Cambium Networks™

Product Overview and Updates Sept 2017

Roy Wittert
Regional Sales Director – Australia, New Zealand and Pacific Islands

Cambium Mission

- Eliminating the digital divide
- Economic opportunities for developing communities
- Unprecedented affordable quality connectivity for all
- Connecting the Unconnected: People, Places, and Things

Cambium Networks Heritage

- Industry leader in Point-to-Point and Point-to-Multipoint IP wireless broadband
- Independent company since 2011 – formerly part of Motorola Solutions
- More than 6 million nodes shipped to thousands of networks in 150 countries
- Profitable and growing business
- Held by Vector Capital investor

Cambium Value Proposition

- **Connect the unconnected** – people, places, and things
- Best-in-class **resiliency, security and scalability**
- **Affordable** solutions targeted at **developing markets** globally
- **Bridge hard to reach distances** wirelessly from 2meters to 245 kilometers
- **Cloud-based management** of devices

The Cambium Networks Difference

- **Technology Innovation**– that puts you in charge of your growth potential
- **Pre-sales support and network design tools –Industry leadership and experience –** seasoned RF expertise that makes a difference
- **Field Reliability** – Backed by notable MTBF metrics that you can rely on
- **Post sales support** - Keeping connected after implementation and always moving toward growth…that is available 24 x 7 when and where you need it


Delivering a complete Network Fabric
Cambium Networks™
Connecting the Unconnected

Applications

- Last Mile – high speed broadband
- Industrial IoT connectivity
- Rural connectivity
- Video surveillance
- Education
- Remote facility connectivity
- Federal and military communications
- Disaster recovery

Service Provider

- Residential access
- Business connectivity
- Turnkey networks for municipalities, enterprise, or industry

Benefits

- Scalability to grow networks to thousands of subscribers
- Industry-leading spectral efficiency to get the most use of limited spectrum
- End-to-end management to reduce downtime and maximize availability
- Proven reliability
- Support services

Bridging the Digital Divide

- **Problem**:
  - National Broadband Plan in Ireland requires rural coverage
  - Fiber too costly
- **Solution**: *cn*Medusa
- **Results**: Able to offer high throughput (50 Mbps) packages and increase coverage area *without* forklift subscriber replacements

Cambium Networks™

Closing the Digital Divide in Ireland

"Prior to installation of the PMP 450m, customers were limited to 8-10 Mbps packages. We can now with confidence provide up to 50 Mbps speeds to customers."

- BARRY WILSON, COUNTRY MANAGER EURONA IRELAND

Challenge

EURONA IRL CONNECTS 3,200 BUSINESS and residential customers in Cavan, Longford, Roscommon, Leitrim, Galway in Ireland. The National Broadband Plan drafted in 2012, recognized the importance of closing digital divide in Ireland, but for many reasons businesses and residents in rural areas remain unconnected to high-speed broadband, and are unable to upload and download large files or stream videos for conference calls or entertainment. Given the disperse population density in rural areas, a wired or fiber technology would not be cost effective to install.

eurona Ireland

Wireless technology had the installation cost advantage, but could not deliver the capacity that subscribers needed - and Eurona IRL saw the opportunity to succeed. Experienced in offering wireless connectivity, they stepped up to the challenge.

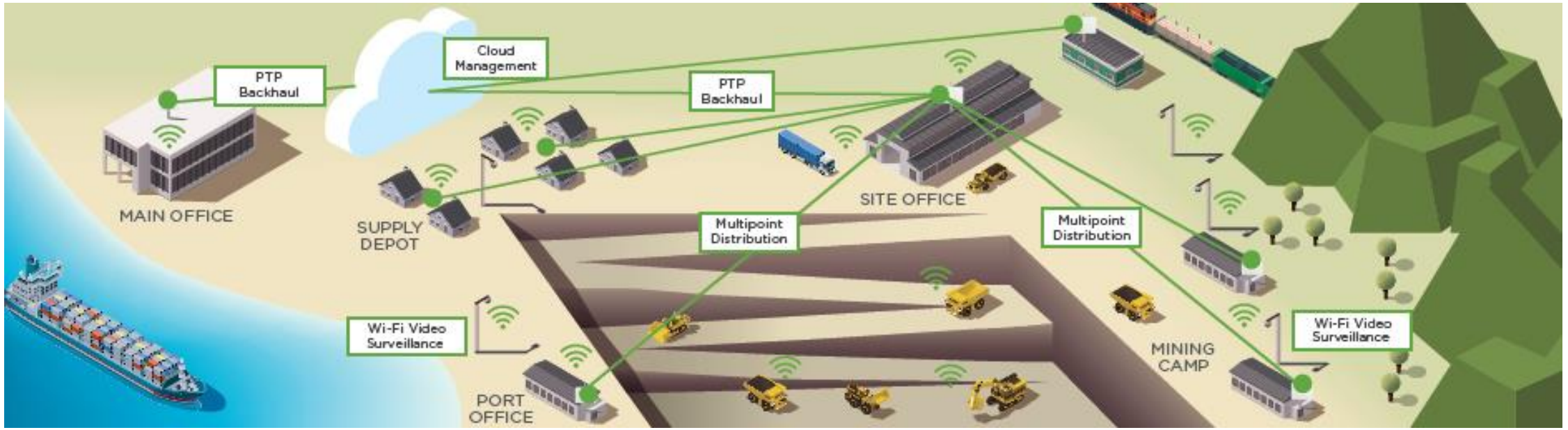
Solution

"DUE TO THE HIGH DEMAND FROM CUSTOMERS and the data rich content on the internet, we have no choice but to move forward with our technology," said Barry Wilson, Country Manager Eurona Ireland. "The introduction of the Cambium Networks PMP 450m with cnMedusa™ technology came at the perfect time for us. With competition from other ISPs we can now move forward with confidence knowing we can provide next generation speed to our customers."

IoT Applications

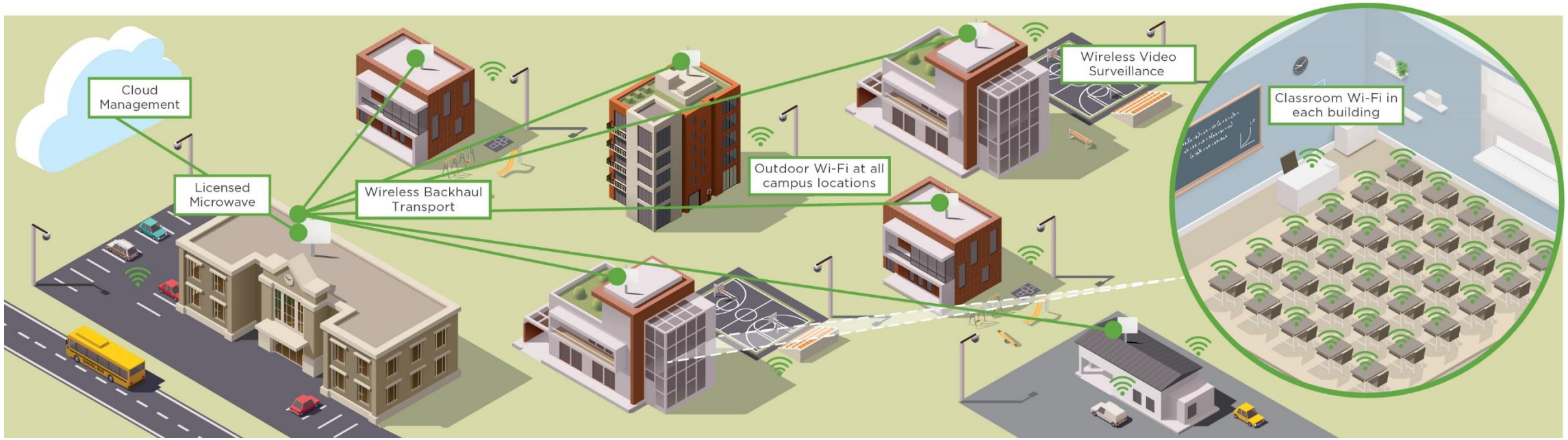
- SCADA data, controls, and sensors
- Remote office access including WiFi hotspots
- Video surveillance and security
- Leased line replacement
- Metering infrastructure
- Intelligent Traffic Solutions (ITS)

Mining



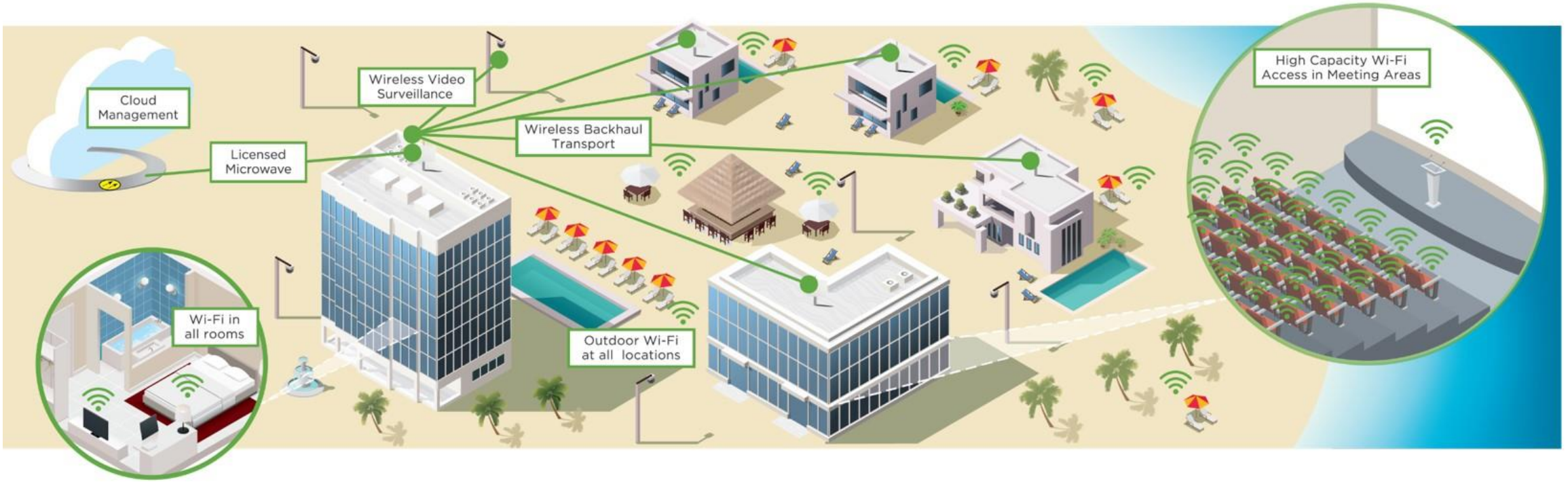
- Enterprise-class WiFi indoors and outdoors for Mining Camps
- Wide-area Point-to-Multipoint distribution for Video Surveillance, Autonomous Mining
- Long-range Point-to-Point backhaul for remote site connectivity.

Education



- Enterprise-class WiFi indoors and outdoors
- End-to-End district-wide network management
- Wide-area Point-to-Multipoint distribution
- Long-range Point-to-Point backhaul

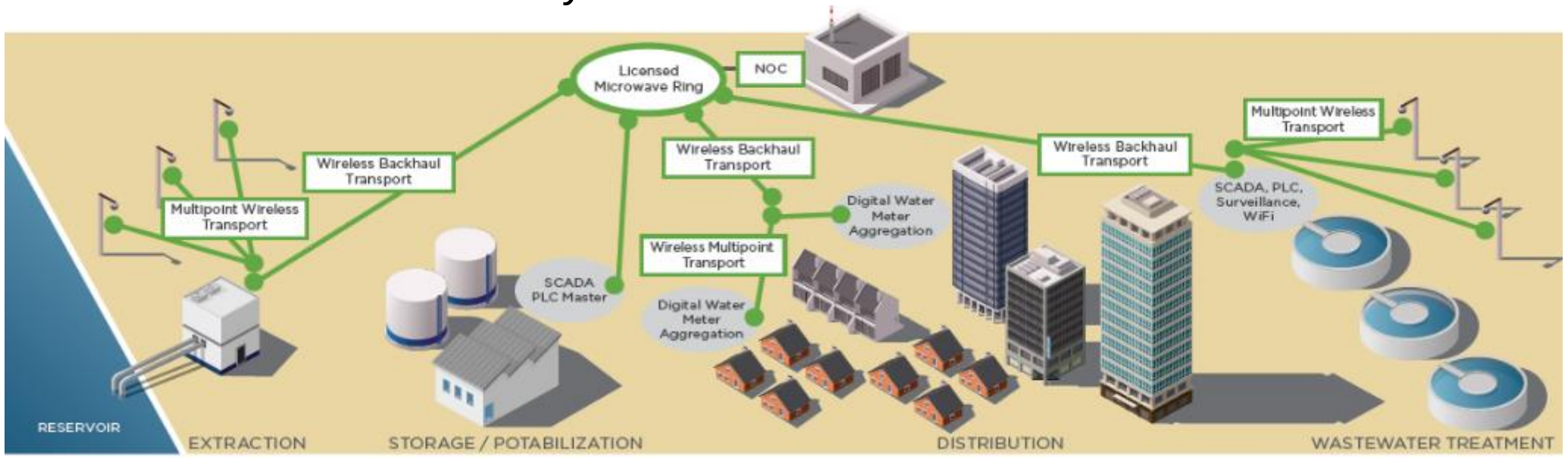
Hospitality



- Enterprise-class WiFi indoors and outdoors
- Wide-area Point-to-Multipoint distribution
- Long-range Point-to-Point backhaul
- End-to-end network management

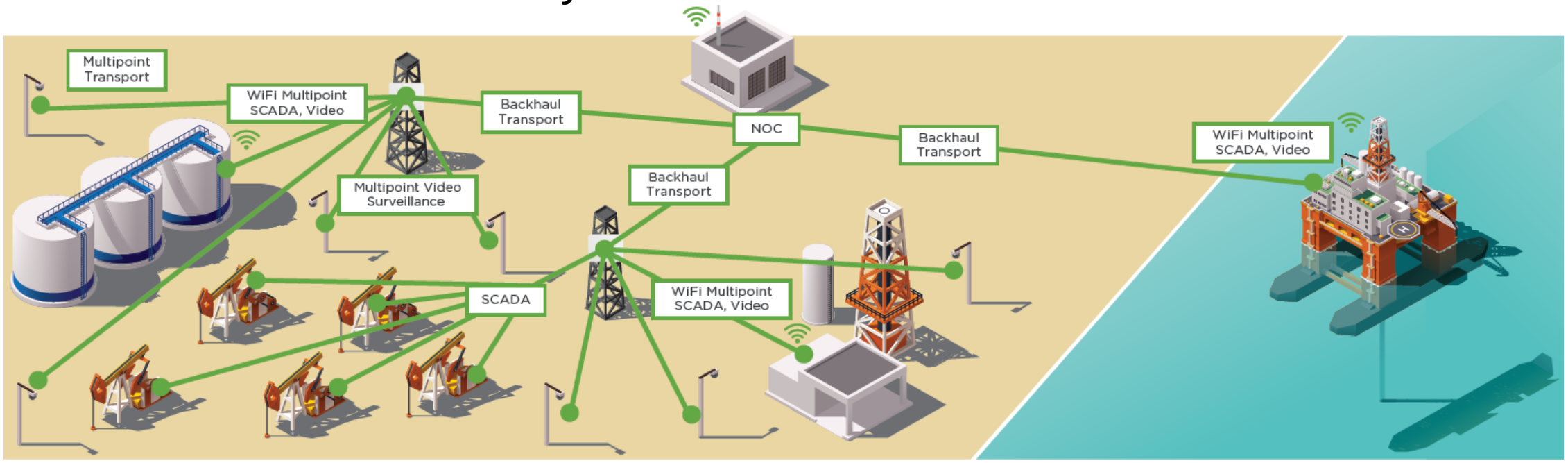
Water/Wastewater/Storm-Water Applications

- Water Meter Aggregation / Backhaul
- SCADA Process Control/Monitoring
- Remote Access Control / Video Surveillance
- Leased Line Replacement
- Remote Office Connectivity

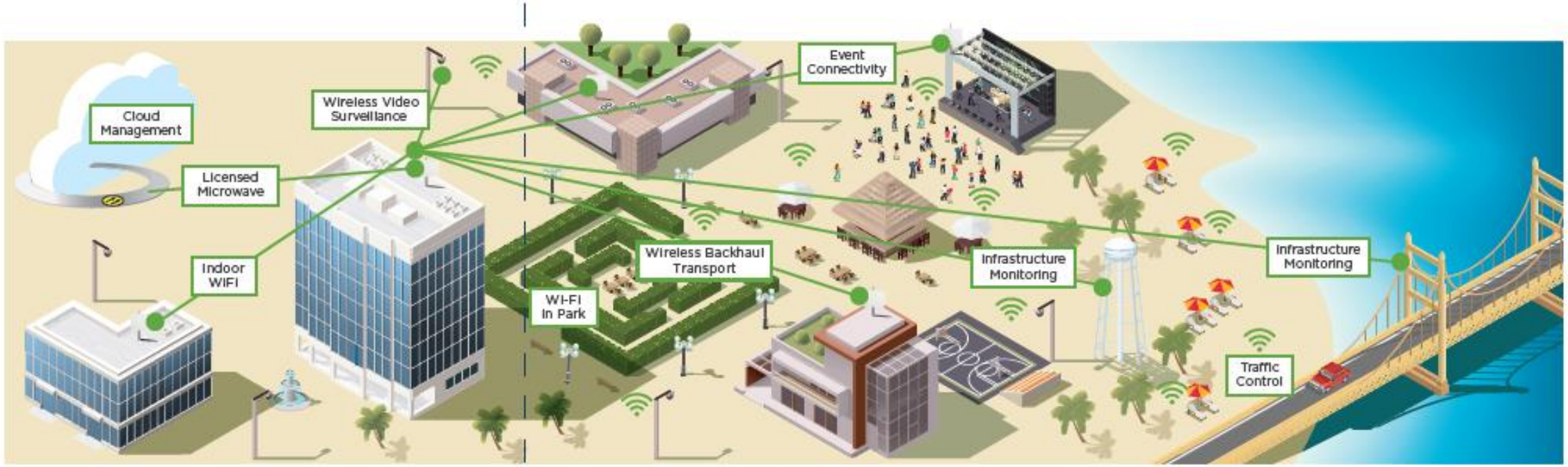


Oil/Gas/Petrochemical Applications

- SCADA Process Control/Monitoring
- Remote Access Control / Video Surveillance
- Leased Line Replacement
- Remote Office Connectivity



Smart Cities



- High capacity connectivity
- Secure communications
- Affordable and rapidly deployed
- Reliable to perform in harsh conditions

Technology

Cambium Networks™

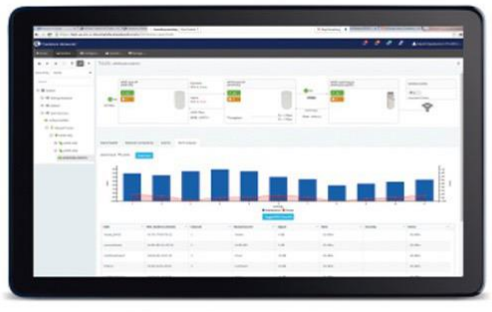
Affordable, Reliable Wireless Connectivity

World-class Wireless Networks

*cn*Pilot™ R201P

E400

E500



*cn*Maestro™

Wi-Fi

*e*PMP™ 2000

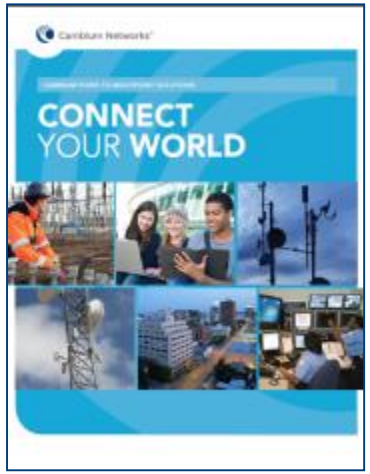
PMP 450m

PTP 700

Distribution Access & Backhaul

Proven Fixed Wireless and WLAN Network Solutions

Product	cnPilot	ePMP	PMP/PTP 450/i	PTP 670	PTP 820	cnReach
Design Focus	Breakthrough indoor/outdoor WiFi access (802.11ac)	Budget Constrained Residential	Robust and Ruggardised. PTP and PMP	Industry Leading Sub-6GHz Performance	Microwave Backhaul	Narrow-Band
Throughput	800 Mbps+	100 Mbps / sector	250 Mbps/sector	450 Mbps	1+ Gbps	10 kbps to 4.4 Mbps
Spectrum (GHz)	2.4, 5.8 GHz	2.4, 5 GHz, **2.6GHz**	2.4, 3.5, 3,65, 4.9 – 5.95GHz and 900MHz	4.9 – 6.0 GHz	6 – 38 GHz	400 MHz / 900 MHz



