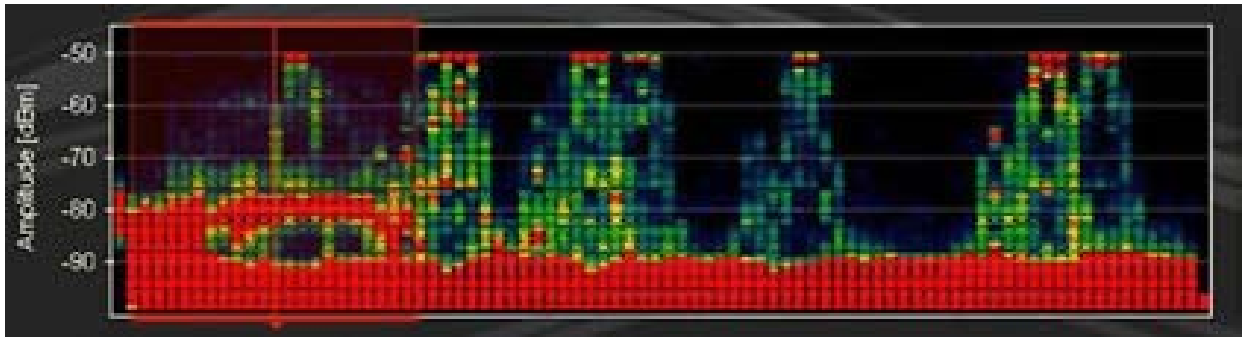
ePMP MAC Protocol Efficiency

“Air Fairness” Adaptive Scheduler

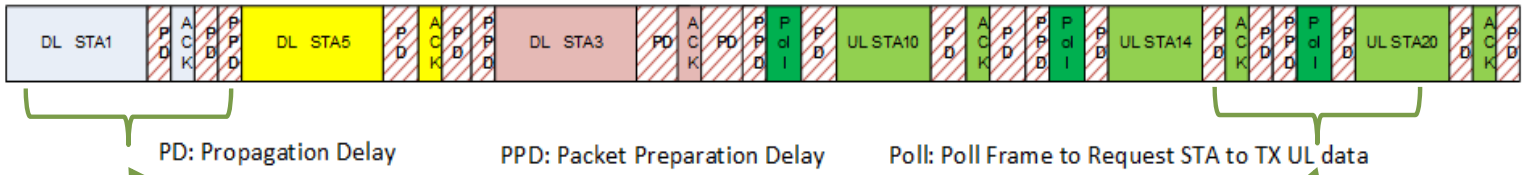
Interference Optimized Rate Adapt Algorithms

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



Competitor's Polling Protocols



Transmit and receive one SM at a time

Propagation delay is compensated for each transmission. ACK/NACKs and retries occurring per Tx & Rx

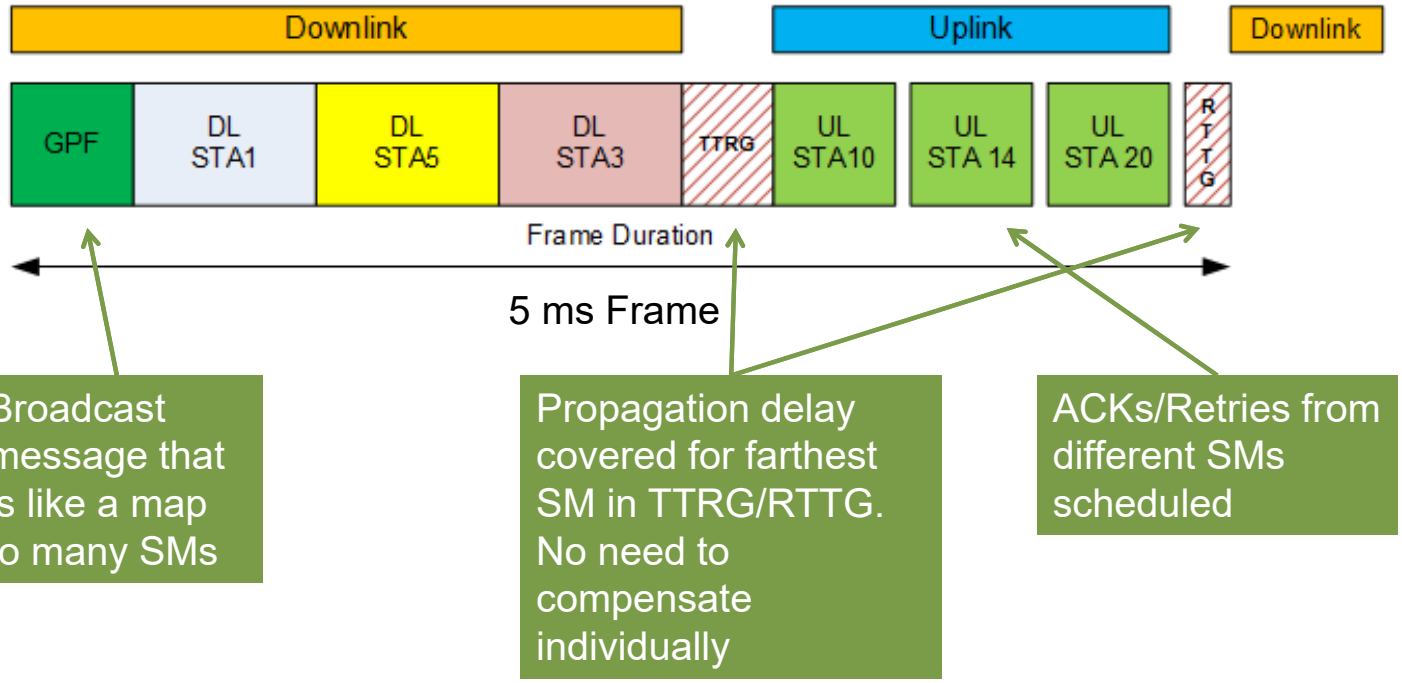
PD is incurred 3 times for each UL transmission (One for Poll and one for UL data and one for ACK)

What does this mean?

- Individual Tx/Rx, Propagation delay all adds up to less time for actual data transmission.
- With increased # of subscribers, latency starts going up drastically and significantly reducing TCP tput
- Interference in one SM could engage CCA, retries and increase latency for overall sector

ePMP MAC Protocol Efficiency

- ePMP has tight control over timing in UL & DL
- Propagation Delay to all SMs at different distances is accommodated for in the TTRG and through timing advance.



ePMP Provides Consistent Real-world Results

"My network struggles from large changes in latency due to standard wi-fi"

"As I add subscribers, the speed of our existing customers drops"

"My current solution does not offer enough modes of operation to handle our service offerings"

ePMP Provides Consistent Real-world Results

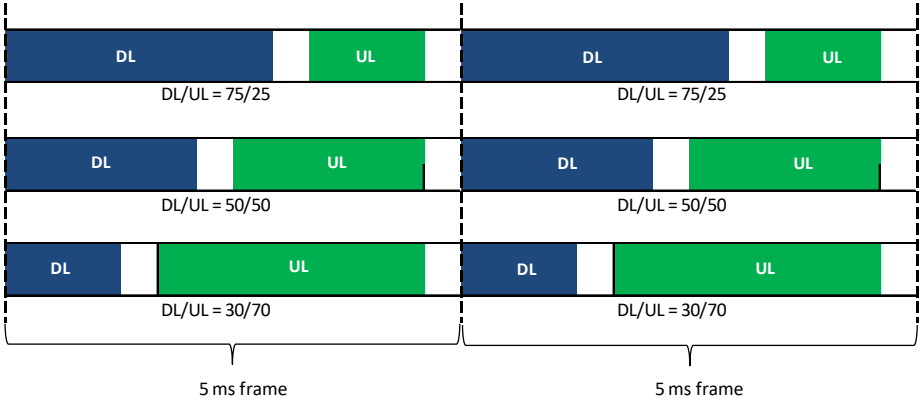
- Consistent latency
- High throughput in the presence of interference
- High real-world throughput as # of SMs are increased
- Numerous modes of operation
  - **ePTP** – For point to point where latency is key
  - **Flexible** – No Sync but 120 SMs and low latency
  - **TDD** – Scalable, Frequency Re-use

ePMP Latency vs. Other Systems

- ePMP in GPS mode will give you latency of 15~17ms in unloaded condition.
  - 5ms frame structure, deterministic Tx/Rx provides consistency in this latency across higher number of subscribers.
  - In WiFi based systems such as Airmax, the latency can dramatically increase as you increase the number of SMs in the network. Fixed allocation systems like Radwin may provide lower latency but cannot scale
- ePMP Flexible mode will give you latency of 5~7ms. System can scale up to 120 SMs with some increase in latency but no frequency re-use
- ePMP optimized PTP mode (only PTP) provides 2~3ms

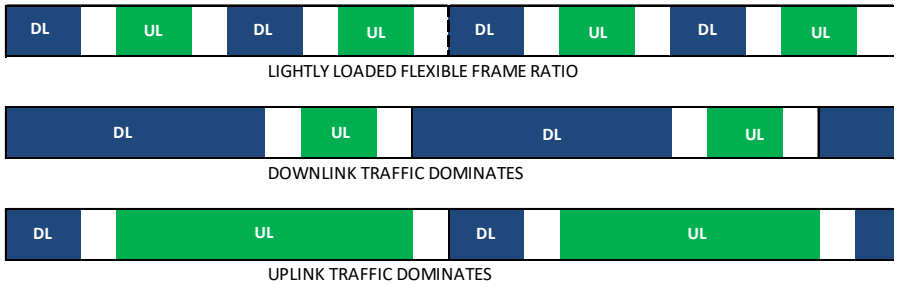
PMP Modes of Operation

GPS SYNC



- Three different DL / UL ratio settings
- Set the same across all Access Points requiring synchronization
- Best for multi-sector, multi-site PMP Networks