- Extreme Capacity, Unparalleled Scalability
- Low-Cost, Low-Complexity, Low-Maintenance Infrastructure
- Scalable from small to region wide deployments
- Consistent throughput and low latency
- Rapid Deployment
- Supports Video, Data, Voice and Control Applications
- NLOS, nLOS and LOS performance
- Very Durable and Reliable

PTP Portfolio Overview

Unlicensed Sub 6GHz

Licensed 6-38 GHz

FEATURE	PTP 450i	PTP 670	PTP 820
			
RF Bands (GHz)	4.9-5.925 GHz 3.5 GHz	4.9 – 6.05	6-42
Technology	TDD	TDD	FDD
Max. Throughput	250+ agg.	450 agg.	**1 Gbps+** **Full duplex**

- Immediate roll-out
- No fee
- LOS/NLOS
- Low Cost

- Licensed spectrum
- license fee
- LOS
- Highest capacity

Licensed Microwave – PTP 820

2
3

PTP 820 Portfolio

Full Outdoor

PTP820S

✓ Single-core

PTP 820C

✓ Dual-core

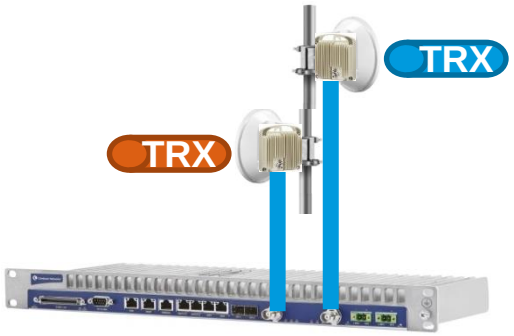
✓ Lic Activate for 2nd Core

Split Mount

PTP820G+RFU-C

✓ Multi-core

✓ Ethernet +E1/T1



All Indoor

PTP820G+RFU-A

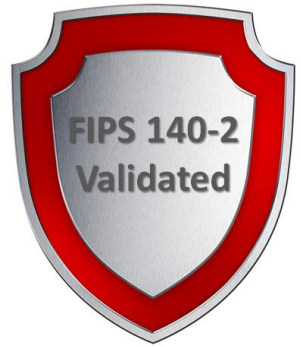
✓ Multi-core

✓ Ethernet +E1/T1

✓ 35dB Tx

PTP 820 Uniqueness

- Ultra high capacity with lower power consumption
  - Tightly integrated, in-house developed radio technologies (e.g., LoS 4X4 MIMO)
  - Capacity-boosting techniques optimized for high layers of LTE
- Leading system gain across entire spectrum
  - High power radios, superior receiver sensitivity
  - Added system gain with LoS 4x4 MIMO
- High service granularity enables network sharing & multiple services
  - High service granularity – Hierarchical QoS (H-QoS)
  - Hardware-ready for emerging and future transport protocols
- Single platform - Single OS across the entire network
  - Common HW architecture with versatile configurations
  - Common SW architecture for simple, end-to-end operations

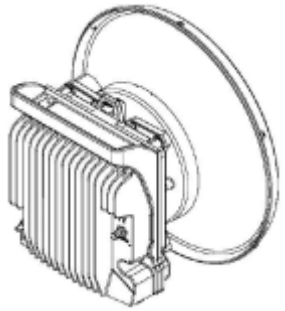


PTP 820S
Compact Full Outdoor

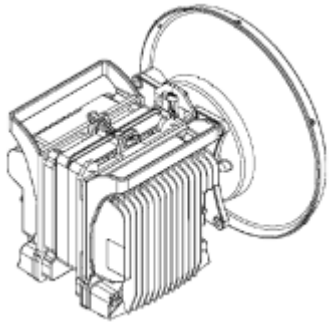
- Single Core Radio, Ultra-high capacity
- Up to 2048 QAM with hitless ACM
- 3.5 to 80 MHz Channel
- AES-256bit Encryption
- Support 1+0, 1+1 HSB, & 2+0
- Easy to install, highly reliable
- Intelligent networking functions
  - Integrated Ethernet switch - MEF Carrier Ethernet 2.0-compliant
  - Intelligent service-centric management – H-QoS and advanced OAM capabilities

PTP 820S Configurations

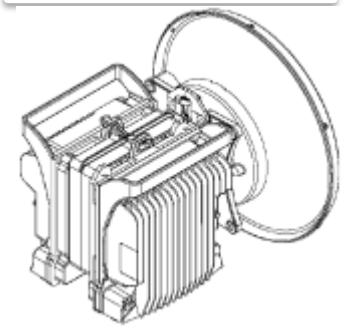
1+0 Direct Mount



1+1 Direct Mount



2+0 Direct Mount
SP or DP



Flexible, Easy to Install direct mount options

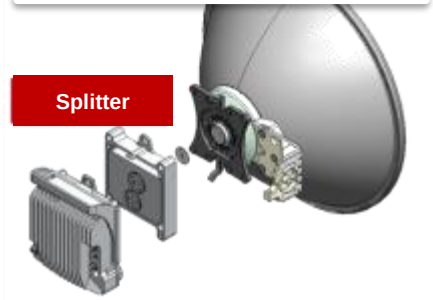
PTP 820C

Compact Full Outdoor High Power Dual-Core

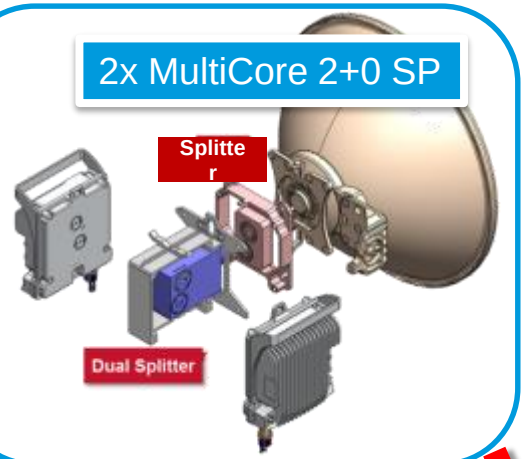
- Dual Core Radio , Ultra-high capacity
- **1+ Gbps** in-a-box, virtual fiber in licensed frequencies
- Up to 2048 QAM with hitless ACM
- 3.5 to 80 MHz channel
- Support 1+0, 2+0, 2 x Dual Core (4+0), LoS 2x2/4x4 MIMO, 1+0 SD, 1+1 HSB, 2+2 HSB
- Second Core Activation from 1+0 ➔ 2+0; with software license keys
- AES-256bit Encryption
- Easy to install, highly reliable
  - Remote activation of the 2nd PTP 820C TRX
  - Future upgrades without additional sites visits
- Intelligent networking functions
  - Integrated Ethernet switch - MEF Carrier Ethernet 2.0-compliant
  - Intelligent service-centric management – H-QoS and advanced OAM capabilities

PTP 820C System Multi Core Configurations

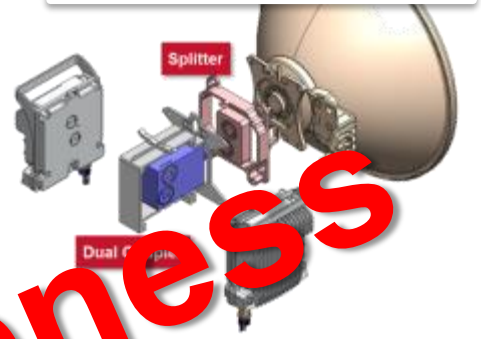
MultiCore 1+0/2+0 SP



2x MultiCore 2+0 SP

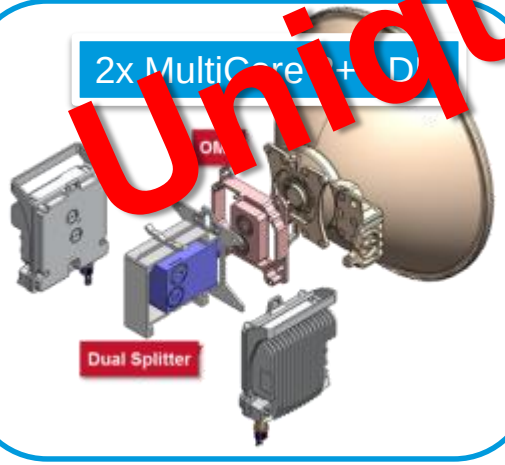


MultiCore 2+2 HSB SP

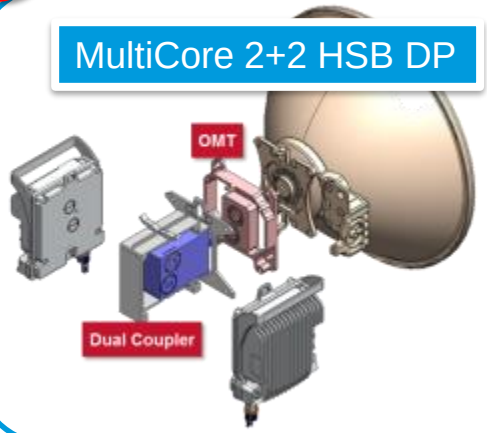


MultiCore 1+0/2+0 DP

2x MultiCore 2+0 DP



MultiCore 2+2 HSB DP



Uniqueness

Flexible, Easy to Install direct mount options

PTP 820C

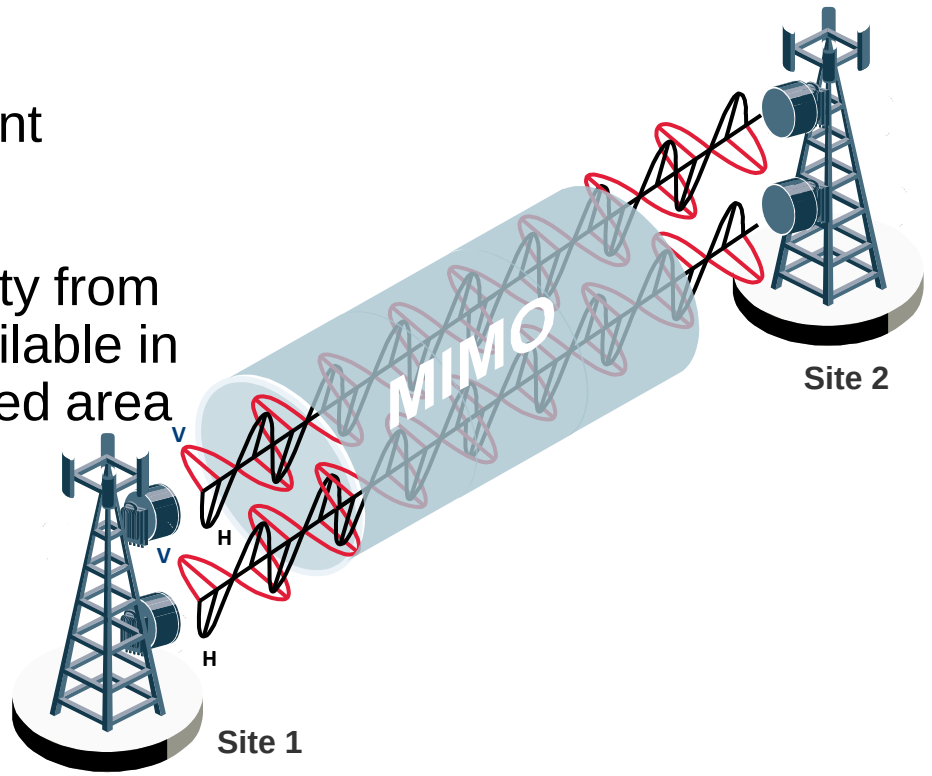
Sets a New Standard in Microwave Transmission

LoS 4x4 MIMO

Quadruples radio throughput using the same spectrum, at half the form-factor

PTP 820C Line-of-Sight (LOS) MIMO on the *SAME CHANNEL!*

- Using the a single channel to quadruple the capacity
- 2 x PTP 820C units at each site
- Simple direct mount installation
- Double the capacity from impossible be available in spectrum congested area



1Gbps on a single 30/28 MHz channel

Upgrading the Capacity without network re-planning

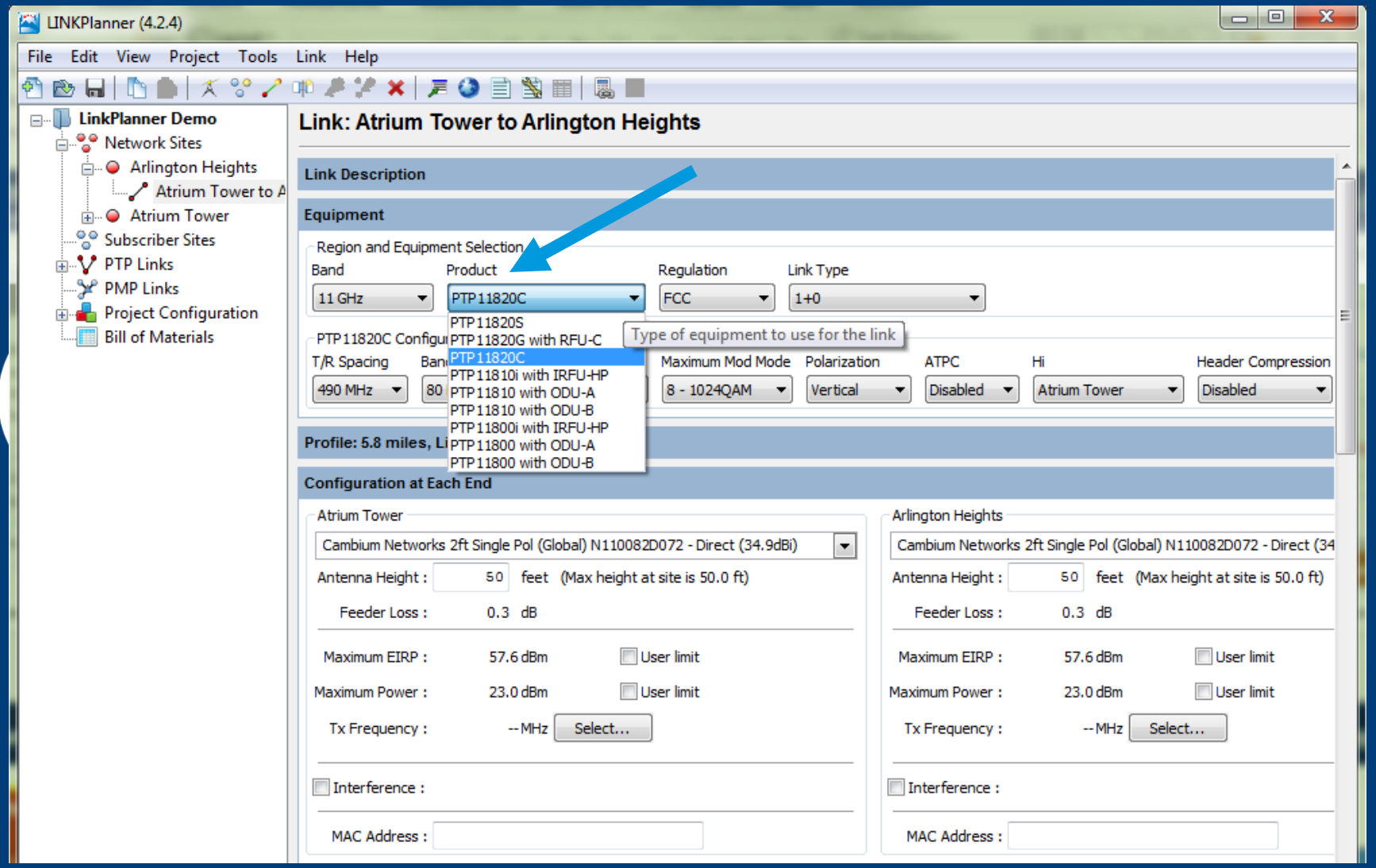
PTP 820G
Multi-Radio Technology Edge Node

- Split mount solution
- Low footprint fixed design - quick, simple and reliable set - 2 radio carriers in 1RU
- Ultra-high capacity over using 1024 QAM (2048 QAM in Rel 8.0, Q2 2015)
- Flexible migration path from legacy TDM to IP:
  - All packet mode - Eth + Pseuduowire TDM
  - Hybrid mode – Native Eth + Native TDM
- 1+0, 1+1HSB, 2+0, 1+0 East west in 1RU
- Easy to install, highly reliable
  - Low footprint, fixed design, quick, simple and reliable set up
- Intelligent Carrier Ethernet Switch
  - H-QoS, MEF Carrier Ethernet 2.0-compliant

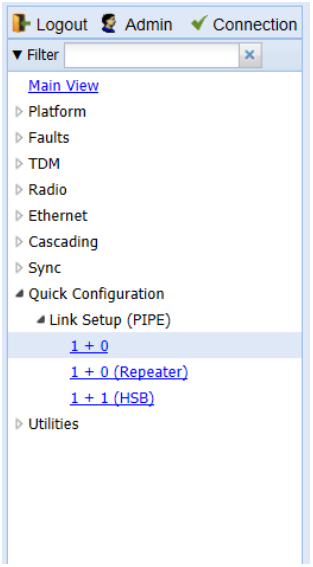
Split Mount: PTP820G + RFU-C

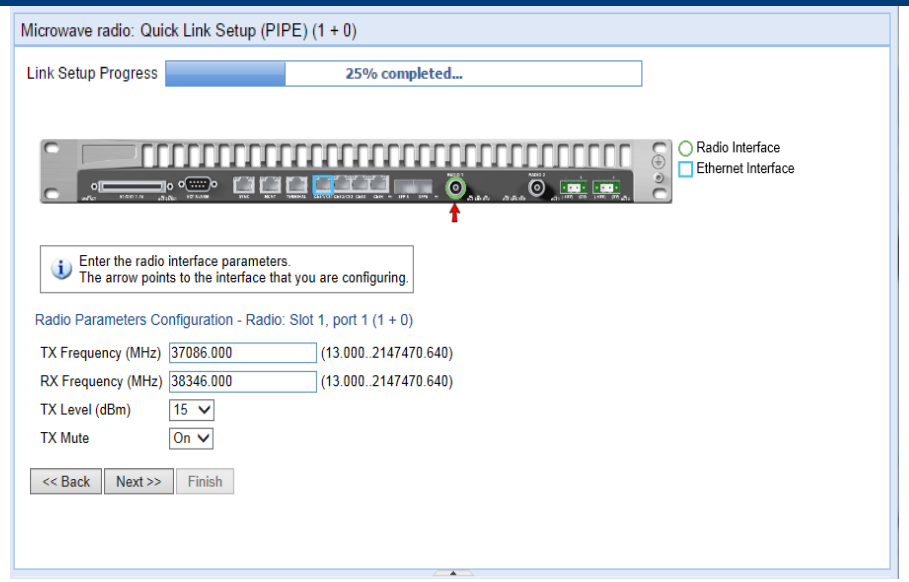
- High Capacity,
- Up to 2048 QAM
- 3.5-60 MHz channels
- MTBF > 110 years
- Compact and light (3.5kg)
- Direct & remote mount installation using the same antenna (1-6 ft)
- Single polarization antenna can be upgraded to dual pole antenna using direct OMT device