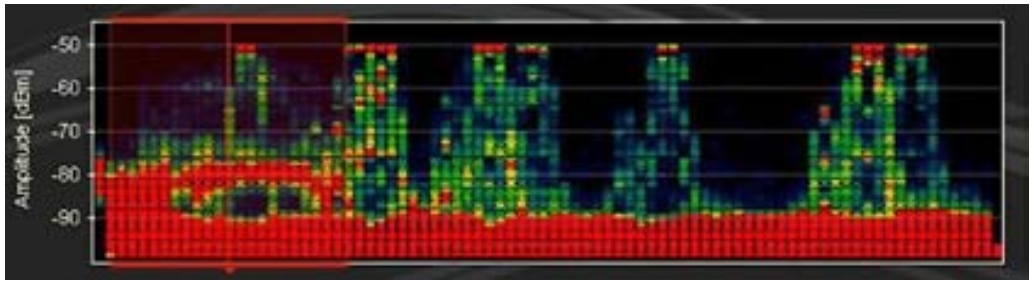
FLEXIBLE



- Dynamic, Adaptable
- Best for localized AP deployments and PTP Links not needing Synchronization

Interference-optimized Rate Adapt Algorithms

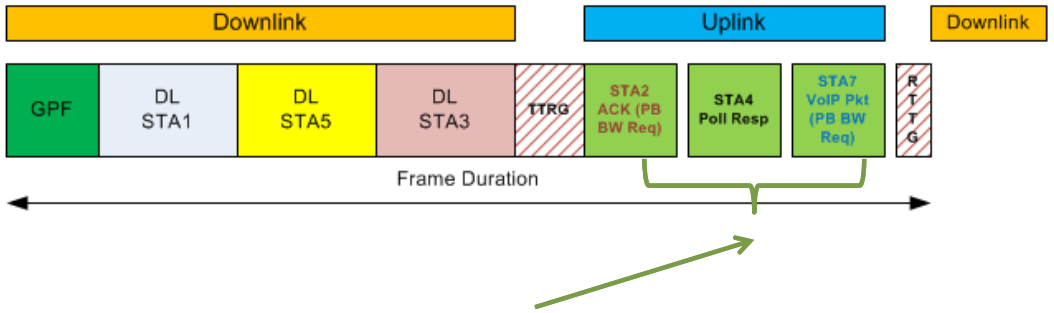
- Adaptive Modulation Algorithms optimized to address the bursty nature of Interference
- Making the right choice between error recovery by retransmissions or down-shifting modulations



VoIP over ePMP

ePMP utilizes the following mechanisms for VOIP delivery

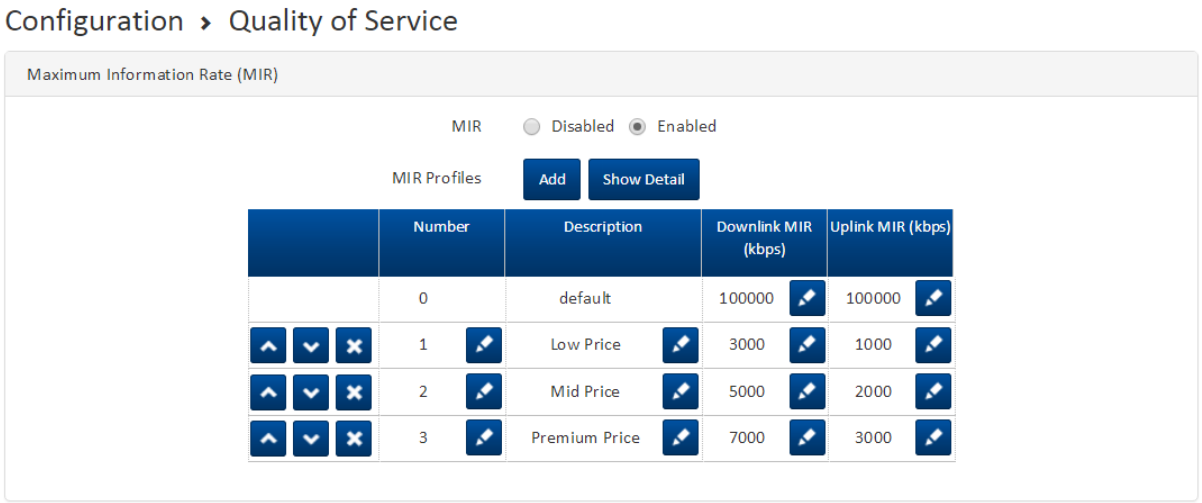
- DL/UL automatic prioritization of VOIP packets within the queues of the radio.
- High priority/ more frequent bandwidth allocation to SMs carrying VOIP traffic
- SMs with VoIP Packets to send will “piggyback” a bandwidth request onto uplink data transfer



SM can send VOIP packet but also request BW for the next voip packet by piggy backing. This allows AP to schedule the SM sooner

Rate Limiting with MIR

The ePMP platform also supports radio data rate limiting (Maximum Information Rate, or MIR) based on the configuration of the MIR table. Operators may add up to 16 MIR profiles on the AP, each with unique limits for uplink and downlink data rates. The SM field **MIR Profile Setting** is used to configure the appropriate MIR profile for limiting the SM's data rate.



Reliable Application Delivery

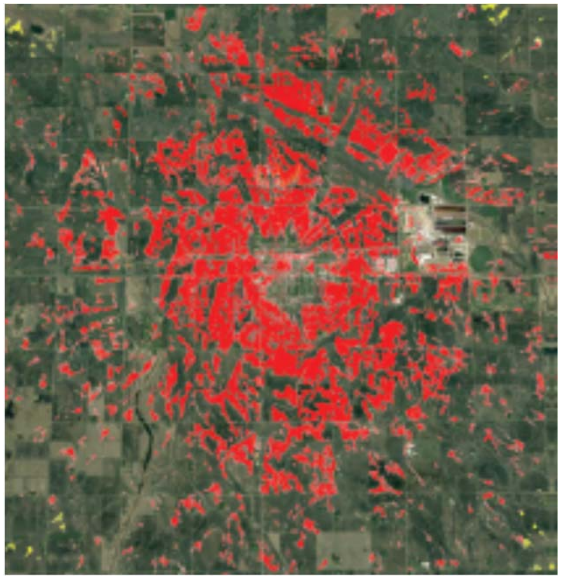
- Unicast Traffic assigned to a priority level by L2/L3 packet markings
- Broadcast/Multicast Traffic can be configured to be **High** or **Low** Priority
- Data is scheduled for OTA Transmission according to its priority
- L2 Markings: VLAN, CoS, EtherType, MAC L3 Markings: IP, DSCP

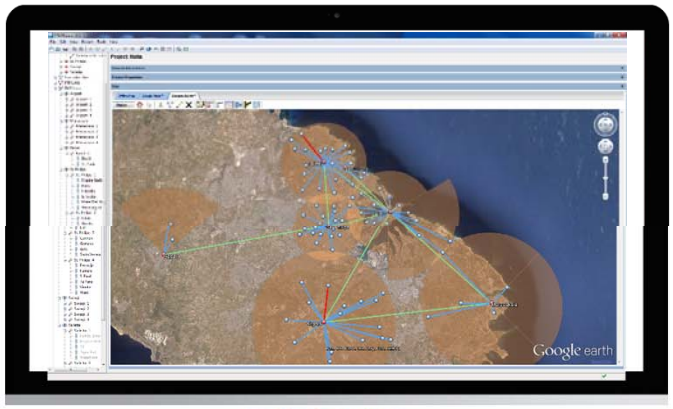
Prioritization can be altered by **SM Priority** parameter

SM Priority

- **Normal -** No Change to Data Priority
- **High -** All non-Voice Ingress (Uplink) Traffic Treated as High Priority
- **Low** - All non-Voice Ingress (Uplink) Traffic Treated as Low Priority

Planning an ePMP Link





ePMP CAPACITY PLANNER

Cambium Networks confidential, not commercially binding

SYSTEM CONFIGURATION

Region	Others
Frequency band	5.7/5.8 [GHz]
Fade Margin	0 [dB]
Channel Bandwidth	20 [MHz]
AP type	Connectorized
AP antenna system	Cambium 90° sector
3rd party connectorized SMs in sector?	Yes
3rd party conn. SM antenna gain	23 [dBi]
3rd party conn. SM antenna cable loss	1 [dB]
Environment	LOS
Range unit	miles
Max range	5 [mi]
Frame duration	5.0 [ms]
Number of SMs/sector	30
Duty cycle	75/25
Max Combined AP Tx power (min MCS)	30 [dBm]
Interference measured?	No
SM antenna for measuring interference	
Downlink interference level	
Uplink interference level	
% of SMs with uneven paths (single stream MCS)	10%

Lower frequency	5725 [MHz]
Upper frequency	5980 [MHz]
AP EIRP limit	- [dBm]
Max AP Tx Power (max MCS)	23 [dBm]
SM EIRP limit	- [dBm]
Max SM Tx Power (max MCS)	23 [dBm]
Max range limit	40.0 [mi]