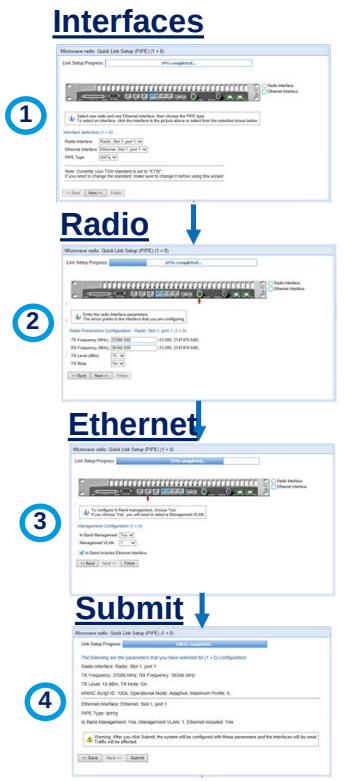
LINKPlanner w/ PTP 820



Installation Wizard

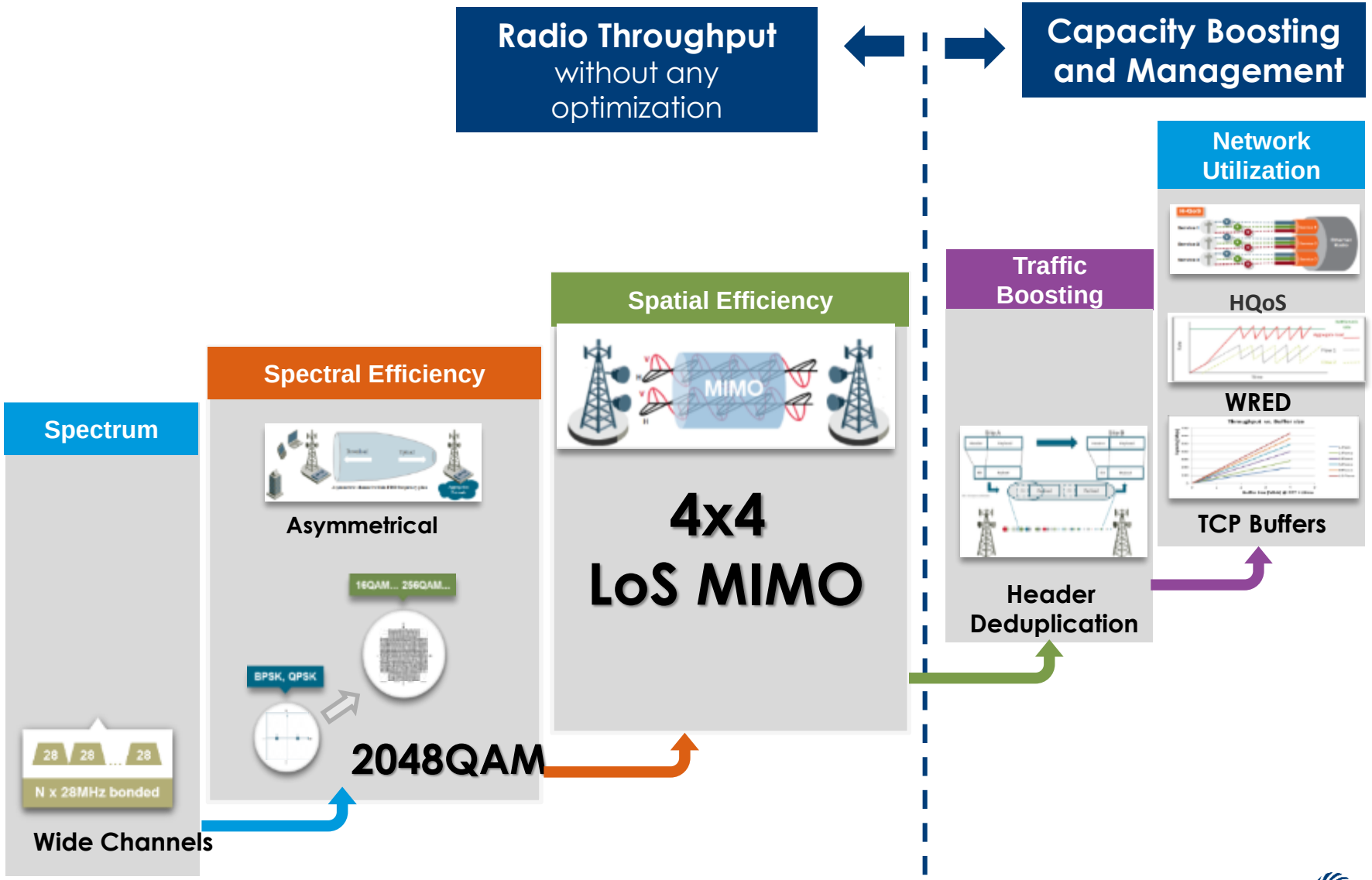




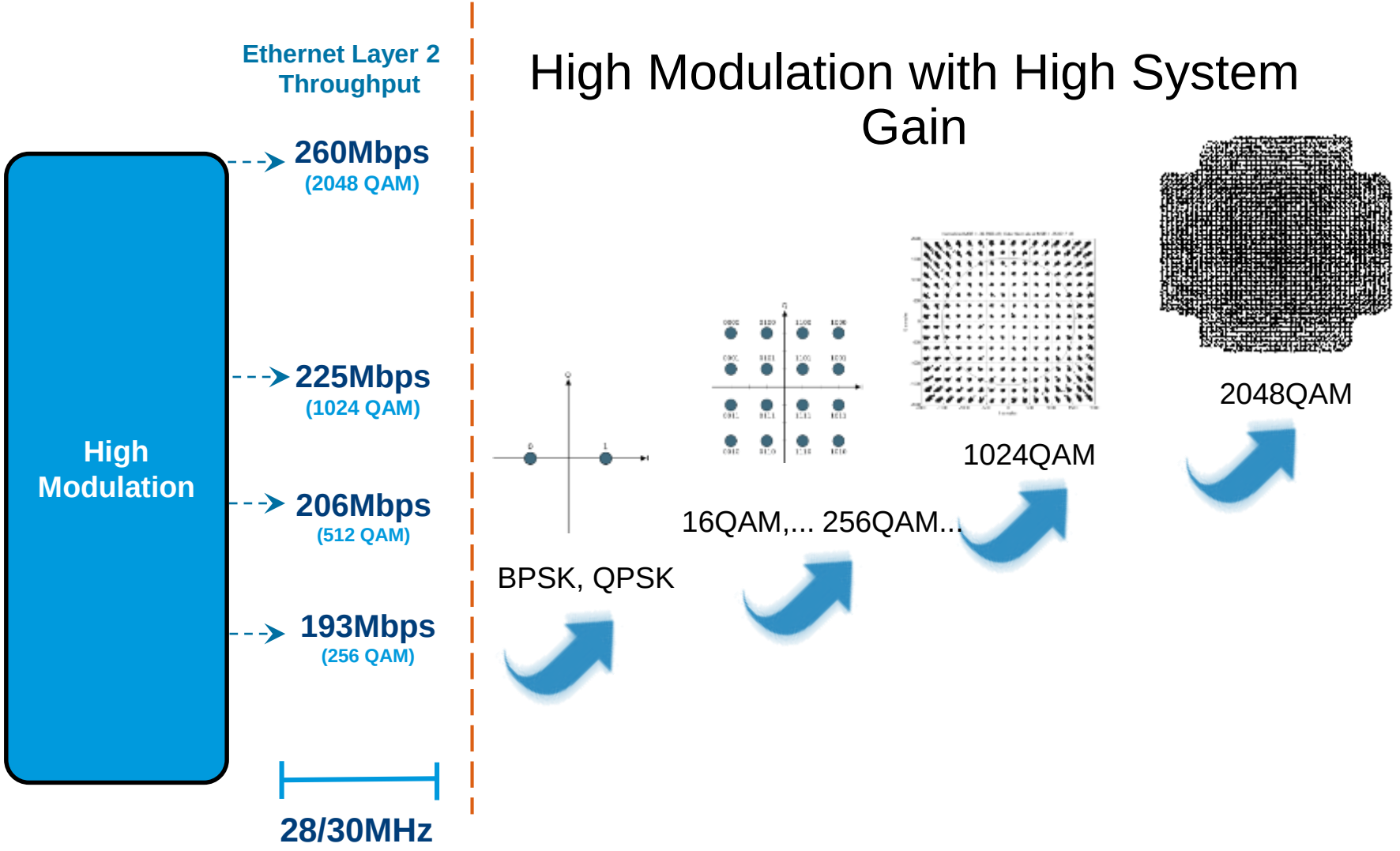


- The installation wizards provide you step by step to establish a working pipe link.
  - 1+0 with Pipe services (PTP820 S/C/G)
  - 1+0 Repeater links with Pipe services (PTP 820C/G)
  - 2+0 MC-ABC (PTP820 C/G only)
  - 1+1 HSB or 1+1 HSB with SD and Pipe services (PTP820G only)
    - TDM services and Pseudowire services

Ultra-high Capacity at Any Spectrum
Multi-Gigabits with High Spectral Efficiency

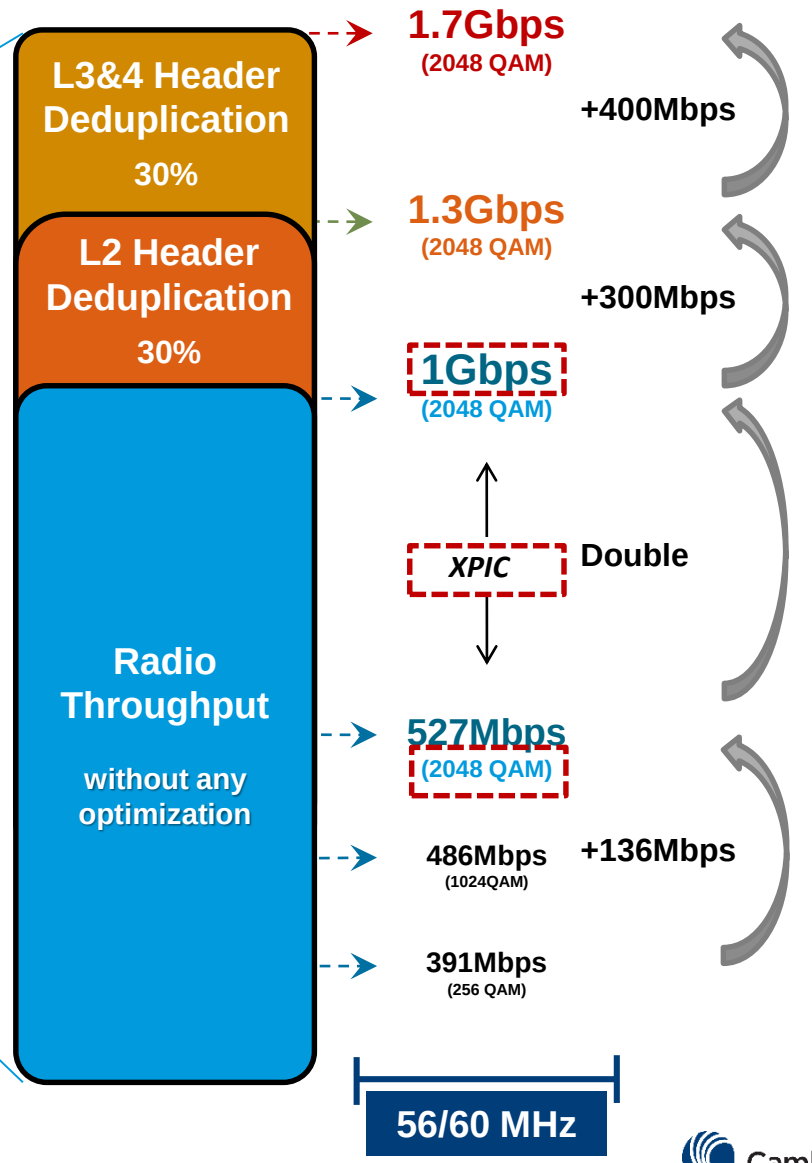


Supports High Modulation – 2048QAM



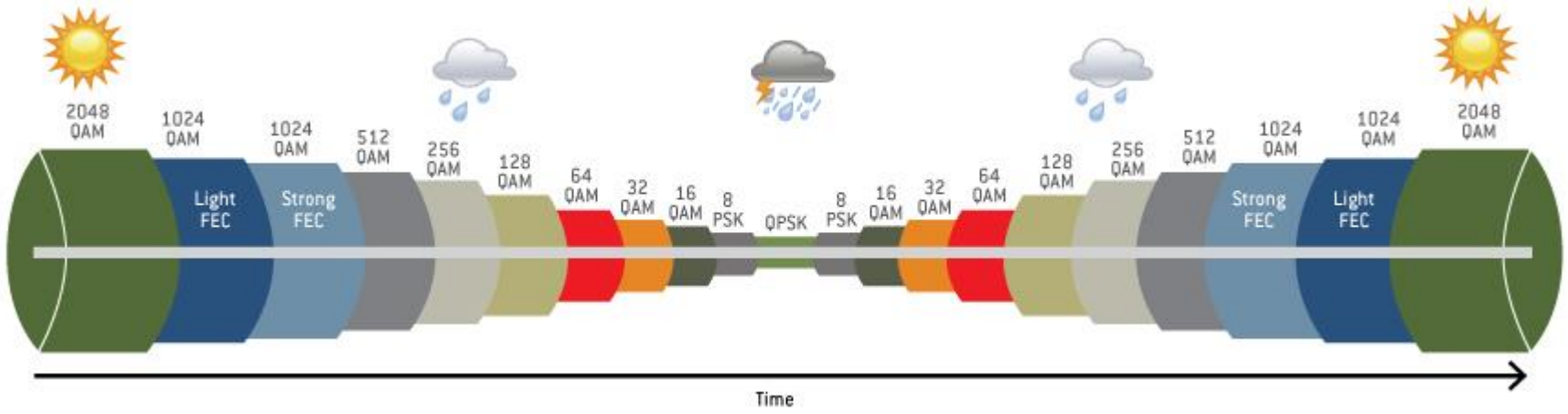
Show Me The Numbers

1Gbps+ in-a-box
in licensed frequencies

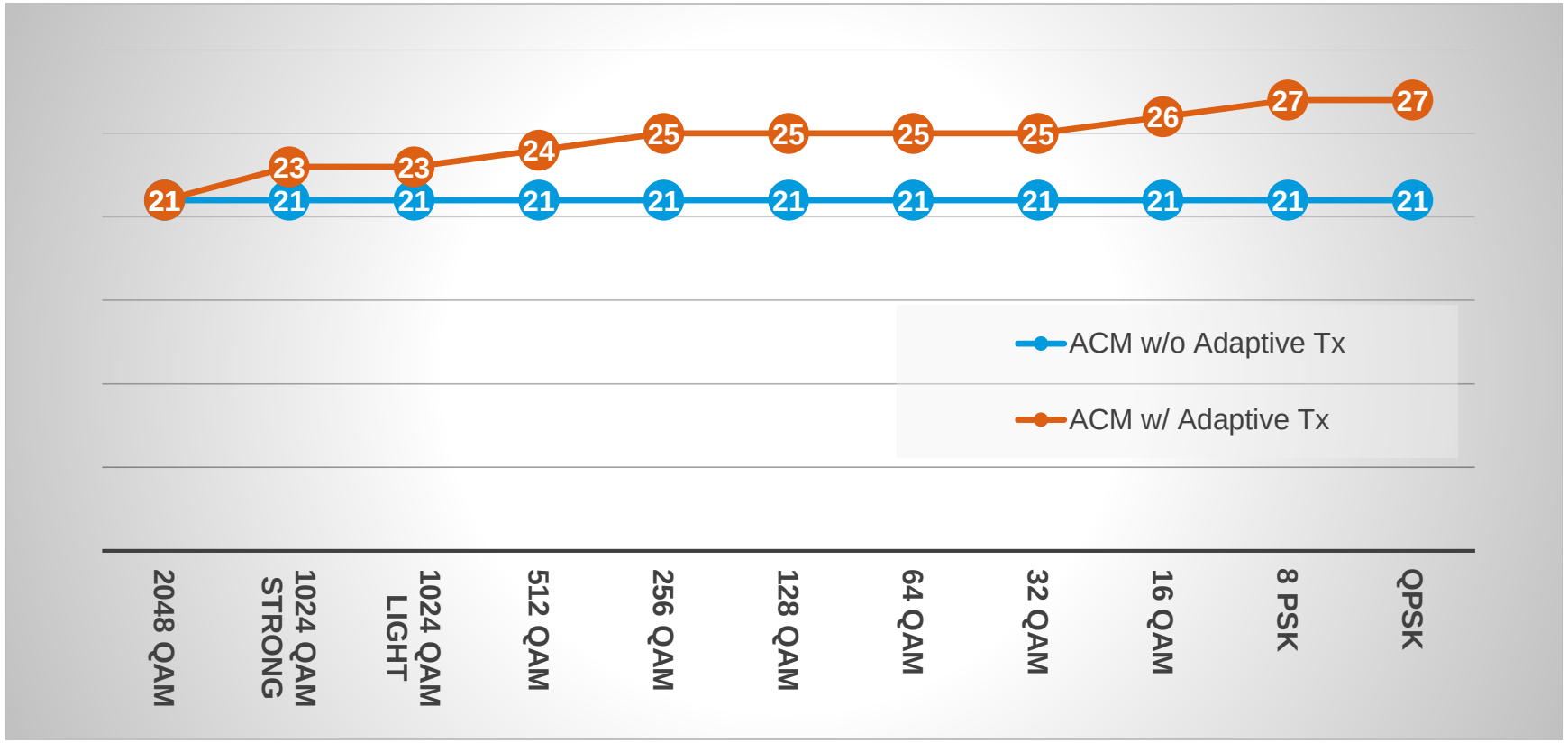


Adaptive Coding and Modulation (ACM)

- **11 steps** of ACM (QPSK to 2048 QAM). In ACM mode, the radio will select the highest possible link capacity based on received signal quality
- The switch is **Errorless and Hitless** (no bit errors introduced)
- During the period of reduced capacity, the traffic is prioritized based on Ethernet **QoS**
- ACM with **Adaptive transmit Power** is introduced in Release 8.0. By default, the adaptive Transmit power is disabled.



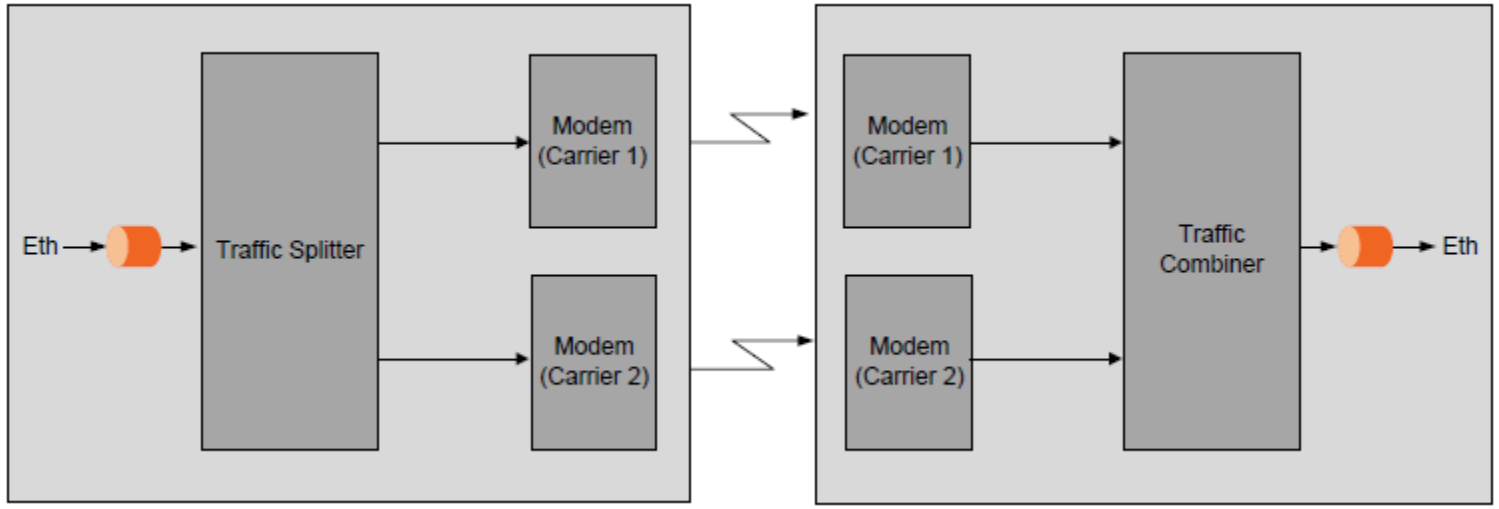
Hitless ACM with Adaptive Tx Power



Example of ACM @ 11 GHz

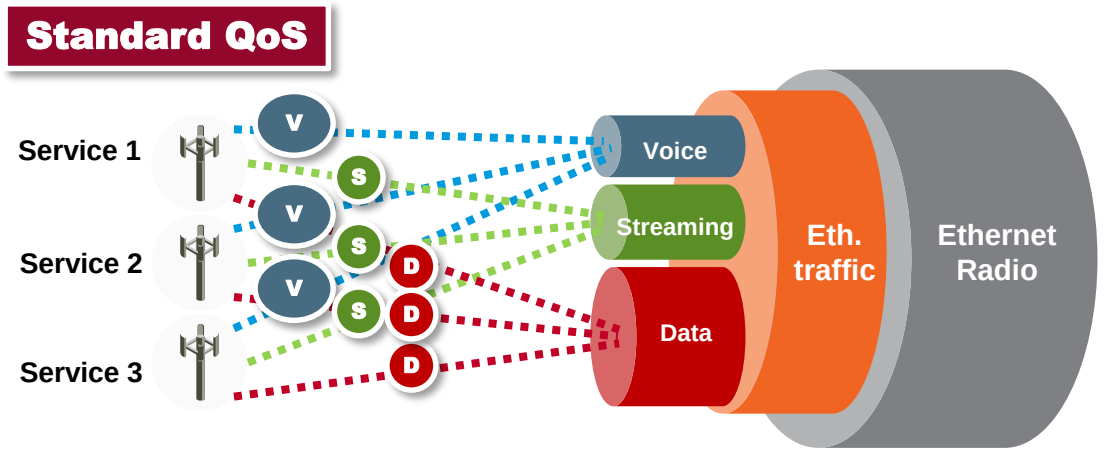
Multi-Carrier ABC

- Create logical bundles of multiple radio links
- Traffic is divided among the carriers optimally at the radio frame level
- Optimize for wireless backhaul applications
- Enable separate radio carriers to be shared by a single Ethernet port
- Provide double capacity, while still behaving as a single Ethernet interface.

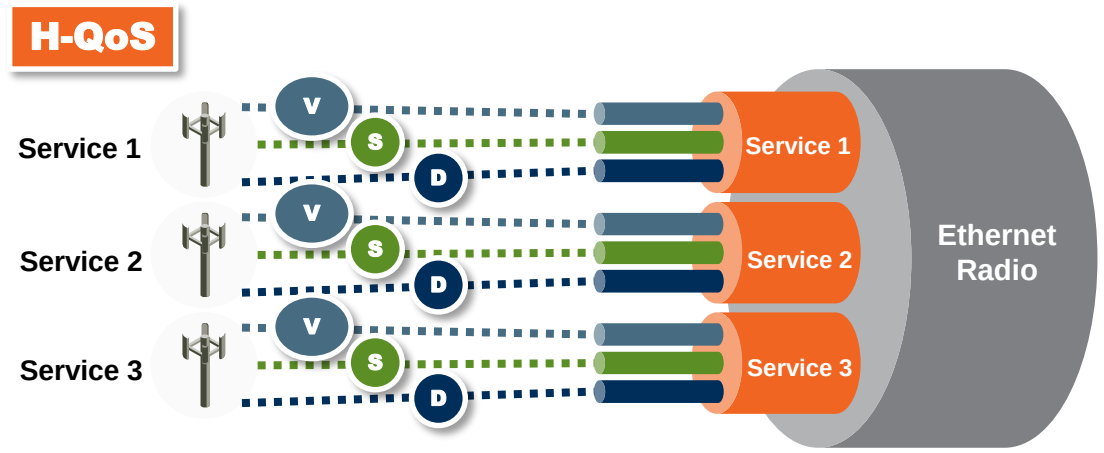


Hierarchical QoS (H-QoS) vs. Standard QoS

- Differentiation between different traffic classes (CoS)
- Services within the same traffic class are treated as a single aggregate with no isolation
- Limited per-service visibility and control



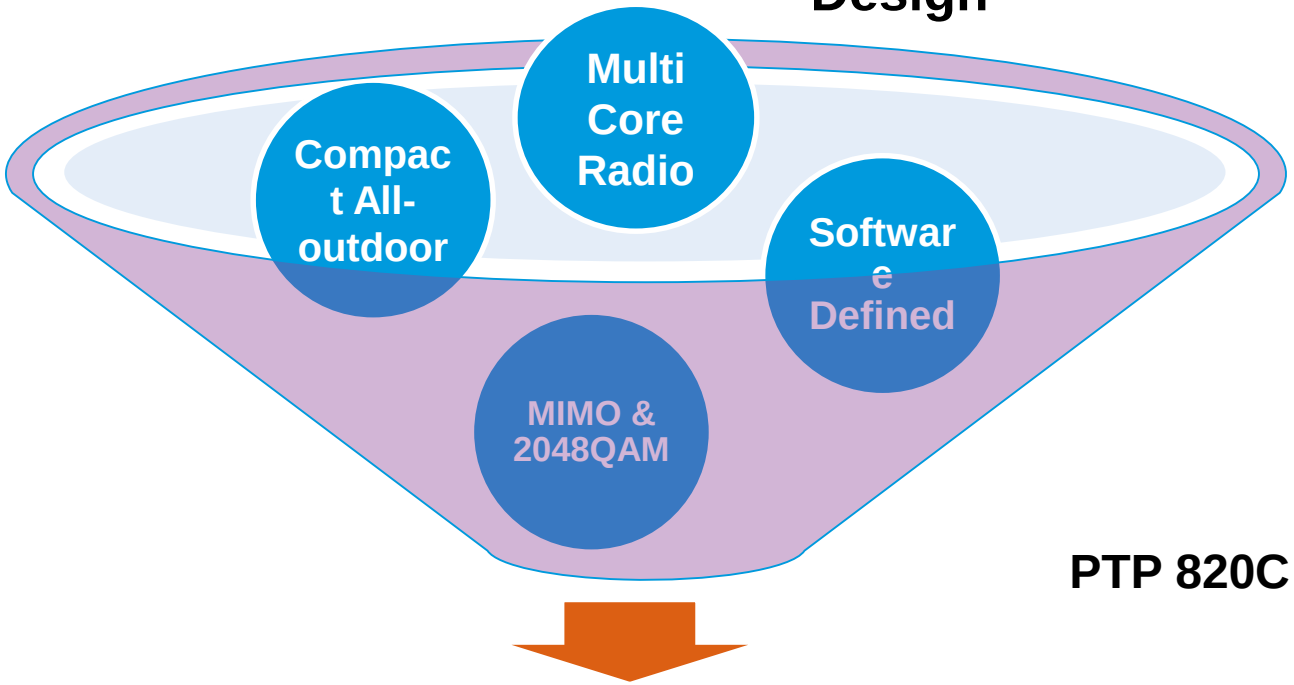
- Each service gets its own personalized treatment
- TDM-grade performance providing per-service full visibility and control



Note: Available in future release

It all results in lower TCO

The First Product to Combine MultiCore Radio, 2048 QAM Modulation and Line-of-sight 4x4 MIMO in a Compact All-outdoor Design



PTP 820C

Lower TCO

Lower installation costs, Less installation material, Fewer accessories, Less power consumption, Less equipment, Less spares, Less space rental, Fewer truck rolls, Less spectrum fees, Fewer sites

Unlicensed (Class Licensed) Backhaul – PTP 670, 550, 450i, ePMP

Sub 6GHz PTP Portfolio

Sub-6 GHz Solutions

ePMP | PTP 450 | PTP 450i | PTP 550 | PTP 670

ePMP Force 180

Integrated Radio configured as a PTP Backhaul radio
Small, sleek form factor delivering high performance.
16 dBi antenna providing increased range

- 5 GHz; -5 | 10 | 20 | 40 MHz;
- Physical layer 2x2 MIMO, OFDM; Ethernet 100/1000 BaseT;

Performance

- BPSK to 64QAM;
- More than 200 Mbps;
- 30 dBm transmit power;
- Panel Antenna 16dBi
- 3 – 5ms typical (one way);

- Environmental IP55;
- Power consumption 10 W typical;

- 10/100/1000BaseT, Compatible with Cambium PoE pinouts (V+ = 7 & 8, Return = 4 & 5) and Standard PoE pinouts (V+ = 4 & 5,
- Return = 7 & 8)

Force 190

- 22 dBi
- 2X2 MIMO
- 8 Degree beamwidth
- 10/100 Ethernet
- Compact packaging
- MSRP $109

Available Now.

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 MINO / 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;

PTP Portfolio: Summary

Sub 6 GHz

PTP 450i

PTP 550

PTP 670

PTP 700

Licensed Microwave

PTP 820S

PTP 820C

PTP 820C HP

RFU-S-HP

RFU-C

RFU-A

PTP 820G

Sub 6 GHz Backhaul

PTP 450i

Comprehensive Network

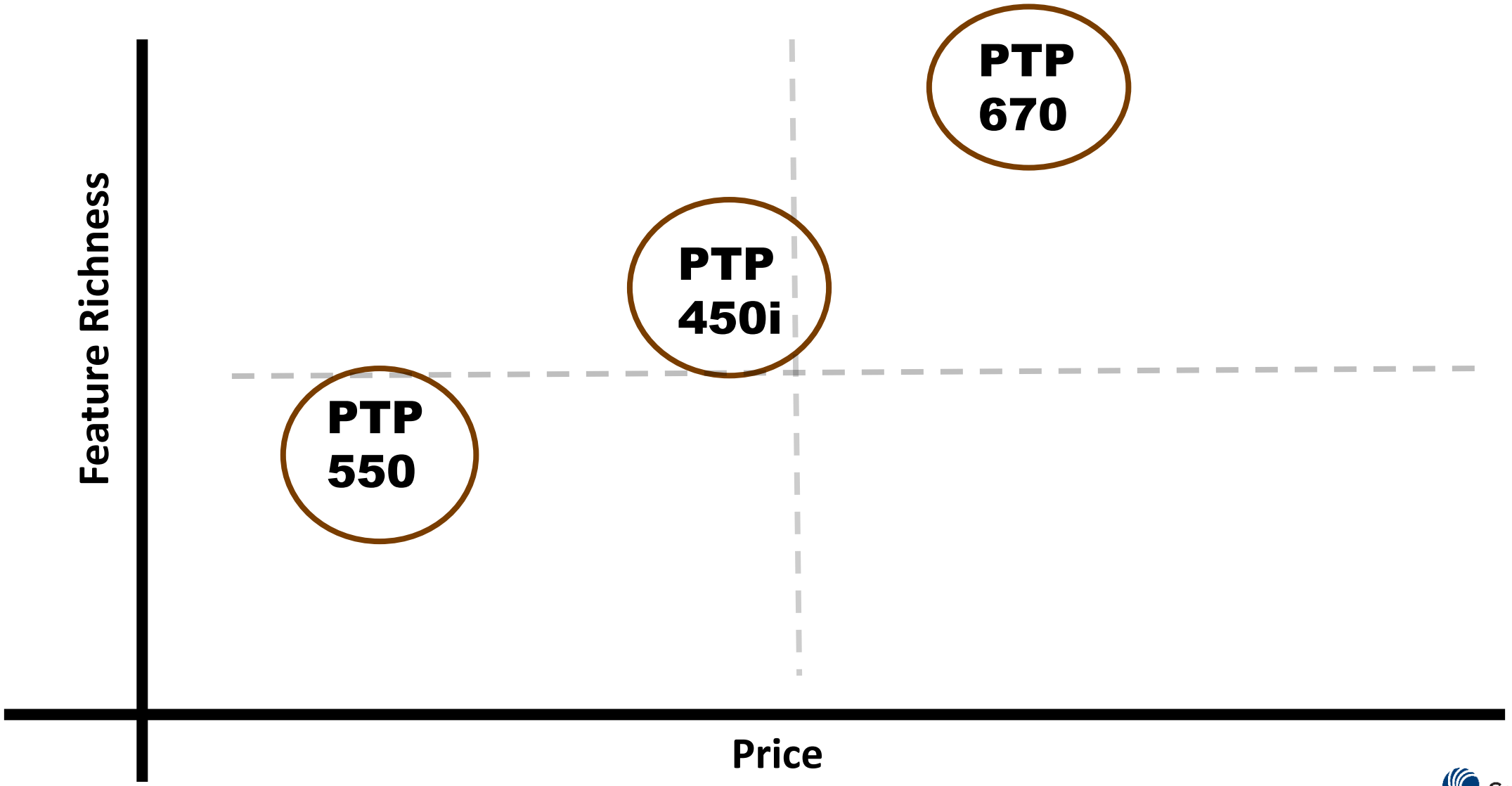
PTP 550

High throughput Network

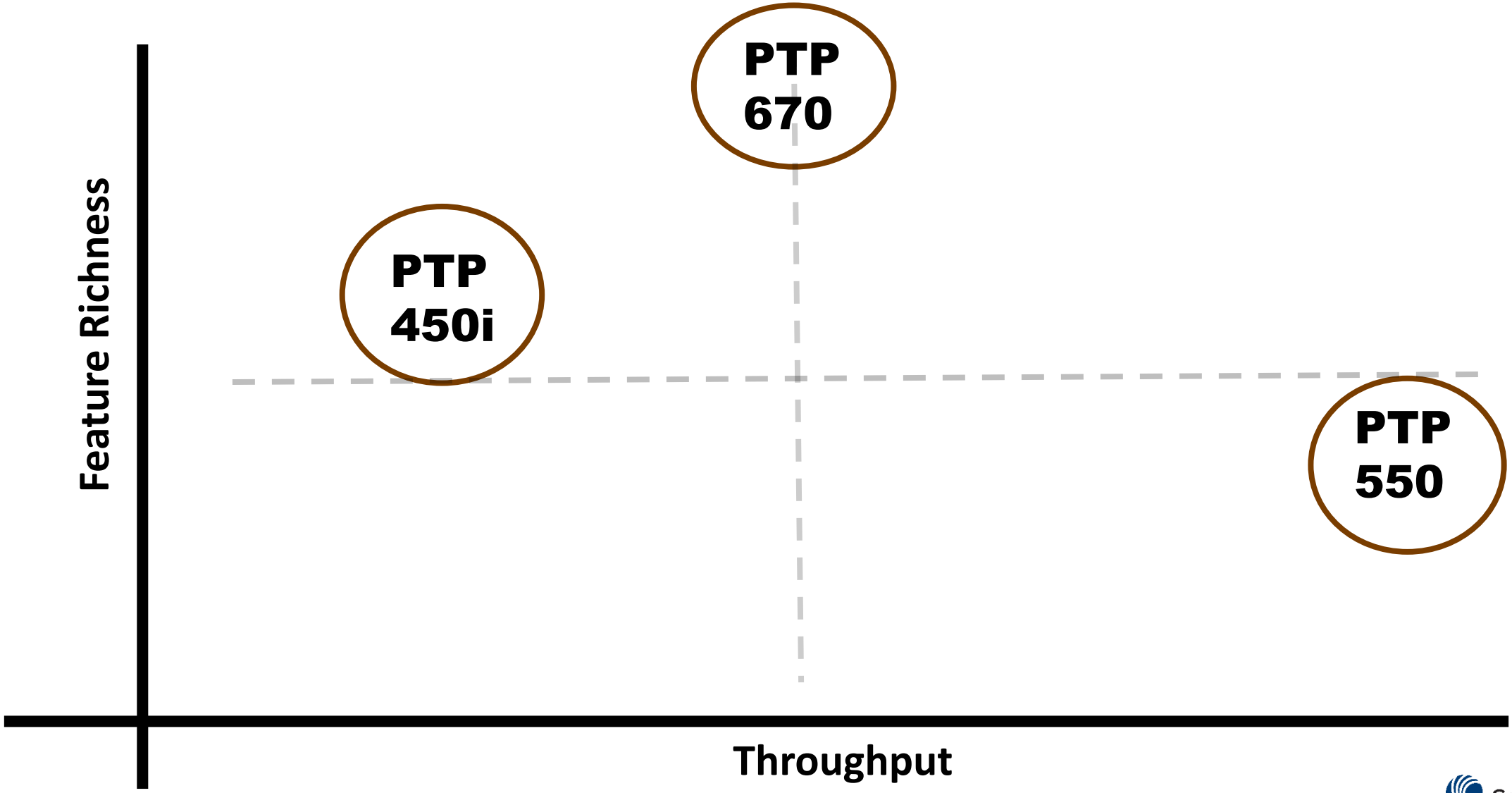
PTP 670

Resilient & Challenging Network

PTP Portfolio Analysis



PTP Portfolio Analysis



PTP 550 : High Throughput Network

Up to 1.36 Gbps Throughput with ARQ
Asymmetric non-contiguous channel aggregation across 5 GHz band
Built-in live spectrum analyzer, Dynamic Spectrum Optimization (DSO) enables to continually scan the band for low interference channels *
Small form factor, IP67 metal housing
TDD Sync using Cambium Sync
Support SFP interface

Frequency Bands/Channels

- 5.1 GHz to 5.9 GHz
- 2 x 20 / 40 / 80 MHz channels

Aggregate Capacity

- Up to 1.36 Gbps

Interfaces

- 1 x Ethernet 100/1000 BaseT with PoE
- 1 x SFP Slot

Adaptive Modulation

- MCS-0 to MCS-9 with two streams(V+H)

Latency

- 3 - 6 ms

Maximum Power & Antenna Gain

- 27 dBm combined output power
- 23 dBi integrated antenna

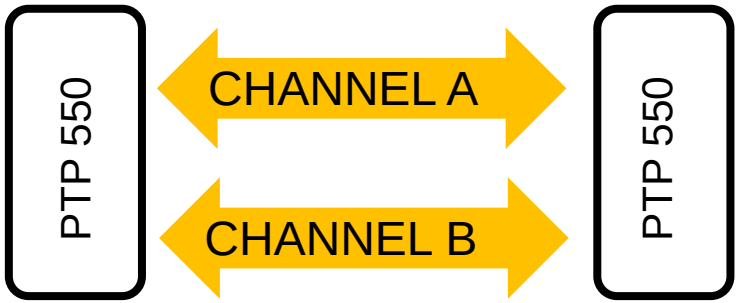
Physical and Security

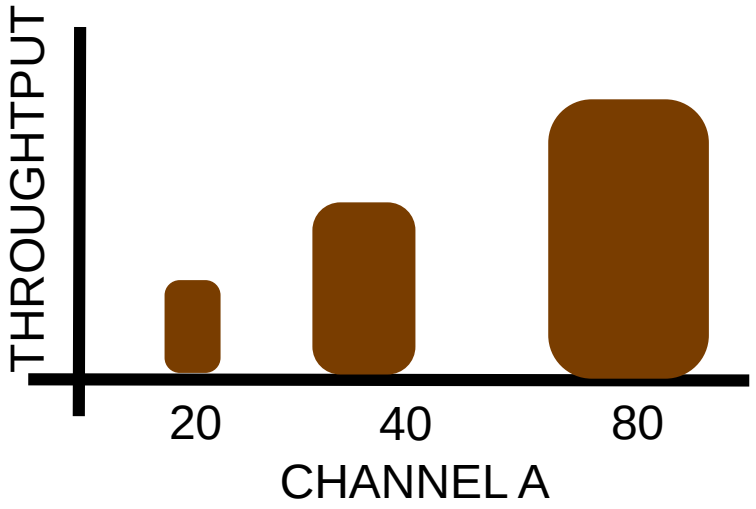
- 128-bit AES, HTTPS and SNMPv3
- All Metal enclosure, IP67

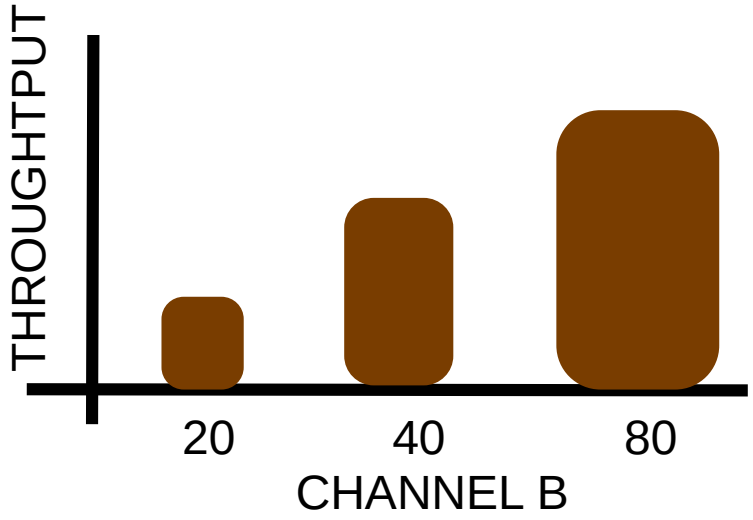
PTP670 vs PTP550

ATTRIBUTES	PTP 670	PTP 550
Frequency Band supported	4.9 to 6.05 GHz	5.1 to 5.875 GHz
Max Throughput	450+ Mbps	1.4 Gbps
Spectral Efficiency	10.1 bpHz	8.75 bpHz
Support Multipoint Mode	Yes, using HCMP	No
Support DSO	Yes	
Support encryption	AES 128/256	AES 128
Support IEEE 1588 and SyncE	Yes, supported	No
Antenna Gain	23 dBi Gain	
Support Jumbo Frame	Yes, up to 9600 Bytes	No
TDD Sync	Yes, supported	