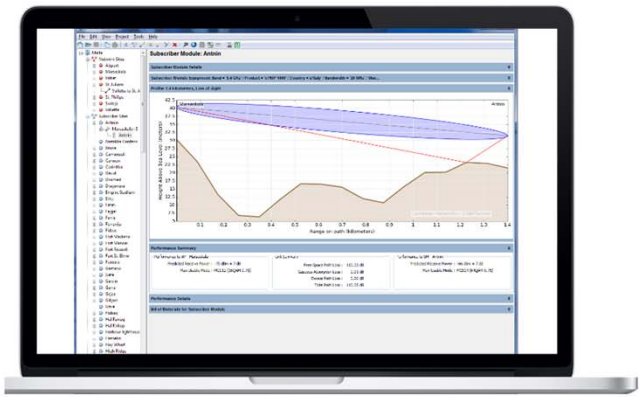
Cambium Networks

CapacityPlanner@cambiumnetworks.com

SM antenna for displaying data: INTEGRATED

LINK BUDGET FOR INTEGRATED ANTENNA

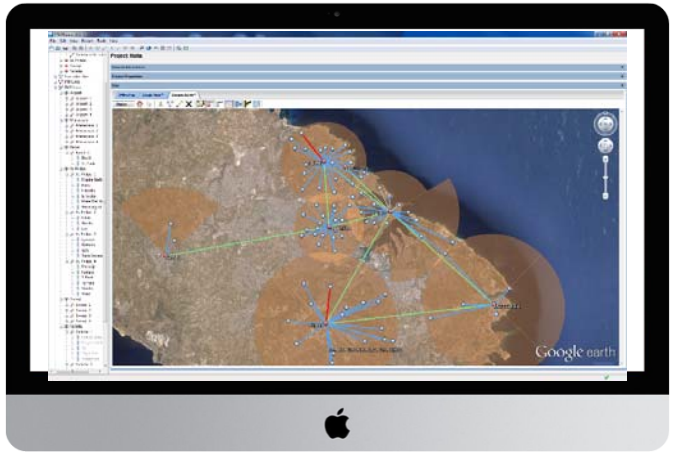
DOWNLINK BUDGET (AP to SM)			UPLINK BUDGET (SM to AP)		
AP Tx Power per chain (MCS15)	20 [dBm]	0.100 [Watts]	SM Tx Power per chain (MCS15)	20 [dBm]	0.100 [Watts]
AP Cable Loss	1 [dB]	0.001 [Watts]	SM Cable Loss	0 [dB]	0.001 [Watts]
AP Antenna Gain	15.0 [dBi]	Connectorized	SM Antenna Gain	13.0 [dBi]	Yes
Combined AP EIRP	37 [dBm]	5.012 [Watts]	Combined SM EIRP	36 [dBm]	4.0 [Watts]
SM Rx Sensitivity (Conservative assumption for single stream MCS; large difference between RSSI of two branches)	-69 [dBm]	64QAM 5/6 MCS15	AP Rx Sensitivity (Conservative assumption for single stream MCS; large difference between RSSI of two branches)	-69 [dBm]	64QAM 5/6 MCS15
	-70 [dBm]	64QAM 3/4 MCS14		-70 [dBm]	64QAM 3/4 MCS14
	-72 [dBm]	64QAM 2/3 MCS13		-72 [dBm]	64QAM 2/3 MCS13
	-77 [dBm]	16QAM 3/4 MCS12		-77 [dBm]	16QAM 3/4 MCS12
	-80 [dBm]	16QAM 1/2 MCS11		-80 [dBm]	16QAM 1/2 MCS11
	-84 [dBm]	QPSK 3/4 MCS10		-84 [dBm]	QPSK 3/4 MCS10
	-86 [dBm]	QPSK 1/2 MCS9		-86 [dBm]	QPSK 1/2 MCS9
	-69 [dBm]	64QAM 5/6 SS MCS7		-69 [dBm]	64QAM 5/6 SS MCS7
	-70 [dBm]	64QAM 3/4 SS MCS6		-70 [dBm]	64QAM 3/4 SS MCS6
	-72 [dBm]	64QAM 2/3 SS MCS5		-72 [dBm]	64QAM 2/3 SS MCS5
	-77 [dBm]	16QAM 3/4 SS MCS4		-77 [dBm]	16QAM 3/4 SS MCS4
	-80 [dBm]	16QAM 1/2 SS MCS3		-80 [dBm]	16QAM 1/2 SS MCS3
	-84 [dBm]	QPSK 3/4 SS MCS2		-84 [dBm]	QPSK 3/4 SS MCS2
	-86 [dBm]	QPSK 1/2 SS MCS1		-86 [dBm]	QPSK 1/2 SS MCS1
SM Cable Loss	0 [dB]	0.001 [Watts]	AP Cable Loss	1 [dB]	0.001 [Watts]
SM Antenna Gain	13.0 [dBi]	Yes	AP Antenna Gain	15.0 [dBi]	Connectorized

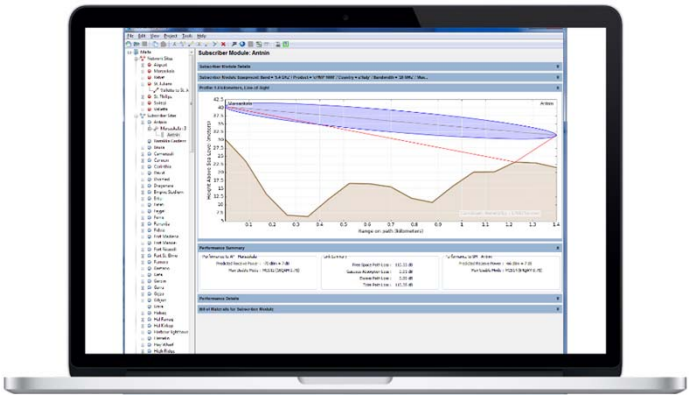


Smart Tools for Planning, Managing, and Troubleshooting

- Plan
  - Free LINKPlanner with Google Maps
  - Free Capacity Planner
- Manage
  - cnMaestro™
- Operation and Troubleshooting (Built-in)
  - eDetect
  - eAlign
  - ACS (Automatic Channel Selection)
  - Link Test, Ping Test, Spectrum Analyzer
  - Detailed Statistics
  - Full SNMP MIB support

Plan your Network with LINKPlanner





- Easily Import Location Information of AP and SM Modules
- View Path Profiles
- Adjust Configuration and Optimize

LINKPlanner Lab: Create Site and Hub

1. Create New Project 

2. Create New Site 
   - Site Name: Golf Club
   - Maximum Height: 20m
   - Latitude: 39.75093N
   - Longitude: 104.84035W
   - Description: Hub Site located at Golf Club

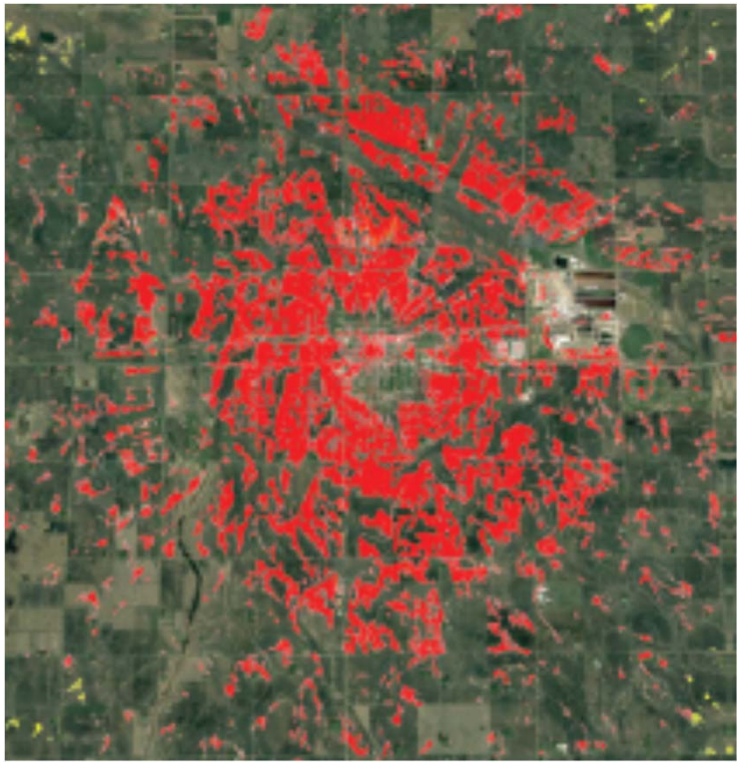
3. Create New Hub
   - Select Golf Club as the Network Site

4. Navigate to the Golf Club Hub Site
   - Modify the automatically created AP to the following
   - Band: 5.8GHz
   - Product: ePMP 1000
   - Country: United States
   - Bandwidth: 20MHz
   - Max Range: 2 miles
   - DL/UL Ratio 75 %
   - SM Registration Limit: 60
   - Sync Source: Internal
   - Antenna Selection: Cambium Networks 90 deg 5 GHz Sector Antenna (15.0 dBi)
   - Antenna Height: 20m
   - Antenna Azimuth: 90 degrees
   - Antenna Tilt: 0 degrees
   - EIRP: 36 dBm (read only)
   - Power: 21 dBm
   - SM Receive Target Level: -60 dBm
   - Interference?: -87.0 dBm

LINKPlanner Lab: Add Subscriber Modules

5. Add New Subscriber Site 
   - Name: Billings Street
   - Maximum Height: 10 meters
   - Latitude: 39.74739N
   - Longitude: 104.82459W
   - Description: Corner of Billings Street and E. Montview Blvd 
6. Add New Subscriber Site
   - Name: Xanadu Street
   - Maximum Height: 10 meters
   - Latitude: 39.75385N
   - Longitude: 104.82905W
   - Description: Customer on Xanadu Street
7. Select Access Point from Navigation Tree
8. Add Subscribers to AP
   Billings Street
   Xanadu Street
9. Navigate to each SM and modify settings as follows
   Antenna Selection: Cambium Networks 30 deg 5 GHz
   Integrated Ant (13.0 dBi)
   Antenna Height: 5m
   Interference: -87.0 dBm
10. Profiles Should have automatically been downloaded
11. Select Google Earth and view links
12. On Billings Street Link, add the following obstructions
    0.808km: 4m
    1.347km: 2.5m

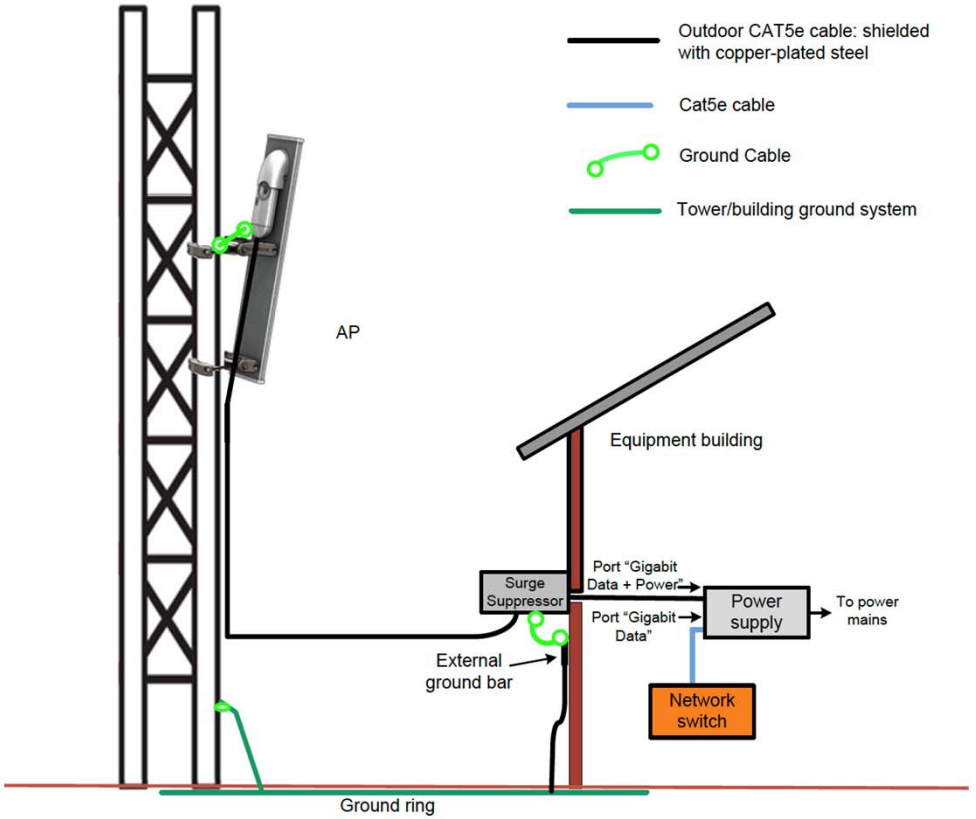
Plan your Network with cnHeat



Hardware Installation

Access Point Installation

- Two installation options:
  - Pole mount (kit supplied with Access Point)
  - Sector mount (shown in following slides)
- Ensure that the ePMP Access Point – Series 1000, 2000, or 3000 is compatible with the intended sector antenna both physically and electrically



Force 180 Installation

Verify included parts

Connect the metal strap and mounting bracket to the pole

Slide the radio assembly onto the mounting bracket (listen for “click”)

Adjust angle

Force 190 Installation

Force 200 Installation

Verify included parts

Insert the center feed tube

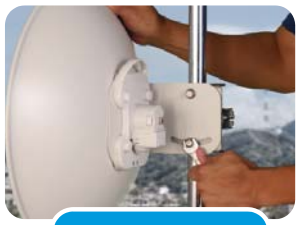
Attach the rear mounting bracket (listen for two “clicks”)

Install four M6 flange screws

Tighten the safety screw for the center feed tube

Attach the pole mount bracket using two M8 flange screws

Insert two M8 x 90 bolts through the pole mounting bracket, tighten evenly



Adjust angle

Sector Antenna Assembly

Quick Start Guide

Cambium Networks™

90/120° Sector Antenna
Model: C050900D021A

Introduction

This sheet details assembly of the 90/120° Sector Antenna.

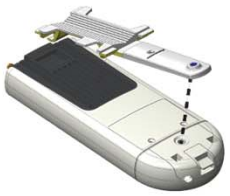
Package Contents

Pole brackets - x2
Front mast clamps - x2
Rear mast clamps - x2
M8x160 bolts - x4
M8x12 screws - x4
M8 nuts - x8
Antenna body - x1
ePMP 1000 holder - x1
ePMP 2000 sector mount - x1
Environmental cover - x1
RPSMA cables - x2

Tools Required

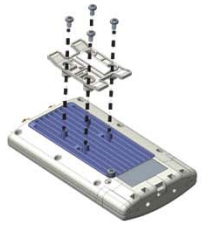
13mm (1/2") wrench
Phillips screwdriver
8mm (5/6") wrench with 5 PSI torque

Step 1 (ePMP 1000)



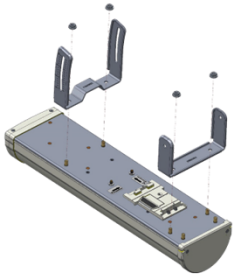
Assemble the ePMP holder to the rear of the ePMP 1000 unit using the M5 bolt included with the ePMP 1000 under the RJ45 cover.

Step 1 (ePMP 2000)



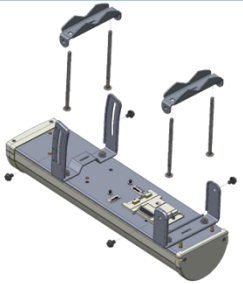
Assemble the ePMP 2000 sector mount to the rear of the ePMP 2000 unit as shown.

Step 2



Assemble the pole brackets to the rear of the sector antenna using the M8 nuts provided and a 13mm (1/2") wrench.

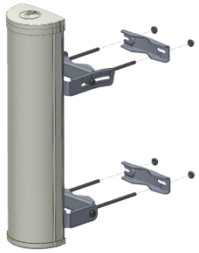
Step 3



Assemble the front mast clamps using the M8x12mm screws provided and a 13mm (1/2") wrench.

Insert the M8x160mm bolts.

Step 4



Assemble the rear mast clamps to the M8x160mm bolts using the M8 nuts provided.

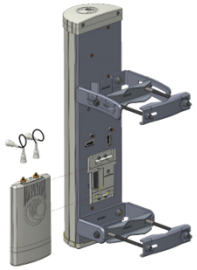
Step 5 (ePMP 1000)

Attach the ePMP 1000 unit to the rear of the sector antenna.

Attach SMA cables between the sector antenna and the ePMP 1000 unit by looping the cables as shown.

Sector Antenna Assembly

Step 5 (ePMP 2000)



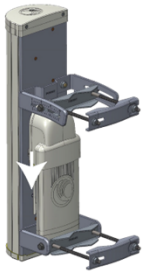
Attach the ePMP 2000 unit to the rear of the sector antenna.

Attach SMA cables between the sector antenna and the ePMP 2000 unit by looping the cables as shown.

Step 6 (ePMP 1000)

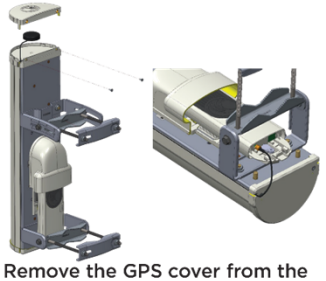
Slide the environmental cover down to lock it in position.

Step 6 (ePMP 2000)



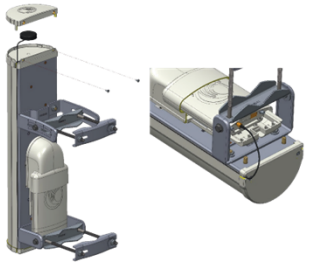
Slide the environmental cover down to lock it in position.

Step 7 (ePMP 1000)



Remove the GPS cover from the sector antenna using a Phillips screwdriver. Insert the GPS antenna and run the GPS cable along the side of the antenna to the SMA port on the ePMP 1000 unit.

Step 7 (ePMP 2000)



Remove the GPS cover from the sector antenna using a Phillips screwdriver. Insert the GPS antenna and run the GPS cable along the side of the antenna to the SMA port on the ePMP 2000 unit.

Step 8

Ensure the GPS cover and ePMP 1000 or ePMP 2000 RJ45 covers are reattached.

Attach the sector antenna to the pole using the rear mast clamps and M8 nuts.

Step 9

Adjust tilt as needed using the top clamp.

Assembly and installation is now complete.

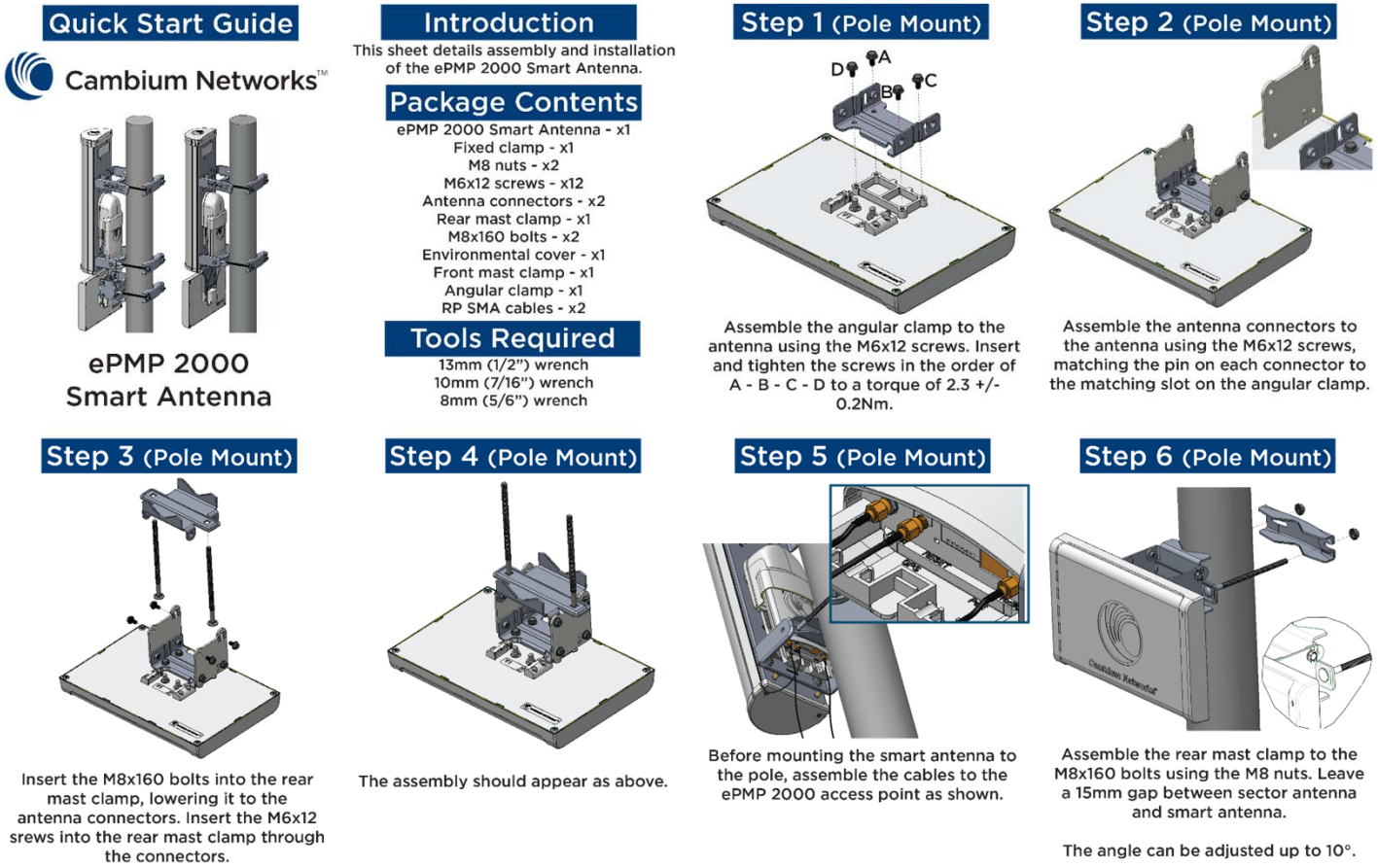
Cambium Networks™ Community Forum

Join the conversation

community.cambiumnetworks.com

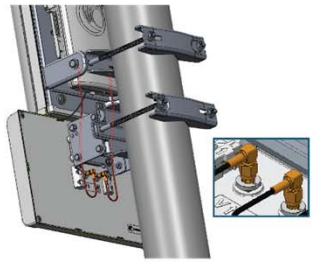
ePMP 2000 Smart Antenna Installation

- Two installation options:
  - Pole mount kit (supplied with ePMP 2000 Smart Antenna)
  - Sector mount (shown in following slides)
- The ePMP 2000 Smart Antenna is powered by the RPSMA connections to the ePMP 2000 Access Point.