ASYMMETRIC CHANNEL BONDING: EXPLAINED

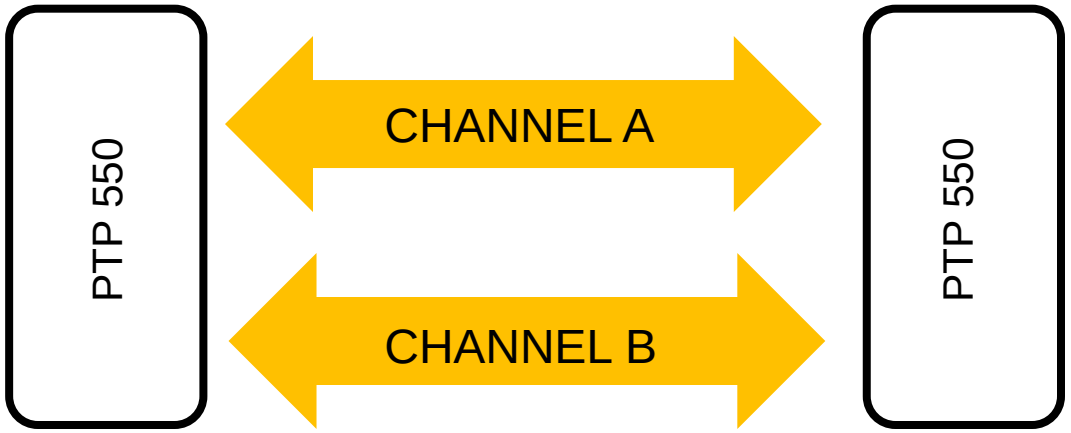






CHANNEL A	CHANNEL B	EXAMPLE SCENARIO	THROUGHPUT
20	20	HIGH INTERFERENCE	350 Mbps
20	40	ONLY ONE CLEAN CHANNEL	500 Mbps
80	20	ONLY ONE CLEAN CHANNEL	850 Mbps
40	40	TWO CLEAN CHANNEL	700 Mbps
40	80	TWO CLEAN CHANNEL	1 Gbps
80	80	TWO FULL CLEAN CHANNEL	1.4 Gbps

Resilient Network & Aggressive Network

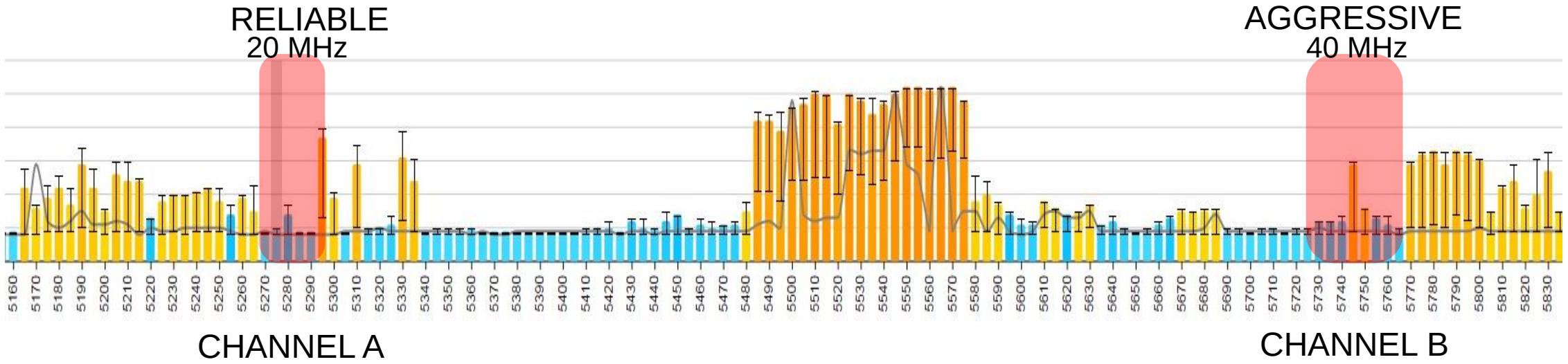


CHANNEL A: SAFE and STABLE

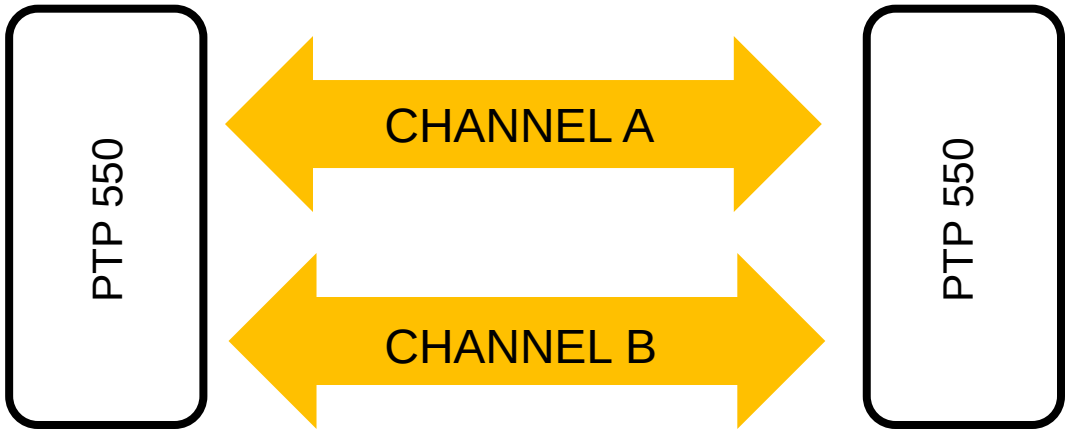
RELIABLE/GURANTEED LINK to customers

CHANNEL B: AGGRESSIVE

Strive for better throughput for customers

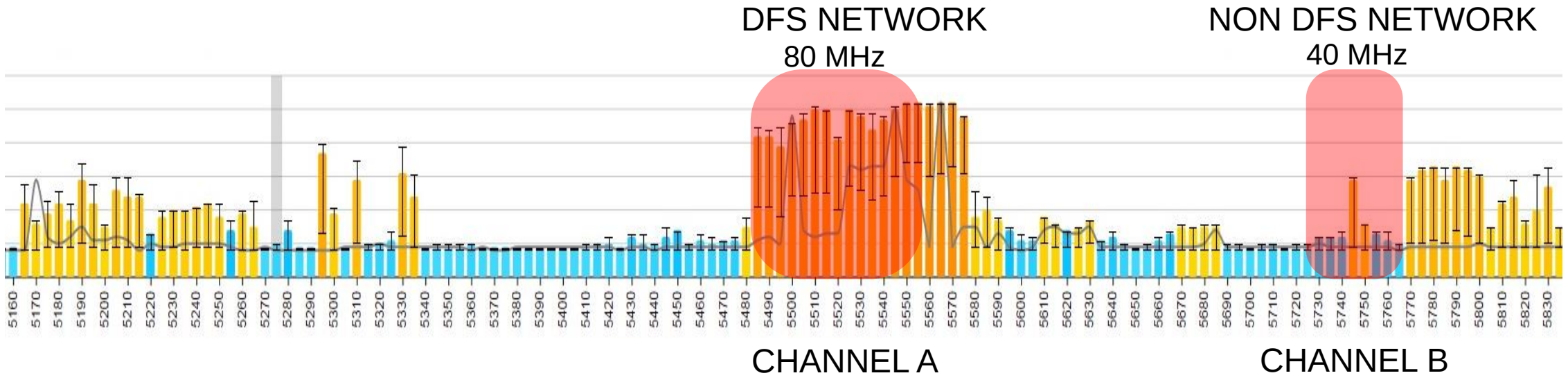


DFS Network & Non-DFS Network



CHANNEL A: DFS NETWORK
CHANNEL B: NON-DFS NETWORK

All traffic gets rerouted in case of DFS HIT from Channel A to Channel B, after DFS is resolved, radio is restored to original state of shared traffic between CHANNEL A & B



PTP 550 : KEY DIFFERENTIATING FEATURE

- 1.36 Gbps Headline Throughput
- Asymmetric non adjacent Channel Bonding (Scenario Below)
  - DFS and Non-DFS
  - Aggressive and Resilient Network
- Asymmetric modulation between two channel
- Link Resilience:
  - Only 1 channel can move during DSO, hence link is always established
- Small form factor and Metal enclosure : Durable
- SPF port :
  - Commercial and Residential complex have fiber built in, hence easier to deploy
- ARQ supported

PTP 450i: Comprehensive Network solution

Max Throughput : 300+ Mbps @ 40 MHz channel
Multiple band options, including 900MHz, 3300 – 3900 MHz and 4900 to 5925 MHz with high processing power
Dynamic Filtering for optimal performance in high noise environments
Multi-function AUX port allowing to add camera, Wi-Fi hot spot, GPS Sync or alignment tone
ATEX/HAZLOC certified models for hazardous deployments

Frequency Bands/Channels

- 900 MHz, 3 GHz, 4900 – 5925 MHz
- 5, 7, 10, 15, 20, 30, 40 MHz

Aggregate Capacity

- Up to 300 Mbps

Interfaces

- 1 x Ethernet 100/1000 BaseT with PoE
- 1 x Ethernet 100/1000 BaseT AUX Port with PoE Output

Adaptive Modulation

- QPSK to 256QAM

Latency

- 3 – 5ms

Ouput Power & Antenna Gain

- 27 dBm combined output power
- 23 dBi integrated antenna

Physical and Security

- 128-bit AES, HTTPS and SNMPv3
- All metal enclosure, IP 67

PTP 450i: ATEX AND HAZLOC CERTIFIED

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

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

PTP 450i : KEY DIFFERENTIATING FEATURE

- 300 Mbps Headline Throughput
- Narrow Channel Bandwidth supported including 5/10/15 MHz
- Dynamic Filtering for optimal performance in high noise environments
- Aux Port Supported can support
  - Wi-Fi Hotspot
  - Camera
  - GPS Sync
- Single platform multiple solution
  - PMP 450i
  - PTP 450i
  - Public Safety (4.9 GHz)
  - ATEX/HAZLOC
- ARQ supported

PTP 450 900 MHz

- Excellent Propagation and Range
  - Up to 122 miles (200 km) in 10MHz channel
- Performance
  - 902-928 MHz ISM band
  - 5, 7, 10 or 20 MHz channels supported
  - 25 dBm maximum Tx power
  - 2x2 MIMO design
  - Up to 130 Mbps in 20 MHz channel
- Power – 30VDC PoE
- Optional 12 dBi Yagi Antenna
  - Dual slant polarization
  - 40° beam width, 41” in length
  - Cables to connect to the ODU

PTP 670 : Field Proven Reliability

Support both PTP and HCMP (High Capacity MultiPoint)
450 Mbps Full Capacity by Default
Dynamic Spectrum Optimization (DSO) enables to continually scan the band for low interference channels
i-OFDM (intelligent Orthogonal Frequency Division Multiplexing) transmits over 1024 sub-carrier and results in high resilience to multi-path interference
Supports Non Line-of-Sight (NLOS) applications
Supports SyncE and 1588v2 Transparent Clock

Frequency Bands/Channels

- 4.9 GHz to 6.05 GHz
- 5, 10, 15, 20, 30, 40, and 45 MHz channels

Aggregate Capacity

- 450 Mbps, with 900k PPS

Interfaces

- 1 x Ethernet 100/1000 BaseT with PoE
- 1 x Ethernet 100/1000 BaseT with 802.3at PoE Output
- 1 x SFP slot port
- 8 x T1/E1 support with external Network Indoor Unit (NIDU)

Adaptive Modulation

- BPSK to 256 QAM

Latency

- 1 – 3 ms

Output Power & Antenna Gain

- 27 dBm combined output power
- 23 dBi integrated antenna

Physical and Security

- 128-bit and 256-bit AES, HTTPS and SNMPv3
- All metal enclosure, IP67

COMPARISON PTP 650 vs PTP 670

PTP 650

$ 3495

$ 2500

PTP 670

HOW TO SETUP BACKWARD COMPATIBILITY

FIRMWARE 650-01-44

PTP 650

FIRMWARE 670-01-44

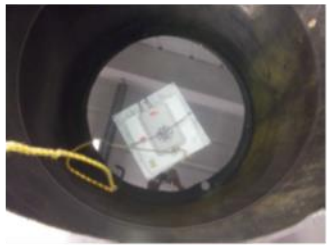
PTP 670

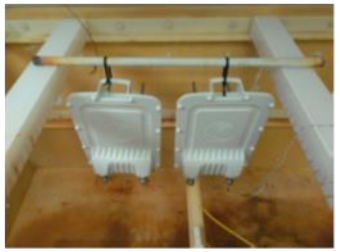
COMMON QUESTIONS:

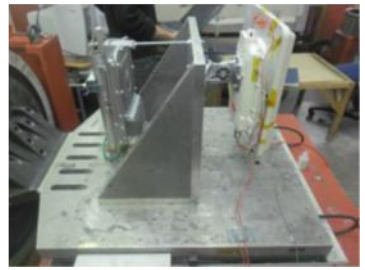
- Is PTP 670 backward compatible with PTP 600 ?
  NO, it is not compatible
- Is PTP 670 backward compatible with PTP PTP650, 650S & 650L ?
  Yes, it is compatible
- Can we have 2 PTP 650 with one firmware on 650-01-44 and another as 650-01-43 ?
  YES, it can be configured this way
- When is this backward compatible Firmware releasing ? *Already released and available on Website*
- Is there is special price for this firmware ?
  NO, this firmware is free
- Will this specific firmware be upgrade to tip of firmware eventually ?
  NO, there will be no development firmware releases

Designed for Harsh Environments

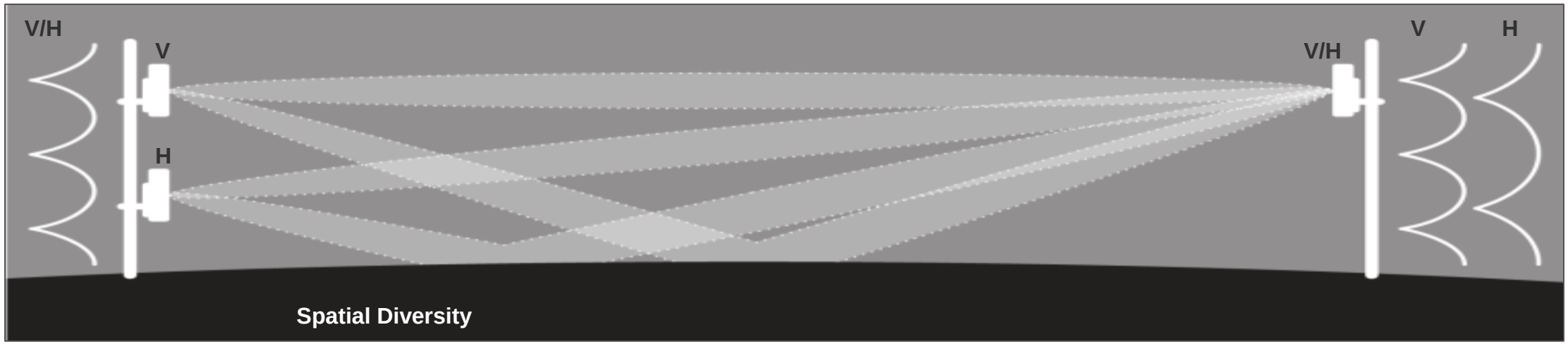
- Wind Survival
  - 200 mph survivability
- Dust / Water Intrusion (IP66/67)
  - Water jets from any direction
  - Immersion in 1 m water
  - Dust tight
- Salt Fog Environment (MIL-STD-810G)
  - Tests resistance to corrosion if face of extended exposure to salt spray
- Shock / Vibration (MIL-STD-810G)
  - Handling, transportation, long-term deployment







SPATIAL DIVERSITY



IDEAL OVER WATER AND FLAT TERRAIN

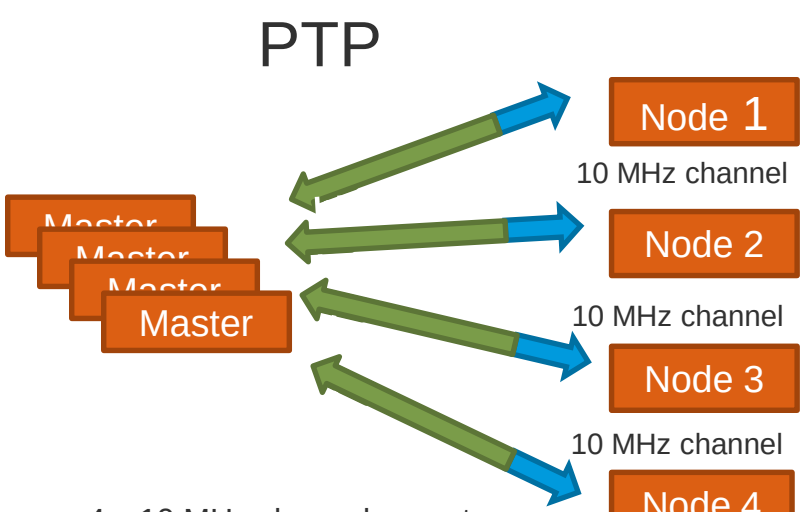
Wireless signals across water or hard surfaces (desert) pose performance and reliability challenges:

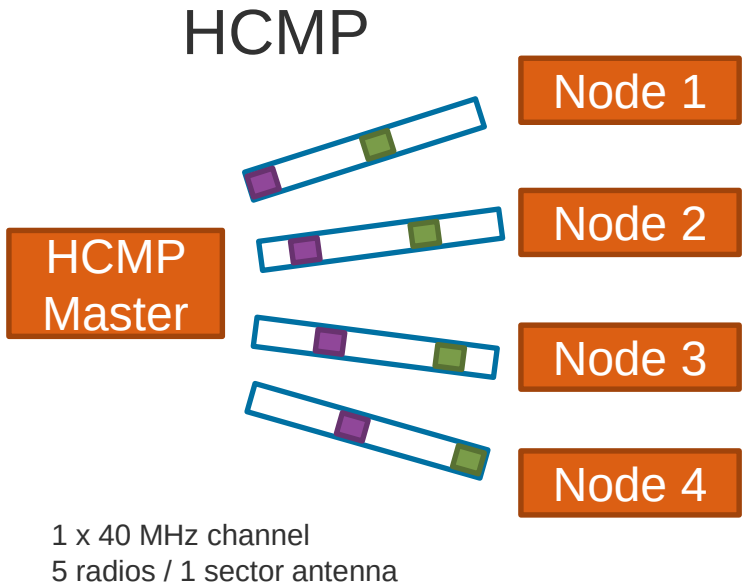
- Highly reflective surfaces create multi-path interference
- Varying water heights create over-sea challenges

Spatially diverse antennas can mitigate the ducting and fading that is typical over water and desert.

HCMP: How does it work ?