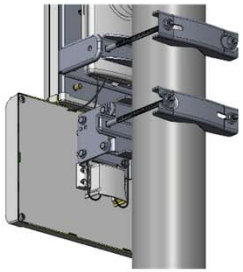
ePMP 2000 Smart Antenna Installation

Step 7 (Pole Mount)



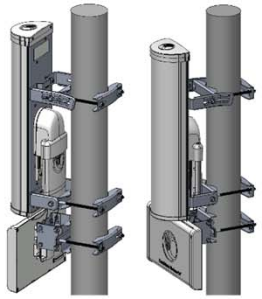
Connect the cables to the smart antenna as shown. Connect left to left and right to right; do not cross the cables.

Step 8 (Pole Mount)



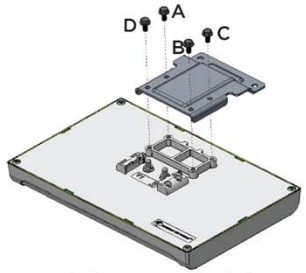
Slide the environmental cover down to lock it in position on the smart antenna.

Step 9 (Pole Mount)



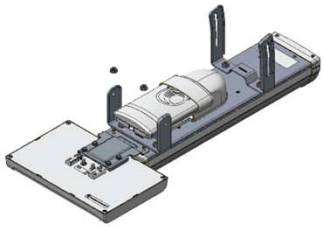
Assembly and installation is now complete.

Step 1 (Sector Mount)



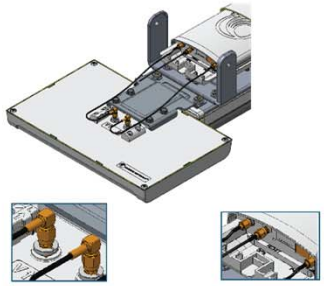
Assemble the antenna fixed clamp to the antenna using the M6x12 screws. Insert and tighten the screws in the order of A - B - C - D to a torque of 2.3 +/- 0.2Nm.

Step 2 (Sector Mount)



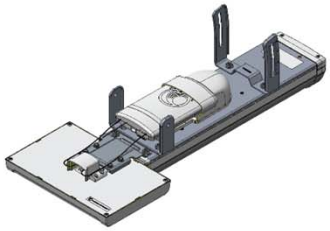
Assemble the fixed clamp to the ePMP 2000 sector antenna using the M8 nuts.

Step 3 (Sector Mount)



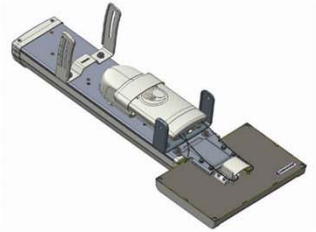
Connect the cables between the smart antenna and ePMP 2000 access point as shown. Connect left to left and right to right; do not cross.

Step 4 (Sector Mount)



Slide the environmental cover down to lock it in position on the smart antenna.

Step 5 (Sector Mount)



Assembly of the ePMP 2000 smart antenna to the ePMP 2000 sector antenna is now complete.

Refer to the ePMP 2000 sector antenna quick start guide for further assembly instructions.

Cabling

- To minimize the possibility of performance problems that may be caused by external sources of interference, it is strongly recommended that shielded CAT5 cable be used in all Cambium ePMP installations.
- Poor quality, poorly constructed and chafed or nicked cables can create intermittent module performance and/or network problems.
- A large majority of technical support calls (35% or more) can be attributed to improper cabling or the use of inferior quality cables.
- Ethernet cables cannot exceed 100 meters (328 feet) in length.
- Use a drip loop to reduce the risk of water following a cable into a module.

Cambium Industrial Cable

Cambium Industrial Cable uses 24 gauge solid bare copper conductors, covered by bonded-pair polymer insulation. The conductors are protected by double layer shielding consisting of a solid foil layer under braded tinned copper mesh, providing excellent shielding while maximizing flexibility. And, the cable is jacketed by industrial grade UV-resistant, abrasion-resistant, and oil-resistant PVC.

Cambium's Industrial RJ45 connectors are specifically designed to work optimally with Cambium Industrial Cable.

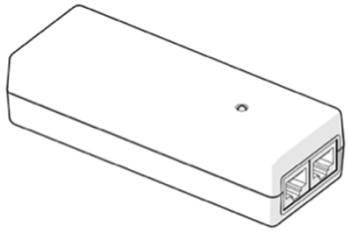
The connectors are fully shielded with integrated strain relief for greater pull strength, utilize a staggered contact design that minimizes crosstalk and maximizes electrical performance, and the contacts are plated with 50 mico-inch thick 24 carat gold, exceeding TIA-1096 specifications and ensuring the best possible connection and oxidation resistance.

Cambium Networks' industrial grade cable is well suited for high-quality durable installations of subscriber modules, access points and enterprise point-to-point links as well as in tactical non-permanent deployments of infrastructure.

Powering

The ePMP power supply is an indoor unit that is connected to the ePMP module and network terminating equipment using Cat5e cable with RJ45 connectors. It is also plugged into an AC or DC power supply so that it can inject Power over Ethernet (PoE) into the module.

For powering ePMP modules, Cambium Networks has tested and recommends using the following 30 V PoE injectors:



In addition to 120 VDC sources, ePMP may also be powered via 48 VDC (third-party PoE adapter) and 220 VDC sources including battery and solar-based installations!

Cambium description	Cambium part number	Pinout
ePMP Power Supply for GPS Radio - no cord	N000900L001A	Pins 7,8: +30 V Pins 4,5: RETURN (Cambium PoE)
ePMP Power Supply for non-GPS Radio - no cord	N000900L002A	

Software Upgrade Lab

Lab

Software Upgrade Lab

Objectives:

1. Configure the management PC
2. Login into the default management tool on all devices
3. Check current software version and update to the latest software version.

Situation: You've gotten an email from Cambium announcing the release of a software update.

Task:

1. Check the version of your current software.
2. Download and install latest software version.

Software Upgrade Lab

1. Divide into groups.
2. Each team will have a work station with 1 AP and 2 SMs already assembled.
3. Each team member should connect their personal PC to one of the 3 devices via the Ethernet plug on the device's power adapter labeled "10/100bit Data" or "Gigabit Data". Assign devices (using paper etc) as AP, SM-1, SM-2).

4. Enter an IP address

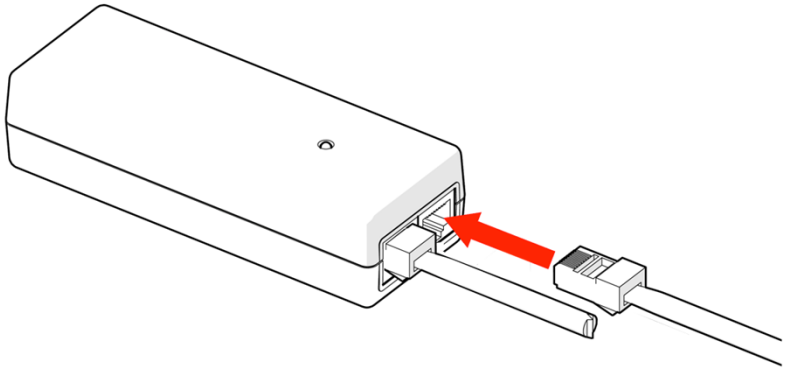
   For AP: **192.168.0.101**

   For SM-1: **192.168.0.102**

   For SM-2: **192.168.0.103**

5. Enter a subnet mask of 255.255.255.0

6. Click OK, then click Close

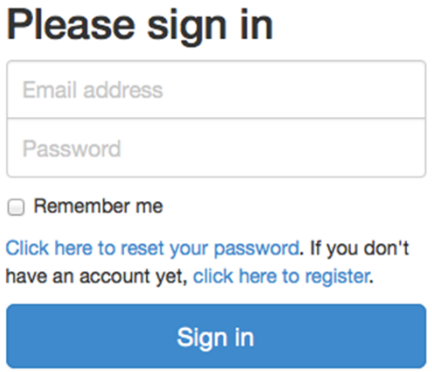


Software Upgrade Lab

1. Open a web browser (Chrome v29, Firefox v24, Internet Explorer 10, Safari v5).
2. Go to the following IP address:
   - For AP: **192.168.0.1**
   - For SM-1: **192.168.0.2**
   - For SM-2: **192.168.0.2**
3. The user interface will appear in 2 styles, depending on software version. Tabs and Content however remain similar.
4. Enter User Name (admin) & Password (admin) for both AP and SMs
   a) Main Menu: Jot down your LAN Mac Address
   b) Select Tools Menu : Software Upgrade
   c) Note existing Software Version

Software Upgrade Lab

5. Using a different web browser, go to: https://support.cambiumnetworks.com/files/epmp
    a. Register for an account.
    b. From your email, follow the link to activate your account.
6. Go to: https://support.cambiumnetworks.com/files/epmp
    a. Download the software version for your device:
    b. ePMP GPS Synched Radio Software
    c. ePMP Non-GPS Synched Radio Software



ePMP Basic Configuration Lab

ePMP

Configuring the Management PC

Use this procedure to configure the local management PC to communicate with the ePMP module.

Procedure:

1. Select **Properties** for the Ethernet port.
2. Select the Internet Protocol (TCP/IP) item:
3. Click **Properties**.
4. Enter an IP address that is valid for the 192.168.0.X network, avoiding:

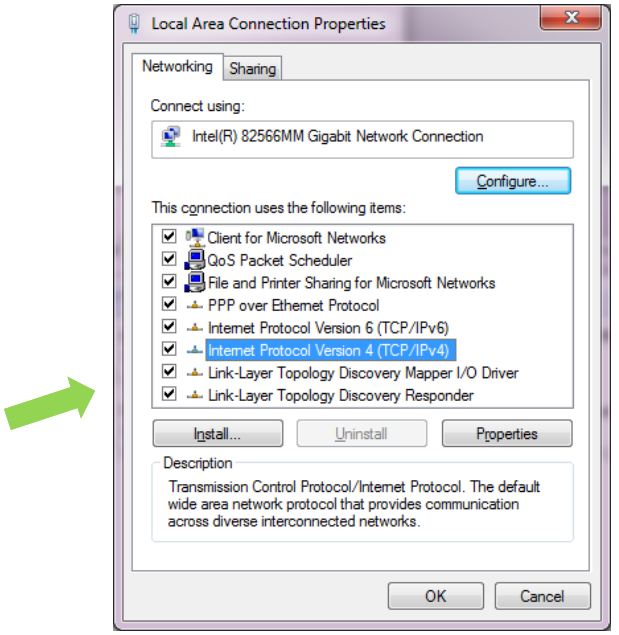
    192.168.0.1, 192.168.0.2, and 192.168.0.3

A good example is 192.168.0.100:

5. Enter a subnet mask of 255.255.255.0.

Leave the default gateway blank.

6. Click **OK**, then click Close



ePMP Default Configuration

IP Address – set to DHCP. If no DHCP server is found, unit drops back to the following IP address based on mode of operation

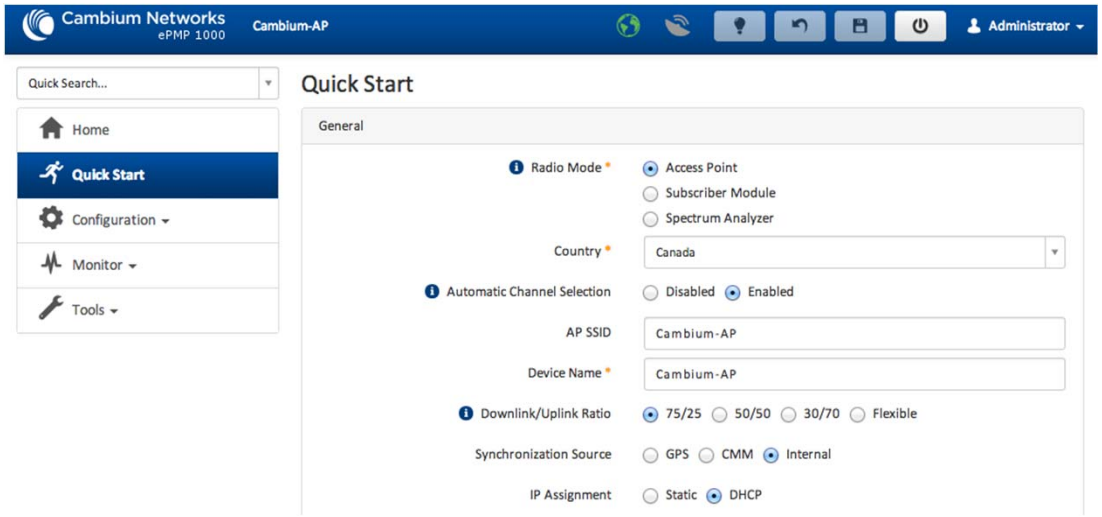
- **AP**: 192.168.0.1
- **SM**: 192.168.0.2
- **Spectrum Analyzer**: 192.168.0.3

User Names and Passwords

- **Administrator (Full Access):** admin / admin
- **Installer (Full but can not add users):** installer / installer
- **Home (Limited Support Access):** home / home
- **Read Only (Monitor Page only):** readonly / readonly

ePMP Access Point Configuration

1. Start the web browser from the management PC.
2. Navigate to menu **Quick Start** or **Installation**



ePMP Access Point Configuration

- Radio Mode
- Driver Mode
- Country
- Max Range
- Automatic Channel Selection
- Frequency Carrier and SSID
- Device Name
- Downlink/Uplink Ratio
- Synchronization Source
- IP Networking, Security

SM Quick Start / Installation

Radio Mode

Network Mode

Driver Mode

IP Address

Country

Security

ePMP Management

cnMaestro

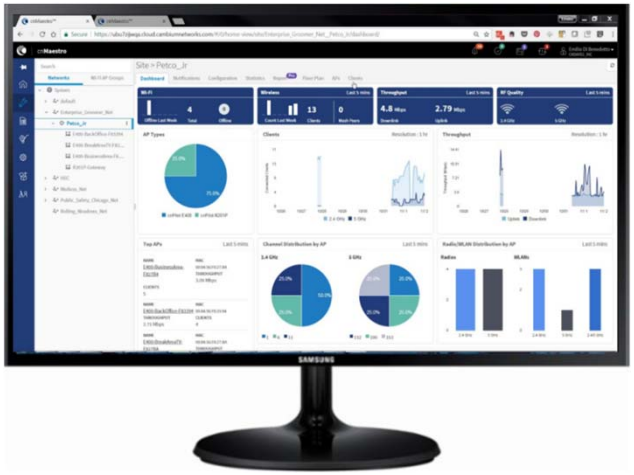
Cambium Networks' **cnMaestro** provides an **integrated, intelligent, easy** way to manage your network in the **cloud**.

Easy onboarding - *Claim your ePMP or Wi-Fi devices in the cloud or on-site*

Monitor your entire network - *Leverage hierarchical dashboards, statistics, and maps to view status and drill into problem areas.*

Configure devices on the cloud – *Automatically provision devices upon registration, or group devices and apply configuration parameters across your network*

Troubleshooting was never so intuitive- *Visualize tower-to-edge device health and evaluate real-time client network connectivity*



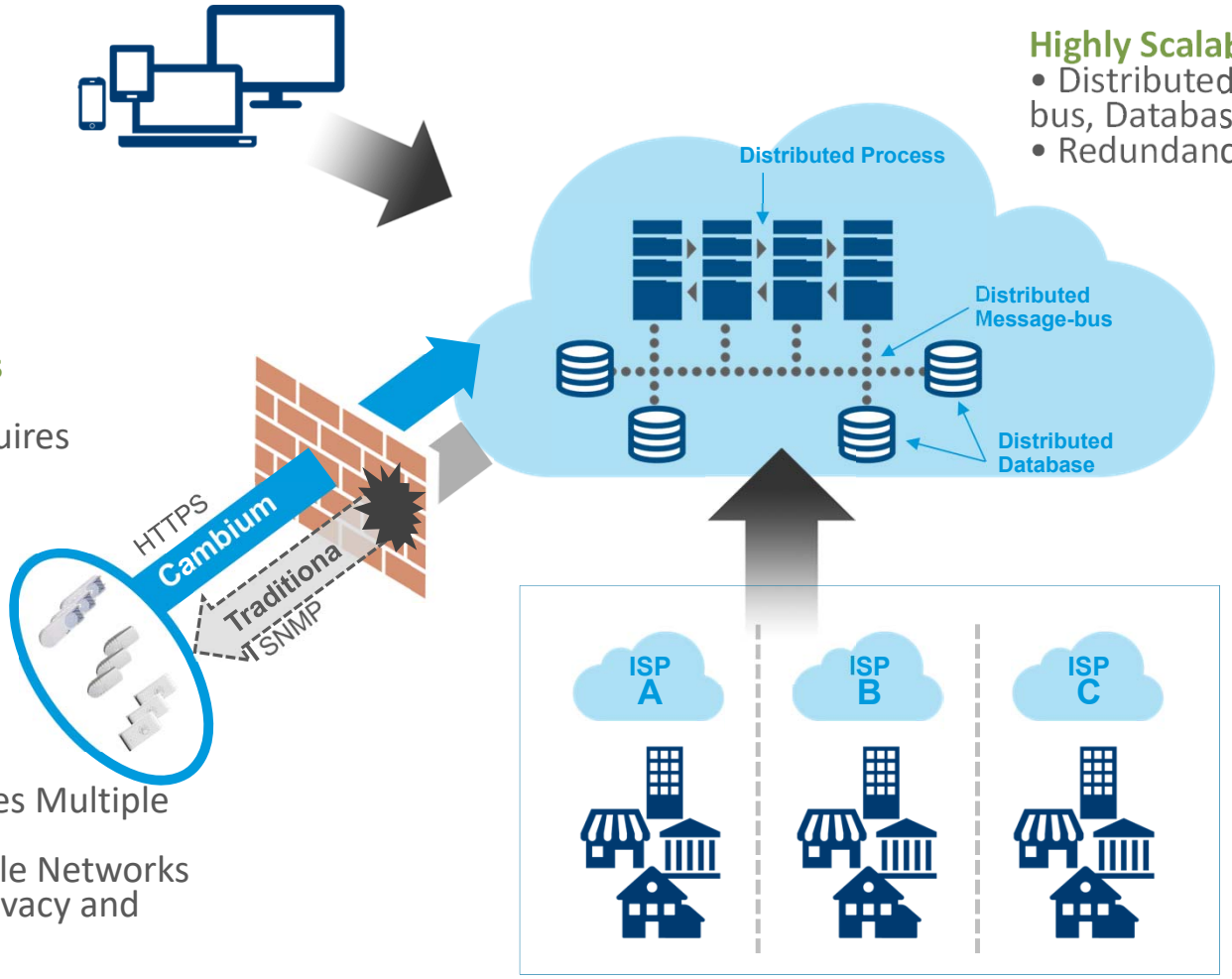
Managing your Network with cnMaestro

New UI Architecture
• Support of Various Devices

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

Instant Discovery of APs
• Traditional SNMP
Slow Discovery Requires Firewall Configuration
• Cambium: Instantly Discovered
• Secure HTTPS

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




ePMP In-Depth
Configuration
Cambium Networks™

ePMP 3000 Access Point MU-MIMO Parameters

MIMO Mode	OFF: Sounding and beamforming are disabled 4x2 Single-User: Enables Single User beamforming mode based on periodic sounding 4x4 Multi-User: Extends SU mode with MU-MIMO to transmit data frames to 2 subscribers simultaneously
Sounding Interval	Sounding period in seconds for active subscribers. Lower value is preferable for frequent channel measurements in noisy environment. Higher value is beneficial to decrease sounding overhead in stationary channel conditions.
Azimuth Sounding cycle	Azimuth sounding provides metrics to the MU-MIMO grouping algorithm based on azimuth diversity. Cycle is configured in Sounding Intervals. Lower cycle value is preferable for nomadic subscribers and for noisy environment. Higher cycle value is beneficial for static subscriber locations in stationary channel conditions.