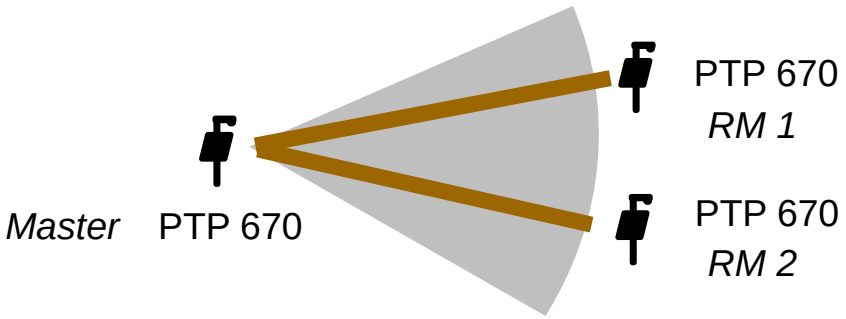
Application Requires: Four HD Camera clusters each requiring 60 Mbps





- HCMP uses:
  - 37% fewer radios
  - less tower load
  - less power
  - fewer antennas
  - simplified alignment

HCMP Mode: Explained

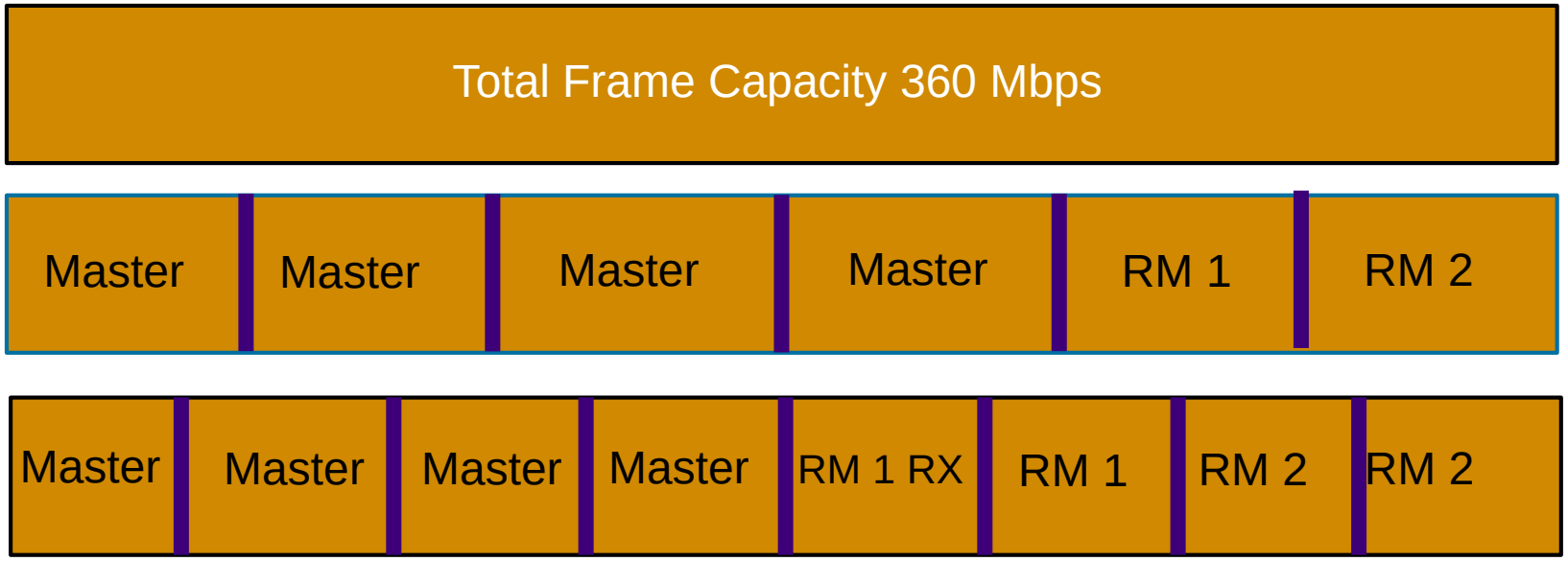


GRAY: TX FREQUENCY
BROWN: RX FREQUENCY

SCENARIO:

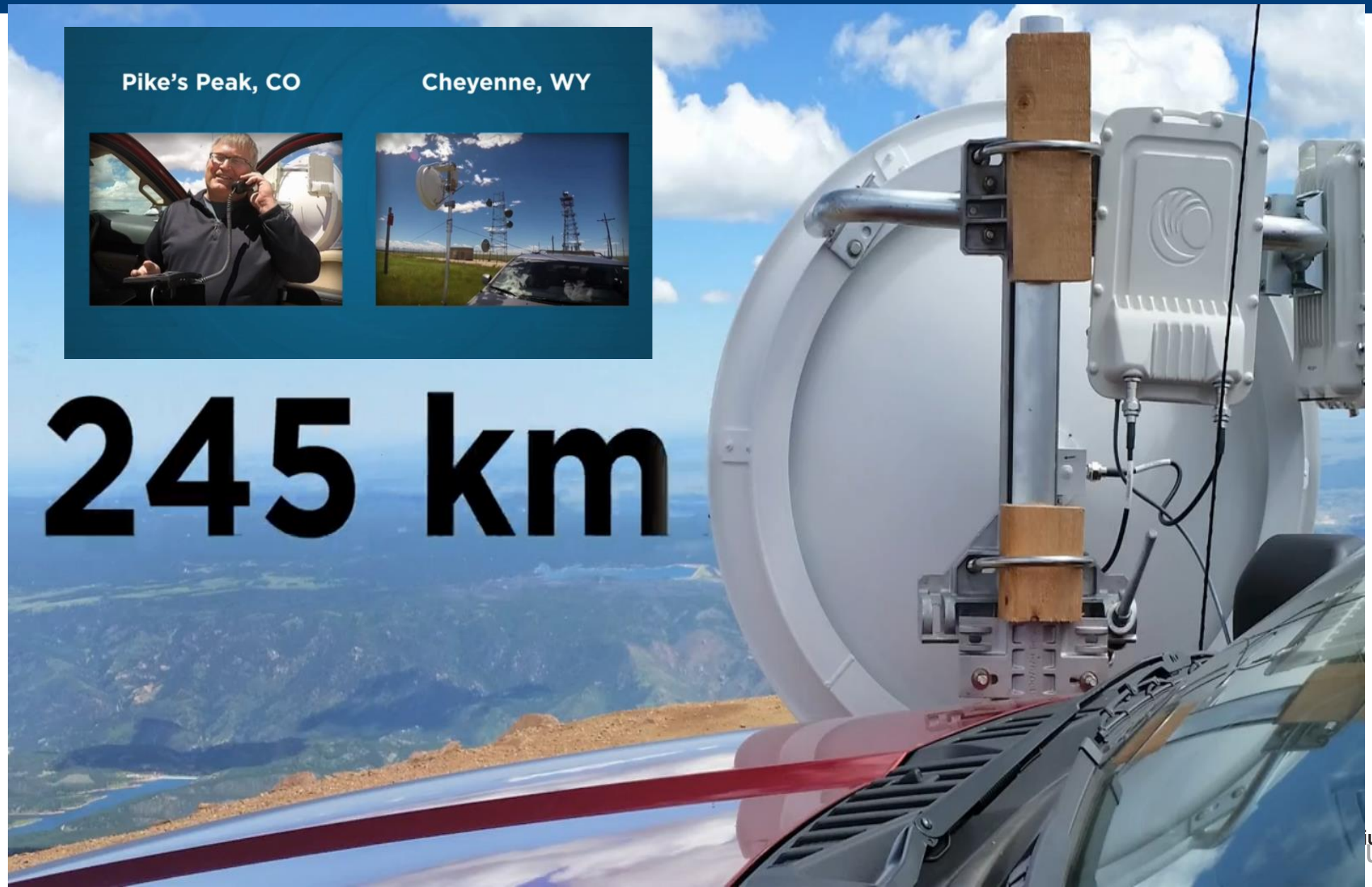
HCMP MASTER: 1
CONNECTORIZED PTP 670 + SECTOR ANTENNA

REMOTE NODES:
TWO INTEGRATED PTP 670



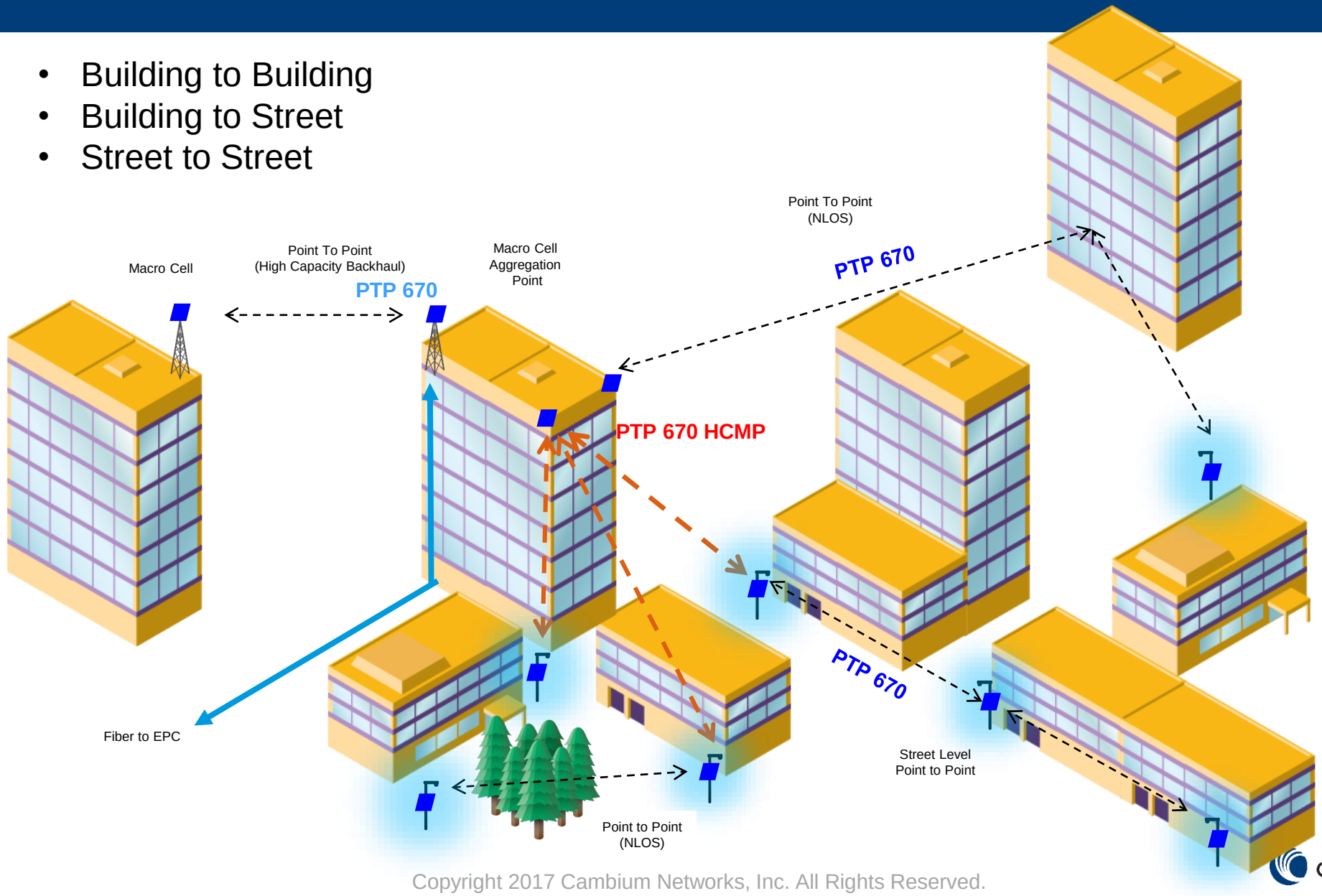
*RN: Remote Node
*M : Master

Longest Link on Record !



HCMP Deployment Scenarios

- Building to Building
- Building to Street
- Street to Street



PTP 670 : KEY DIFFERENTIATING FEATURE

- 450+ Mbps Headline Throughput
- Best Spectral efficiency (Maximum Bang for your Buck): 10.1 bits/Hz
- Narrow Channel Bandwidth supported including 5/10/15 MHz
- 850K Packets per second processing ideal for Backhaul solution
- HCMP (High Capacity Multi-Point) supported
- Topline security features
  - OTAR (Over the Air Rekeying)
  - AES 128/256 Encryption
  - Encrypt security parameters
  - Un-used port lock down
  - Multiple Level Access
- Flexibility and Versatility built into Radio
  - Split frequency
  - Adaptive duty cycle
  - Supports IEEE 1588v2 and SyncE

Quick Deploy Positioner

- Applications
  - First responders (public safety / national guard / CIVLEA)
  - Rapid tactical deployment (DoD)
  - Oil/Gas re-alignment after re-location of mast head
  - Cell on wheels / temporary deployments
- Eliminates need for on-site techs
- Tightly integrated all-outdoor solution
- Goes live in <3 minutes
- Compatible with PTP 650, 700, 450i, and PMP 450i

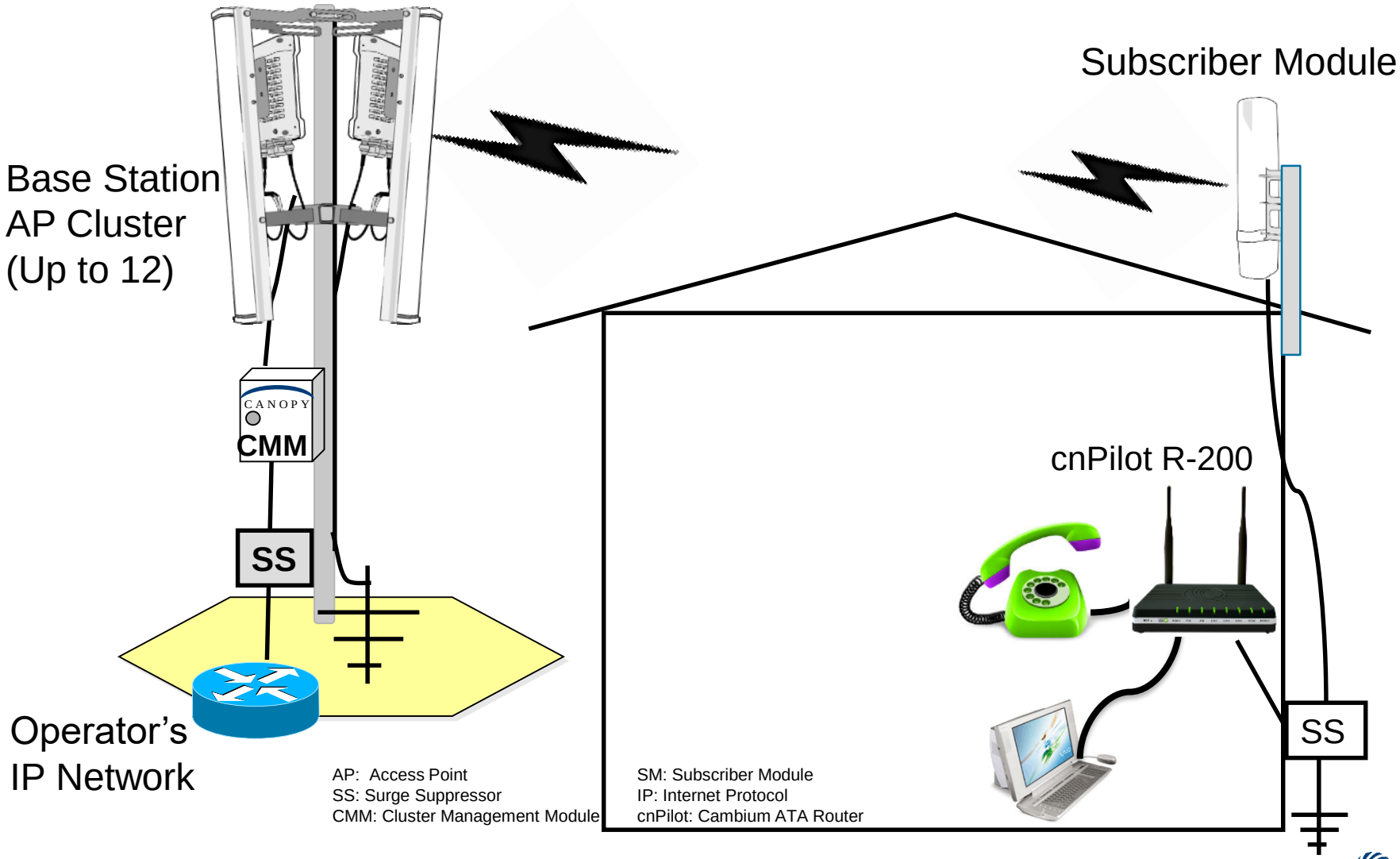
PTP 450i vs PTP 550 vs PTP 670

RADIO COMPARISON	PTP 450i	PTP 550	PTP 670
Frequency Range	4.9 to 5.925	5.15 to 5.95 Ghz	4.9 to 6.05 Ghz
Top Line Throughput	300 Mbps	1.36 Gbps	450 Mbps
Channel BW Supported	5/10/15/20/30/40 MHz	2X 20/40/80 MHz(Up to 160 MHz)	5/10/15/20/30/40/45 MHz
Efficiency	7.5 bit/Hz	8.5 bits/Hz	10 bit/Hz
Packet Processing per second	45 K pps	100 K pps	850 K pps
Antenna Gain	23 dBi	23 dBi	23 dBi
Max Tx Power	27 dBm	27 dBm	27 dBm
Latency	3-5 ms	3-6 ms	1-3 ms
QOS	3 Level /Diffserve 802.1q	3 Level	8 Level
Aux Port	Yes	No	Yes
SFP Port	No	Yes	Yes
Live spectrum analyzer	No	Yes	Yes
Sync-E	No	No	Yes
ARQ	Yes	Yes	No
Range	125 Miles	40 Miles	155 Miles
IEEE 1588 V2	No	No	Yes
IPv6	Yes*	Yes	Yes
DSO Feature	No	Yes	Yes
HCMP	No	No	Yes
Encryption	AES 128/AES 256*	AES 128	AES 128/ AES 256
Max Frame Size	1500	1700	9600
IP Rating	IP67	IP67	IP67

*Roadmap

Multipoint Distribution – PMP 450

Applications: PMP 450 Series Residential



PMP 450i

- Ultra Wide-band 900MHz, 4900-5925 MHz; 3300 – 3900 MHz
- Enhanced Performance
  - Dynamic interference filtering
  - Increased transmit power
  - Better receive sensitivity
- Rugged IP66/67 Enclosure
- Agile
  - 802.3at PoE compatible
  - Auxiliary port with PoE output
  - 5, 10, 15, 20, 30 and 40 MHz channel

PMP 450: Access Point Options

Evolution of Platform →

450 AP

450i AP

450m AP

PMP 450: Subscriber Module Options

Antenna Options

Integrated Antenna

CLIP (5 GHz only)

Reflector Dish

Connectorized SM

PMP 450d

450i Connectorized

450i Integrated High Gain

Wideband SM - July/Aug

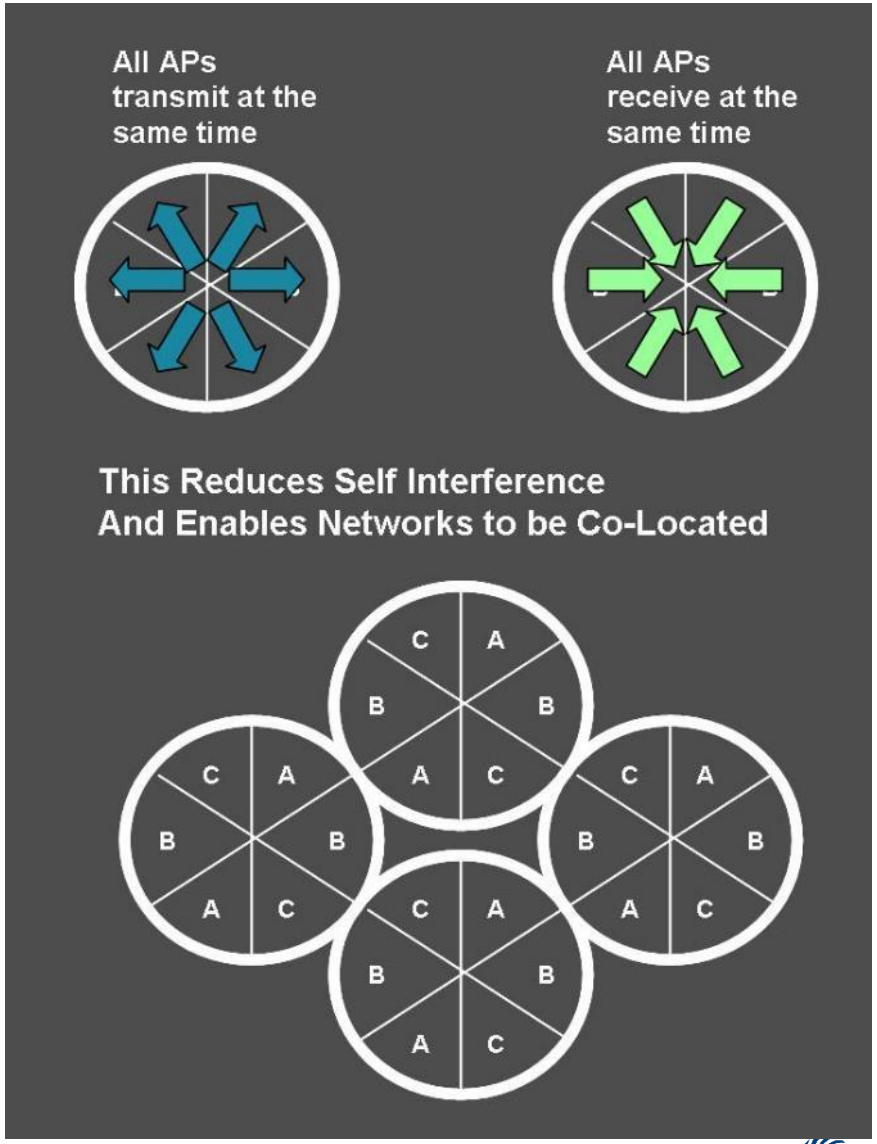
- **Two Form Factors:**
  - Integrated mid-gain antenna (17 dBi) similar to Force 180
  - High Gain integrated antenna (25 dBi), similar to Force 200
- **New FPGA / SoC architecture**
  - Next-gen processor, **Enhanced Packet Processing**
  - Better support for wider channels → more throughput
  - **Wideband support (4.9 – 5.925 GHz)**
- **I/O changes**
  - Single **Gigabit** Ethernet port
  - Audio jack for alignment tone
- **Re-use of 30 VDC Power scheme**
  - Same power supply as current 450 SM
  - Polarity Agnostic – Can use “Canopy” or “UBNT” 30 VDC PSU
- **Expected Prices (MSRP):**
  - $299 for mid-gain version
  - $349 for Integrated dish version