AP Radio Parameters

DFS Alternate Frequencies and Channel Bandwidth:

Only used in the configured **Country Code** and **Frequency Carrier** requires DFS. DFS event triggers will attempt Alternate 1, Alternate 2, and then back to the primary settings.

- **Alternate Channel Bandwidth**

  Channel bandwidth used for RF transmission if a DFS detection causes the radio to switch to an alternative

- **Alternate Frequency**

  Frequency carrier used for RF transmission if a DFS detection causes the radio to switch to an alternative*

*Caution – Ensure frequency is also available in the **SM Scan List**.

PTP Access:

Off: The system is configured to operate in PMP mode (i.e. more than one SM may connect to the AP)

Connect 1st SM: The system is configured to accept only the 1st registered SM. Network entry will be denied for all subsequent SM network entry requests.

MAC Filtered: The system is configured to accept only one SM registration, and this registration is limited by SM MAC Address (the SM Wireless MAC Address).

AP Radio Parameters

Transmitter Output Power

Combined power of the AP's two transmitters.

Antenna Gain

- Amount of gain introduced by an external antenna (minus cable loss). Used to Equivalent Isotropic Radiated Power (EIRP) level.
- Depending on Country Code, warning messages will be displayed if the unit's TX power or EIRP exceed regional regulations. The save button will be disabled until corrected.

SM Target Received Power Level

- AP monitors each SM's received power and automatically adjusts SM's transmitter output power (ATPC) so that received power is not greater than Target Level.
- Ensure SM is not transmitting excessive energy (raising system noise level) and that the SM is able to achieve an optimal modulation state (and maximum achievable throughput).
- Should be set no higher than -60 dBm in order to prevent interference from co-located co-channel sectors.

DL/UL Ratio

Configure the schedule of downlink traffic in relation to the uplink traffic on the radio link.

- 75/25, 50/50, 30/70 are fixed DL/UL ratios for all radio traffic
- Flexible mode allows the radio to dynamically choose the amount of the total radio's aggregate throughput that is used for downlink and uplink resources, every frame.
- Flexible mode is only available when synchronization is set to Internal
- CAUTION - if the AP is in cluster or is in range of another AP, then you must set this parameter on all other APs in the cluster and in range exactly the same. (excluding flexible) Otherwise, overlapping RF transmissions will introduce system interference.

AP Radio Parameters

Synchronization Source

GPS: Synchronization timing is received via the AP's connected GPS antenna. Co-located or in-range APs receiving synchronization via GPS or CMM will transmit and receive at the same time, thereby reducing self-interference.

CMM: Synchronization timing is received via the AP's Ethernet port via a connected Cambium Cluster Management Module (CMM). Co-located or in-range APs receiving synchronization via GPS or CMM will transmit and receive at the same time, thereby reducing self-interference. For more information on CMM configuration, see the *PMP Synchronization Solutions User Guide*.

SM Radio Parameters

Review these parameters:

- Scan Channel Bandwidth
- Max Tx Power
- Antenna Gain
- Network Entry RSSI Threshold
- Uplink Max Rate

Quality of Service (QoS)

Priority Queues

1. Voice Priority (Always Highest when Enabled)
2. High Priority
3. Low Priority

The QoS Scheduling Algorithm employs attributes of :

- Air fairness
- Priority based
- Starvation avoidance
- Voice Priority is sent w/o ACK to minimize latency

Quality of Service (QoS)

ePMP offers a Flexible 2-Level Prioritization Scheme

Prioritization based on Traffic Markings

Layer 2 Markings

- **VLAN** - VLAN Address 802.1q
- **CoS** - VLAN Priority Bits 802.1p
- **EtherType** - Ethernet Frame Type
- **MAC** - Source/Dest/Both MAC Addr.

Layer 3 Markings

- **IP -** Source/Dest IP Addr.
- **DSCP** - Priority Bits - (CoS)

Prioritization based on SM Priority

SM Priority

- **Normal -** No SM Priority
- **High -** All Ingress Traffic Treated as High
- **Low** - All Ingress Traffic Treated as Low

* All **Broadcast** traffic has a dedicated Priority configuration setting (High or Low)

* All **Multicast** traffic has a dedicated Priority configuration setting (High or Low)

AP Quality of Service and Systems Page

Maximum Information Rate (MIR) Limiting

- Up to 16 MIR profiles can be added to the MIR table on the AP
- Each profile (1-16) can have unique limits for uplink and downlink data rates.
- The SMs **MIR Profile Setting** is used to assign the appropriate MIR profile number from the AP, for limiting the SM's data rate.
- The default profile (0) cannot deleted or changed and is assigned to any SM without a profile setting

Traffic Priority

- Enabled: The QoS Classification Rules table is editable and is utilized by the device to classify traffic
- Disabled: The QoS Classification Rules table is greyed-out and all traffic is sent at the same priority level

VoIP Priority

- Enabled: When enabled, two entries are added to the QoS Classification Rules The addition of these rules ensures that VoIP traffic passed over the radio downlink is given highest priority.
- The CoS and DSCP values may be modified to accommodate non-standard VoIP equipment.
- Disabled: When disabled, VoIP traffic is scheduled normally along with all other user data.

Monitor Menu

Use the Monitor menu to access device and network statistics and status information. This section may be used to analyze and troubleshoot network performance and operation.

- Performance
- System Status
- Wireless Status
- Network Status
- System Log page

AP Wireless Status Page

General Stats

Shows current

- Frequency
- Channel Bandwidth
- TX Power
- Number of connected SM's
- *Status of LAN & WAN ports
- Regulatory Country Code

* Shows hardware port status, not connection status

PTP / PMP - Lab

QoS Lab

ePMP

Security Lab

ePMP

Cambium Networks

ePMP Tools

Tools Menu

The Tools menu provides several options for upgrading device software, configuration backup/restore, analyzing RF spectrum, testing device throughput, and running ping and traceroute tests.

- Software Upgrade
- Backup / Restore
- eDetect
- Spectrum Analyzer
- eAlign
- Automatic Channel Selection
- Wireless Link Test
- Ping Utility
- Traceroute Utility

ePMP Troubleshooting

General Planning for Troubleshooting

Effective troubleshooting depends on measures that you take before you experience trouble in your network. Cambium recommends for each site:

- Identify troubleshooting tools that are available at your site (such as a protocol analyzer).
- Identify commands and other sources that can capture baseline data for the site. These may include:
  - -Ping
  - -tracert or traceroute
  - -Throughput Test results
  - -Throughput data
  - -Configure GUI page captures
  - -Monitor GUI page captures
  - -Session logs
- Start a log for the site, including:
  - -Operating procedures
  - -Site-specific configuration records
  - -Network topology
  - -Software releases
  - -Types of hardware deployed
  - -Site-specific troubleshooting process
  - -Escalation procedures
  - -GPS latitude/longitude of each network element

Fault Isolation Process

- Attempting to isolate the problem to the level of a system, subsystem, or link, such as:
  - AP to SM
  - AP to CMM
  - AP to GPS
  - CMM to GPS
  - Power
- Researching system logs of the involved equipment.
- Answering the questions listed in the following section.
- Reversing the last previous corrective attempt before proceeding to the next.
- Performing only one corrective attempt at a time.

Questions to Help Isolate the Problem

When a problem occurs, attempt to answer the following questions:

What is the history of the problem?

- Have we changed something recently?
- Have we seen other symptoms before this?

How wide-spread is the symptom?

- Is the problem on only a single SM? (If so, focus on that SM.)
- Is the problem on multiple SM's? If so,
  - Is the problem on one AP in the cluster? (If so, focus on that AP)
  - Is the problem on multiple, but not all, aps in the cluster? (If so, focus on those aps)
- Is the problem on all aps in the cluster? (If so, focus on the CMM and the GPS signal.)

Questions to Help Isolate the Problem

Based on data in the System Log:

- Is intermittent connectivity indicated? (If so, verify your configuration, power level, SNR, cables and connections, and the speed duplex of both ends of the link).
- Does the problem correlate to loss-of-sync events?

Are connections made via *shielded* cables?

Does the GPS antenna have an *unobstructed* view of the entire horizon?

Troubleshooting Ethernet Connectivity

If the device has lost or does not establish Ethernet connectivity:

- Check that the AP and SM's devices are connected using the recommended (straight or cross connected) Ethernet cable between PoE (Data) and Laptop.
- Check the Ethernet interface status. The status should be up and establish the speed to 1Gpbs/100Mbps.
- If the devices are not reachable with the operator assigned IP address then reset the device using the recommended factory default settings.
- Now try reaching out with default IP address of device. For AP 192.168.0.1 and SM with 192.168.0.2.
- If these IP addresses are not reachable the other option to reach to the devices are using its fallback IP address 169.254.1.1. This IP is available on both AP and SM.

Troubleshooting the Radio Link

If the module has lost or does not establish radio connectivity:

- Check that the AP and SM's are configured with the same **Frequency Carrier**.
- If operating in a region where DFS is required, ensure that the SM's **Frequency Carrier List** contains the frequencies configured in the AP's **DFS Alternate Frequency Carrier 1** and **DFS Alternate Frequency Carrier 2** fields.
- Check that the **Channel Bandwidth** is configured the same at the AP and at the SM.
- On the AP, verify that the **Max Range** setting is configured to a distance slightly greater than the distance between the AP and the furthest SM that must register to the AP.

Troubleshooting the Radio Link

- Check that the AP's **Synchronization Source** is configured properly based on the network configuration.
- Verify the authentication settings on the AP and SM. if **Authentication Type** is set to **WPA2**, verify that the **Pre-shared Key** matches between the AP and the SM **Preferred AP List**
- Check that the software at each end of the link is the same version.
- Check that the desired AP's SSID is configured in the SM **Preferred AP List**.
- On the SM, check the **DL RSSI** and **DL SNR** values. Verify that for the SM installed distance, that the values are consistent with the **threshold, power and link loss** in the user manual or Link Capacity Planner.

Troubleshooting Unreliable or Slow Links

If there is some activity but the link is unreliable or does not achieve the data rates required:

- Check that the interference has not increased by monitoring the uplink and downlink SNR values reported in the AP page **Monitor**, **Wireless Status**
- Check that the RSSI values reported at the AP and SM are proper based on the distance of the link – see **threshold, power and link loss** tables in the User Manual**.**
- Check that the path loss is low enough for the communication rates required.
- Check that the AP or SM has not become misaligned.
- Review your Quality of Service configuration and ensure that traffic is properly classified and prioritized.

GPS Firmware

- Via the AP web management interface, navigate to Monitor > GPS and verify that GPS Firmware version is equal:
  -(1st Generation ePMP 1000 - Units purchased 2015 and prior) After upgrading, this version should show as AXN_1.51_2838.
  -(2nd Generation ePMP 1000 and ePMP 2000 - Units purchased 2016 and after) After upgrading, this version should show as AXN_5.1_8174.
- If the AP is configured with a different version follow the steps below

1. When upgrading multiple v1.0.3 (or later) integrated devices, ensure that the browser cache is cleared at the beginning of the upgrade process.
2. Log in to the device GUI via the management IP
3. Navigate to page Tools, Software Upgrade
4. Under the Main Software section, set the Upgrade Option to URL to pull the software file from a network software server or select Local File to upload a file from the accessing device. If URL is selected, enter the server IP address, Server Port, and File path.
5. If Local File is selected, click Browse to launch the file selection dialogue. Select the same package that is used to upgrade the device software. The new GPS firmware is a part of the software upgrade packages.
6. Click Upgrade
7. Once the software upgrade is complete, click the Reset icon.

Module Has Lost or Does Not Gain GPS Synchronization

To troubleshoot a loss of sync, perform the following steps:

1. If the AP is receiving synchronization via CMM, verify that the CMM is properly receiving sync via its attached GPS antenna (see *PMP Synchronization Solutions User Guide*). Verify that the cables from the CMM to the network switch are at most 30 ft (shielded) or 10 ft (unshielded) and that the network switch is not PoE (802.3af) capable. Double-check cable condition and quality of terminal connections. The GPS antenna requires a good view of the sky, and should not be mounted at the highest point of the tower. For best satellite tracking results a clear view of the southern horizon is required.
2. If the CMM is receiving GPS synchronization pulses, verify that the AP's **Synchronization Source** is set to **CMM** and that the AP's GPS status bar icon is lit green.
3. If the AP is receiving synchronization via its internal GPS module and an external GPS antenna, verify the cabling from the AP to the GPS antenna, and verify that the AP's **Synchronization Source** is set to **GPS**.

Antenna Troubleshooting

Troubleshoot an issue with the ePMP 2000 Smart Antenna:

- Ensure the cables are connected correctly between the ePMP 2000 Smart Antenna and ePMP 2000 Access Point. They must not be crossed.
- Ensure the ePMP 2000 Access Point is using the 56V power supply provided or an 802.3at power supply that is providing adequate power. This can be verified by checking the System Summary page on the ePMP 2000 Access Point GUI.

  -If not enough power is being supplied, replace the power supply.

Trouble shoot an ePMP 5 GHz 90/120 Sector Antenna:

- Check the mechanical down-tilt in use. The ePMP 5 GHz 90/120 Sector Antenna has -2 degrees of vertical electrical tilt. If it is installed using the same mechanical down-tilt as other sector antennas, the coverage may not match what is expected.
  - This can be addressed by adding mechanical up-tilt of 2 degrees if needed.

ePMP Troubleshooting - Lab

ePMP Troubleshooting

Checking the Power Supply LED

Ethernet LED is off

Meaning: There is no Ethernet traffic between the AP/SM and power supply.

Action: The fault may be in the LAN or AP/SM cable:

- Remove the LAN cable from the power supply, examine it and confirm it is not faulty.
- If the PC connection is working, remove the AP/SM cable from the power supply, examine it, and check that the wiring to pins 1&2 and 3&6 is correct and not crossed.

Testing Hardware and Ethernet Packet Errors

- Before testing hardware, confirm that all outdoor cables, that is those that connect the AP or SM to equipment inside the building, are of the supported type, as defined in the user manual.

- How to test the hardware when it fails on startup or during operation:
  - Log into the AP or SM and click **Monitor**, **Performance**.
  - Click **Reset System Counters** at the bottom of the page and wait until **LAN RX – Total Packet Counter** has reached 1 million.
  - If the counter does not increment or increments too slowly, because for example the ePMP system is newly installed and there is no offered Ethernet traffic, then abandon this procedure and consider using the procedure **Test ping packet loss**.

- Check the **LAN RX – Error Packet Counter** statistic. The test has passed if this is less than 10.

Testing Ethernet Packet Errors

- Test ping packet loss - using a computer, it is possible to generate and monitor packets lost between the power supply and the AP/SM. This can be achieved by executing the Command Prompt application which is supplied as standard with Windows and Mac operating systems.
- Ensure that the IP address of the computer is configured appropriately for connection to the AP or SM under test, and does not conflict with other devices connected to the network.
- If the power supply is connected to an Ethernet switch or router then connect the computer to a spare port, if available.
- If it is not possible to connect the computer to a spare port of an Ethernet switch or router, then the power supply will need to be disconnected from the network in order to execute this test:

  -Disconnect the power supply from the network.

  -Connect the computer directly to the LAN port of the power supply.

  -On the computer, open the Command Prompt application.

Testing Ethernet Packet Errors

Test ping packet loss (continued):

- Send 1000 ping packets of length 1500 bytes. The process will take 1000 seconds, which is approximately 17 minutes.
- If the computer is running a Windows operating system, this is achieved by typing (for an IPv6 address, use the **ping6** command):

  ping –n 1000 –l 1500 <ipaddress>

  where <ipaddress> is the IP address of the AP or SM under test.

  If the computer is running a MAC operating system, this is achieved by typing:

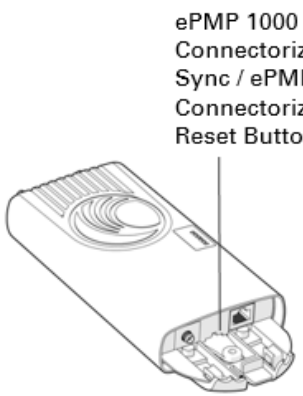
  ping –c 1000 –s 1492 <ipaddress>

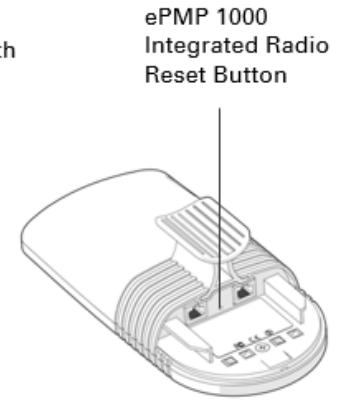
  where <ipaddress> is the IP address of the AP/SM under test.
- Record how many Ping packets have been lost. This is reported by Command Prompt on completion of the test.
- The test has passed if the number of lost packets is less than 2.

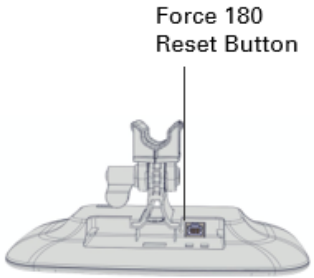
Using the Device External Reset Button

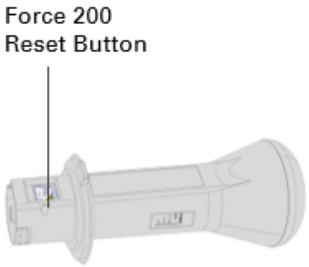
ePMP AP's and SM's feature an external button which serves two purposes:

- To reset the device (briefly depress the button for more than two seconds but less than ten seconds then release)
- To reset the device to its factory default configuration (depress the button for more than ten seconds then release)









Factory Defaulting by Power Cycling

Operators may reset an AP or SM to default factory configuration by a sequence of power cycling (removing power to the device. This procedure allows operators to perform a factory default reset without a tower climb or additional tools.

1. Remove the Ethernet cable from PoE jack of the power supply for at least 10 seconds.
2. Reconnect the Ethernet cable to re-supply power to the ePMP device for 3-5 seconds and disconnect cable to power off the ePMP device for **3-5 seconds**. (1st power cycle)
3. Reconnect the Ethernet cable to re-supply power to the ePMP device for 3-5 seconds and disconnect cable to power off the ePMP device for **3-5 seconds**. (2nd power cycle)
4. Reconnect the Ethernet cable to re-supply power to the ePMP device for 3-5 seconds and disconnect cable to power off the ePMP device for **3-5 seconds**. (3rd power cycle)

Factory Defaulting by Power Cycling

5. Reconnect the Ethernet cable to re-supply power to the ePMP device for 3-5 seconds and disconnect cable to power off the ePMP device for **3-5 seconds**. (4th power cycle)
6. Reconnect the Ethernet cable to re-supply power to the ePMP device for at least 30 seconds and allow it to go through the boot up procedure (Note: Device will go through an additional reset automatically). This will reset the current configuration files to factory default configuration.
7. Access the ePMP device using the default IP address of 192.168.0.1 (AP), 192.168.0.2 (SM), or fallback address of 169.254.1.1*

*Note: Fallback address in versions earlier then 2.1 was 10.1.1.254

ePMP Optimization

Reference Information

User Guides: http://www.cambiumnetworks.com/guides
Training: https://learning.cambiumnetworks.com
Support website: https://support.cambiumnetworks.com

Community Forum
http://community.cambiumnetworks.com/
Discussion Forums
- Products
- Network Planning
- Languages
- Business Issues

Knowledge Base with technical detail documents
Submit development Ideas
Real world connectivity Stories