Available in July, 2017

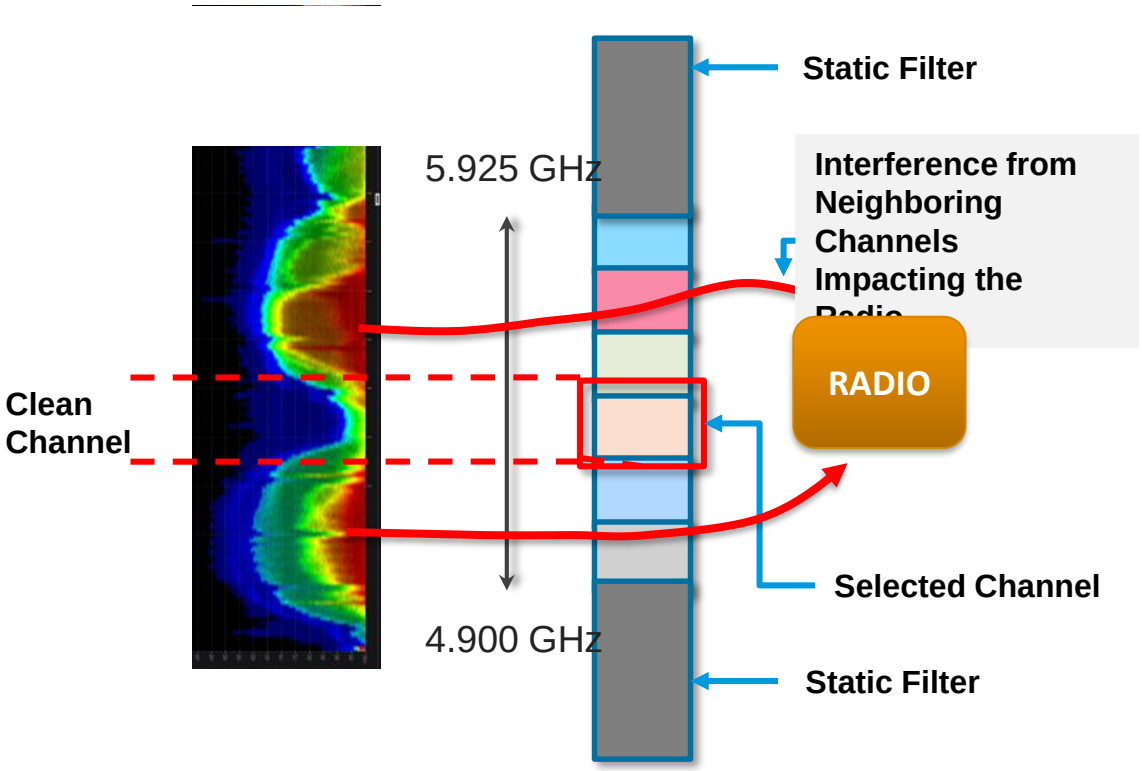
Available in Aug, 2017

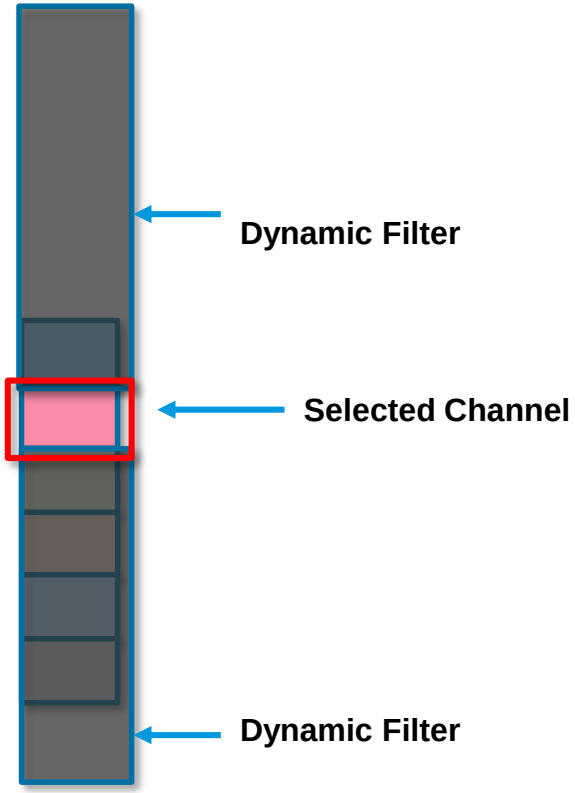
GPS Synchronization

- AP and SM communication is synchronized (all APs and SMs have controlled alternating communication) – reducing self interference
  - All SMs within a network
  - All APs within a cluster
  - All APs on a tower (multiple clusters)
  - All APs on all towers in the network
- Enables channel re-use and easy to deploy multi-sector, multi tower networks (minimal tower separation)
- Use the same number of channels to serve a higher number of users



Dynamic Interference Filtering Technology





Spectrum

Traditional Fixed Filter

Makes radio susceptible to neighboring channel interference

Cambium's Dynamic Filtering

Wraps around selected channel, filtering out interference from neighboring channels

PMP 450i 900 MHz Overview

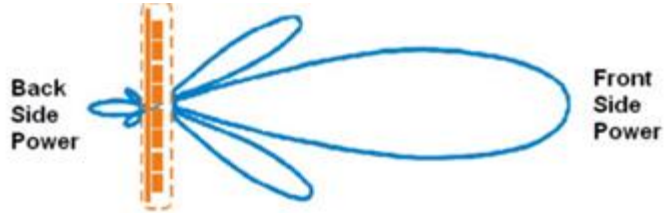
- **900 MHz ISM band Operation**
  - 902-928 MHz
  - 5, 7, 10 or 20 MHz channels supported
- **2x2 MIMO design**
  - Allows higher capacity
- **Power Scheme - New for AP, Same for SM**
  - AP will be 802.3at PoE compatible (56 VDC)
  - SM will be 30 VDC, and can **re-use existing PSU**
- **Next Generation Architecture**
  - **Utilizing PMP 450i architecture**
  - Maximize Spectral efficiency
    - Using GPS timing and colocation with PMP 100 900 MHz
- **Product Design Goal**
  - Under similar RF conditions, similar channel size, **3x - 4x PMP 100**
  - 4 Mbps capacity to **12-16 Mbps capacity**
  - In clean spectrum, **PMP 450 900 MHz can provide 100+ Mbps per sector**

Cambium 900MHz Antennas

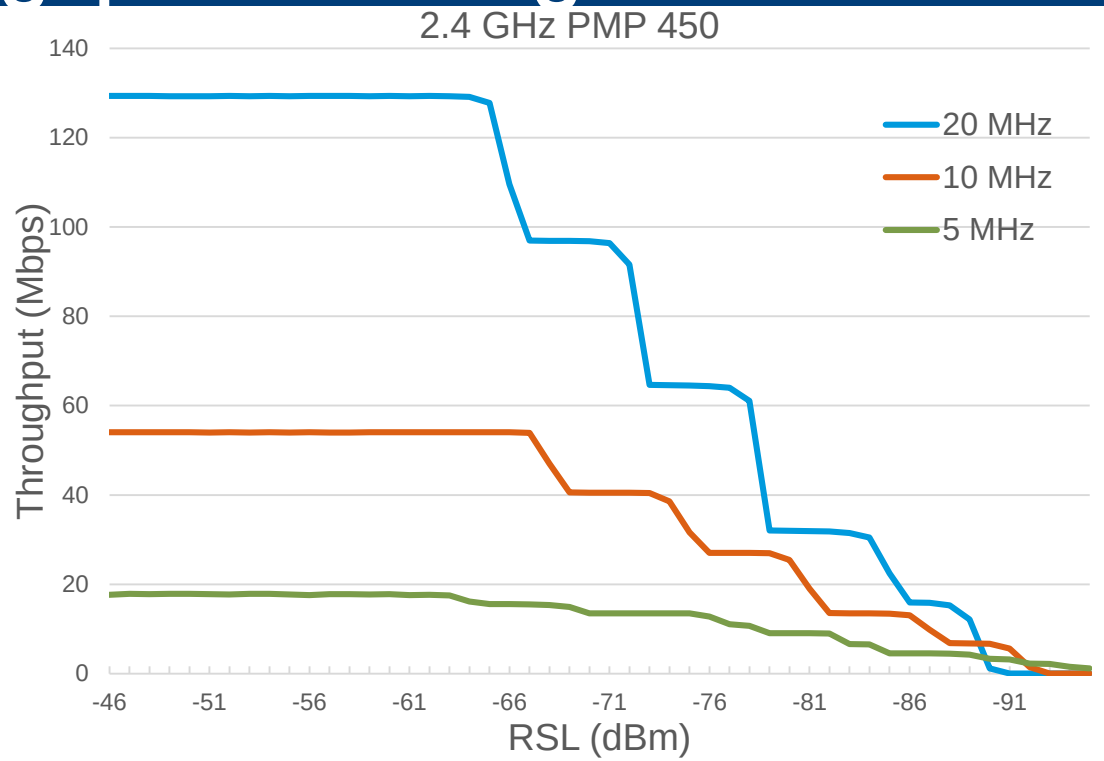
- Performance Differentiation
  - Dual slant polarization system to isolate from Vertical or Horizontal deployments
  - High Front to Back ratios to allow Frequency Re-use and high Spectral Efficiency

- SM Yagi Antenna
  - Dual slant
  - 40° beam width
  - 41” in length
  - Cables to connect the SM

- AP Sector Antenna
  - 902-928 MHz
  - 65 degree (3 dB beam width)
  - Can be used for 60 or 90 degree sector
  - Front/Back Ratio: > 32 dB
  - 35” x 11” x 5”
  - AP radio mounts to back of antenna



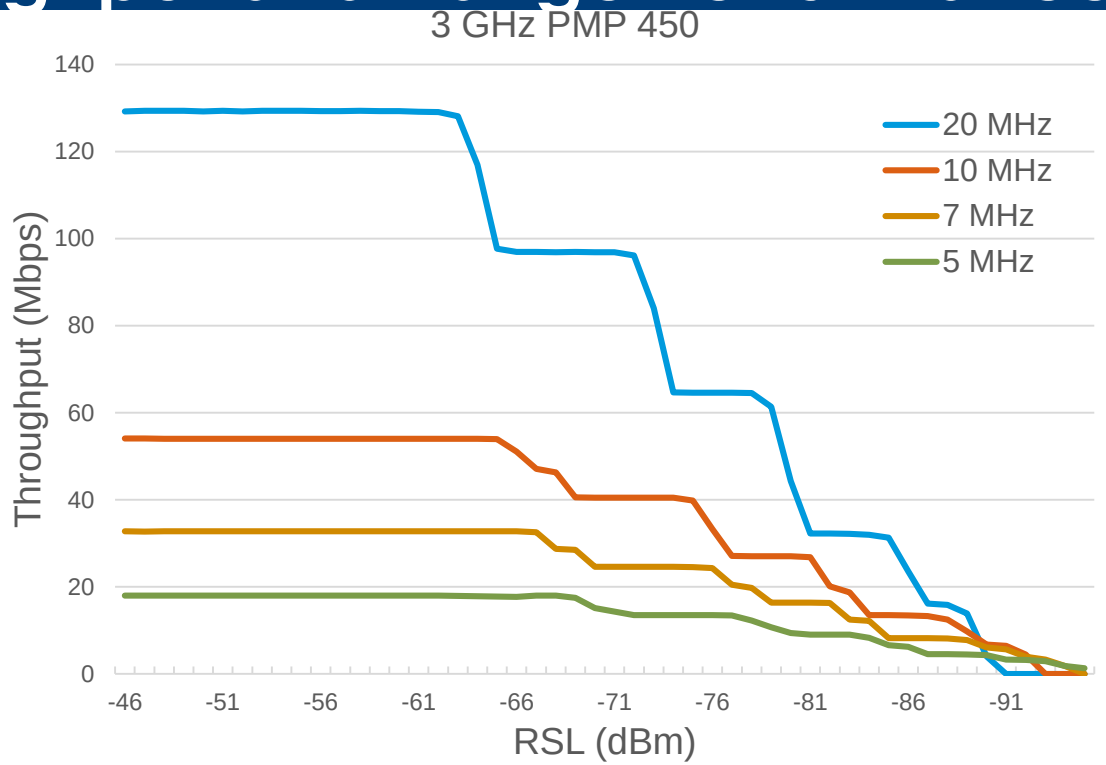
PMP 450 @ 2.4 GHZ
Throughput and Range Performance



Modulation Mode	Sensitivity (dBm)	T-put (Mbps)	CNR (dB)
256QAM (8x)	-66	125	32
64QAM (6X)	-73	90	24
16QAM (4X)	-79	60	17
QPSK (2X)	-86	30	10
QPSK (1X)	-86	15	8

20 MHz Channel -- Maximum LOS range mi (km)			
Frequency Band	Modulation	Integrated (7 dBi)	Offset Reflector (19 dBi)
2.4 GHz	256QAM (8X)	1.7 (2.8)	6.8 (11)
	64QAM (6X)	3.6 (5.8)	14.3 (23)
	16QAM (4X)	7.6 (12)	30 (49)
	QPSK (2X)	16 (25)	40 (64)
	QPSK (1X)	22 (36)	40 (64)

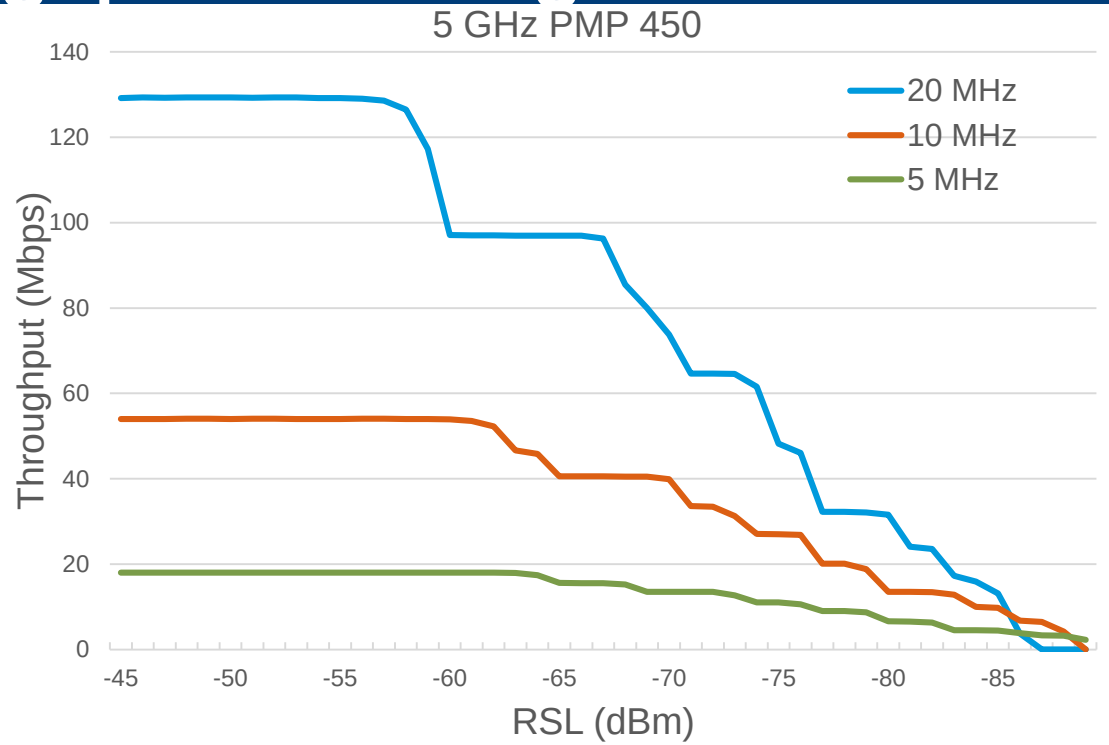
PMP 450 @ 3 GHZ
Throughput and Range Performance



Modulation Mode	Sensitivity (dBm)	T-put (Mbps)	CNR (dB)
256QAM (8x)	-65	125	32
64QAM (6X)	-72	90	24
16QAM (4X)	-78	60	17
QPSK (2X)	-85	30	10
QPSK (1X)	-85	15	8

20 MHz Channel -- Maximum LOS range mi (km)			
Frequency Band	Modulation	Integrated (8 dBi)	Offset Reflector (19 dBi)
3 GHz	256QAM (8X)	0.8 (1.3)	3 (4.6)
	64QAM (6X)	2 (3.3)	7.2 (11.6)
	16QAM (4X)	4.5 (7.3)	16 (26)
	QPSK (2X)	11 (18)	40 (64)
	QPSK (1X)	16 (26)	40 (64)

PMP 450 @ 5 GHZ
Throughput and Range Performance



Modulation Mode	Sensitivity (dBm)	T-put (Mbps)	CNR (dB)
256QAM (8x)	-61	125	32
64QAM (6X)	-72	90	24
16QAM (4X)	-78	60	17
QPSK (2X)	-84	30	10
QPSK (1X)	-84	15	8

20 MHz Channel -- Maximum LOS range mi (km)					
Frequency Band	Modulation	Integrated (9dBi)	CLIP (17dBi)	Offset Reflector (24dBi)	PMP 450d (25dBi)
5.8 GHz	256QAM (8X)	0.3 (0.6)	1 (1.6)	2 (3.1)	2.2 (3.5)
	64QAM (6X)	1.1 (1.8)	3.2 (5)	6.3 (10.2)	7 (11.3)
	16QAM (4X)	2.3 (3.6)	6.3 (10.2)	12.6 (20)	14 (23)
	QPSK (2X)	5 (8)	14 (22.5)	28 (45)	31 (50)
	QPSK (1X)	7 (11.3)	20 (32)	40 (64)	40 (64)

450i SYNC Options

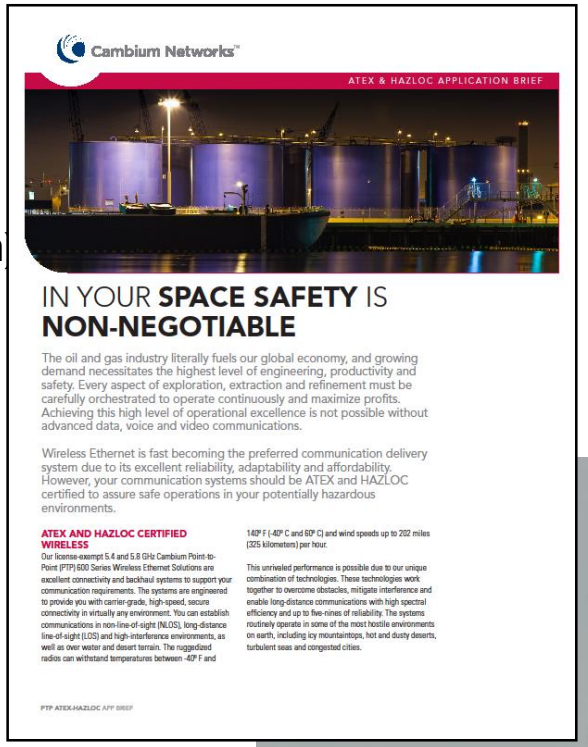
Device	Capabilities	Requirements
CMM4 – 1090CKHH, 1091HH, 1092HH	Power and SYNC Mixture of 450i, 450, 100	56V power supply RJ-45 Adaptor cables
CMM5 – C000000L556A	Supports GigE Mix 650, 450i, 450	56VDC Power Supply
UGPS Module – 1096H	SYNC	RJ-45 cable to AUX Port

CMM5

UGPS

ATEX / HAZLOC Oil & Gas Applications

- Target Markets:
  - PetroChem
  - Utility (Generation and Transmission)
  - Defence
- Solution:
  - PTP/PMP 450i Series
  - 4.9 to 5.925 GHz
  - ATEX and HAZLOC Compliant
  - Dedicated SKUs
- Value Proposition
  - Universal radio for all applications
    - Non LOS
    - Over Water
    - Over long distance
    - High RF interference
  - Avoid expensive NEMA
  - Established field reliability
  - Easy to plan and install link


Cambium Networks™

ATEX & HAZLOC APPLICATION BRIEF

IN YOUR **SPACE SAFETY** IS **NON-NEGOTIABLE**

The oil and gas industry literally fuels our global economy, and growing demand necessitates the highest level of engineering, productivity and safety. Every aspect of exploration, extraction and refinement must be carefully orchestrated to operate continuously and maximize profits. Achieving this high level of operational excellence is not possible without advanced data, voice and video communications.

Wireless Ethernet is fast becoming the preferred communication delivery system due to its excellent reliability, adaptability and affordability. However, your communication systems should be ATEX and HAZLOC certified to assure safe operations in your potentially hazardous environments.

ATEX AND HAZLOC CERTIFIED WIRELESS

Our license-exempt 5.4 and 5.8 GHz Cambium Point-to-Point (PTP) 600 Series Wireless Ethernet Solutions are excellent connectivity and backhaul systems to support your communication requirements. The systems are engineered to provide you with carrier-grade, high-speed, secure connectivity in virtually any environment. You can establish communications in non-line-of-sight (NLOS), long-distance line-of-sight (LOS) and high-interference environments, as well as over water and desert terrain. The ruggedized radios can withstand temperatures between -40° F and 140° F (-40° C and 60° C) and wind speeds up to 202 miles (325 kilometers) per hour.

This unrivaled performance is possible due to our unique combination of technologies. These technologies work together to overcome obstacles, mitigate interference and enable long-distance communications with high spectral efficiency and up to five-nines of reliability. The systems routinely operate in some of the most hostile environments on earth, including icy mountaintops, hot and dusty deserts, turbulent seas and congested cities.

PTP ATEX-HAZLOC APP BRIEF

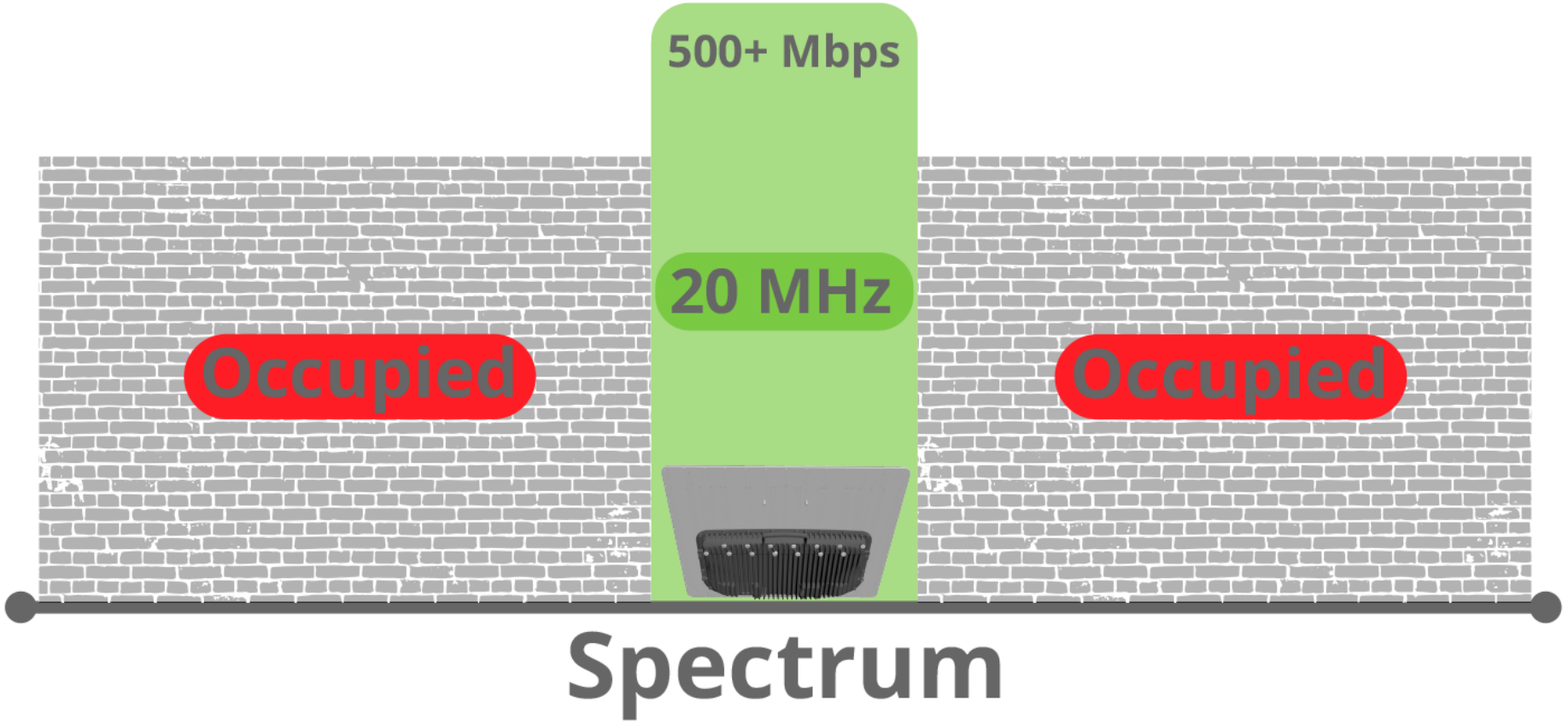
Go MASSIVE

cambiumnetworks.com/gomassive

Cambium Networks™

Why Go Massive Now?

Why not Just Increase Channel Size?



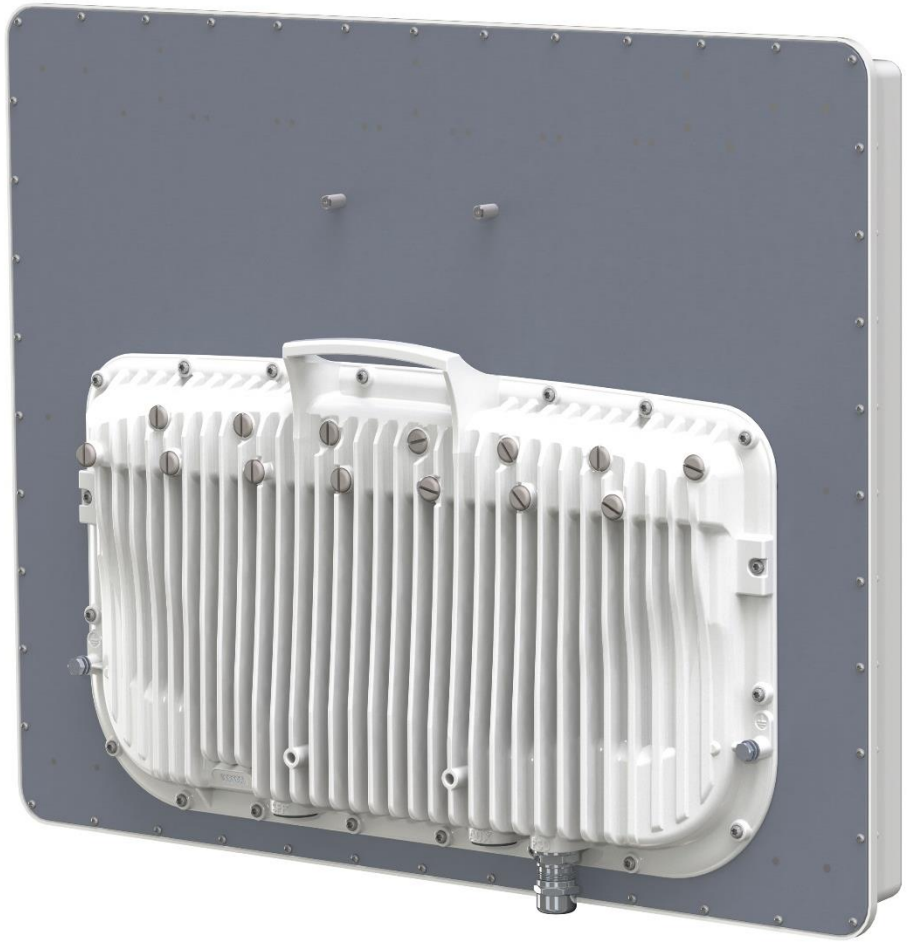
MU-MIMO Technology

- Typical multiplexing techniques divide the two critical resources “Frequency (channel)” or “Time” among multiple users
  - FDMA (Frequency Division Multiple Access)
  - TDMA (Time Division Multiple Access)
  - CDMA (Code Division Multiple Access)

- MU-MIMO adds spatial multiplexing (SDMA)
  - Various users (subscriber modules) are at different locations and directions
  - MU-MIMO uses all available frequency and time to communicate with multiple users simultaneously

PMP 450m

- Massive MU-MIMO technology
- Industry leading spectral efficiency
  - Delivers 500 Mbps throughput in a 20 MHz channel
- Links with up to 7 SMs simultaneously
- Increases sector capacity by 3 – 4X
- Improved performance in high interference
- Uses current PMP 450 SMs



MU-MIMO Operation ---- this is 5G!!!

1. The access point identifies which subscribers are connected
2. Sounding collected from each SM
3. The antenna array forms a narrow beam covering the subscriber of interest and uses it to transmit and/or receive data
4. This process can occur simultaneously for multiple SMs

Bridging the Digital Divide

- **Problem**:
  - National Broadband Plan in Ireland requires rural coverage
  - Fiber too costly
- **Solution**: *cn*Medusa
- **Results**: Able to offer high throughput (50 Mbps) packages and increase coverage area *without* forklift subscriber replacements

Cambium Networks™

Closing the Digital Divide in Ireland

"Prior to installation of the PMP 450m, customers were limited to 8-10 Mbps packages. We can now with confidence provide up to 50 Mbps speeds to customers."

- BARRY WILSON, COUNTRY MANAGER EURONA IRELAND

Challenge

EURONA IRL CONNECTS 3,200 BUSINESS and residential customers in Cavan, Longford, Roscommon, Leitrim, Galway in Ireland. The National Broadband Plan drafted in 2012, recognized the importance of closing digital divide in Ireland, but for many reasons businesses and residents in rural areas remain unconnected to high-speed broadband, and are unable to upload and download large files or stream videos for conference calls or entertainment. Given the disperse population density in rural areas, a wired or fiber technology would not be cost effective to install.

eurona Ireland

Wireless technology had the installation cost advantage, but could not deliver the capacity that subscribers needed - and Eurona IRL saw the opportunity to succeed. Experienced in offering wireless connectivity, they stepped up to the challenge.

Solution

"DUE TO THE HIGH DEMAND FROM CUSTOMERS and the data rich content on the internet, we have no choice but to move forward with our technology," said Barry Wilson, Country Manager Eurona Ireland. "The introduction of the Cambium Networks PMP 450m with cnMedusa™ technology came at the perfect time for us. With competition from other ISPs we can now move forward with confidence knowing we can provide next generation speed to our customers."

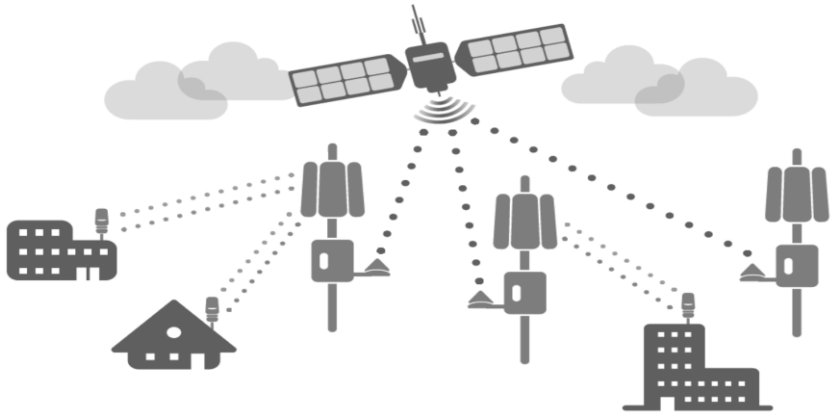
Multipoint Distribution - ePMP™

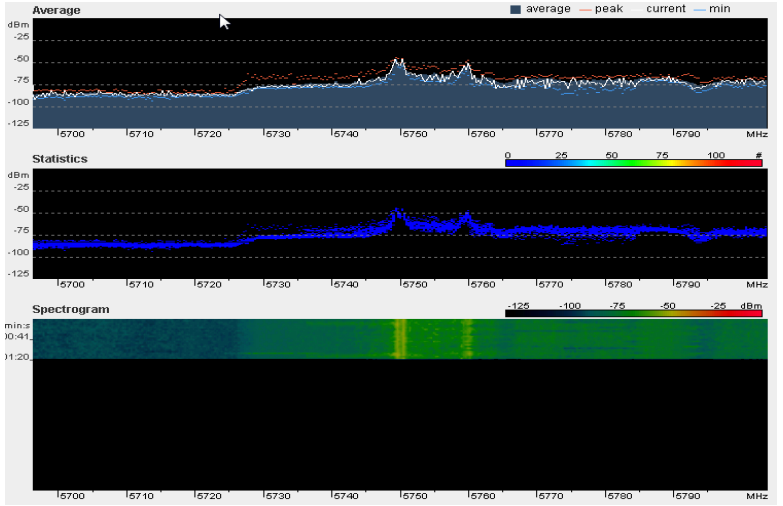
ePMP Key Applications

- High density enterprise access in tough interference environments
- High performance video surveillance network backhaul
- Cost-effective coverage in rural areas
- Easy-to-deploy WiFi backhaul

Superior Performance in Real World Conditions

- Unlicensed spectrum is congested!
- eFortify technology increases interference tolerance to provide higher performance and consistent latency under external interference
- GPS Synchronization provides a solid foundation for your network's deployment and growth
- Rate adapt algorithms adjust radio operation automatically to boost performance and resiliency
- Hypure:
  - Beam Steering
  - Channel Filtering.





ePMP Portfolio

Access Points

ePMP 2000
5 GHz
Full
Lite

ePMP 1000
5 GHz
2.4, 2.5 GHz
Full
Lite

ePMP 2000 Access Point with Intelligent Filtering

- Next Generation ePMP Access Point
- Frequency reuse via GPS synchronization
- Supports up to 120 SMs
- Available in Lite (10 SM) or Full models
  - License Key to upgrade Lite to Full
- 802.3at compliant gigabit Ethernet port
- Wide Frequency range: 5150 – 5970 MHz
- Intelligent Filtering to reduce impact of off-channel interferers
- Interface to optional Smart Antenna

ePMP 2000 Sector Antenna

- Frequency Re-use: 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 *e*PMP 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 Portfolio

Sector Antennas

5 GHz Sector Antenna
90 and 120 degree

2.4/2.5 GHz Sector
Antenna
90 and 120 degree models

ePMP 2000 Smart Antenna

- ePMP 2000 exclusive
- Enables Smart Beamforming
- Does not replace Sector Antenna (uplink only)
- Wide frequency range: 5150 – 5970 MHz

ePMP Portfolio

Subscriber Modules

Force 180
5 GHz

Force 200
5 GHz
2.4 GHz
2.5GHz coming

CSM
5 GHz
2.4, **2.5 GHz**

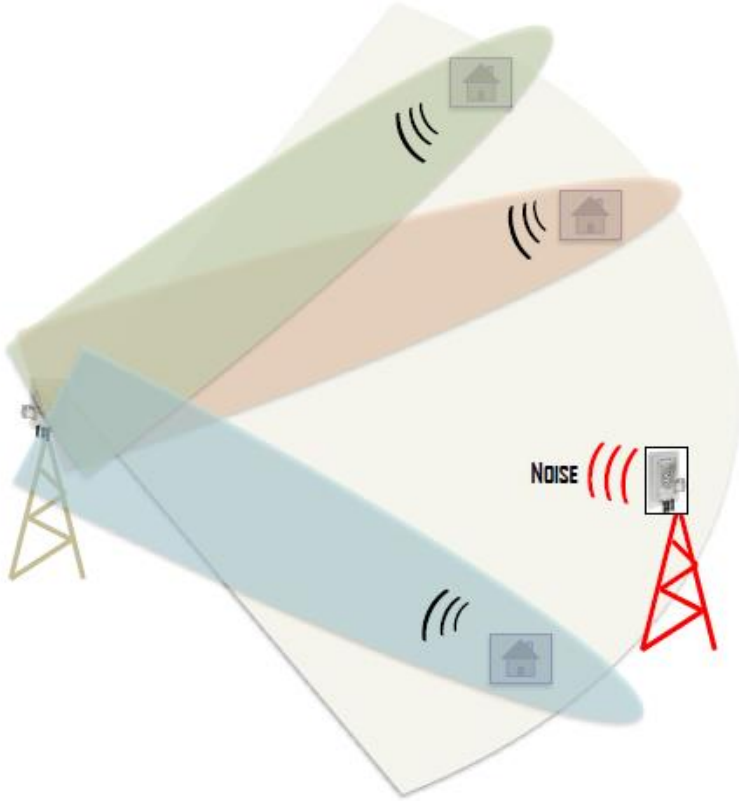
ISM
2.4 GHz

ePMP superiority

Hypure Technology

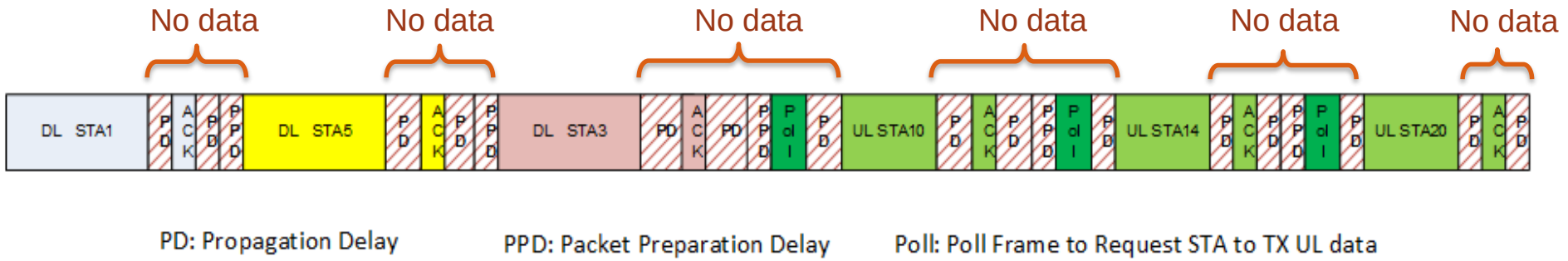
Hypure

- Superhet-like dynamic filter, working both in TX and RX chains
- Beam steering with smart antenna (UL only)



TDD/TDMA with sync

How competitive solutions work…



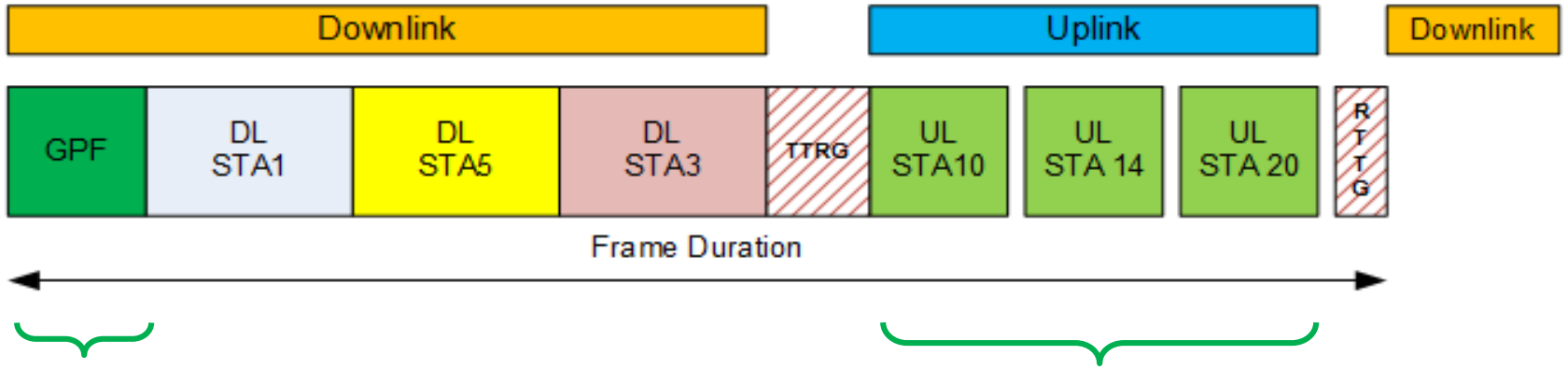
- Transmit and receive one STA at a time
- Propagation delay is compensated for each transmission. ACK/NACKs and retries occurring per Tx & Rx
- PD is incurred 3 times for each UL transmission (One for Poll and one for UL data and one for ACK)

<u>What does this mean?</u>

- 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

How it works in ePMP

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



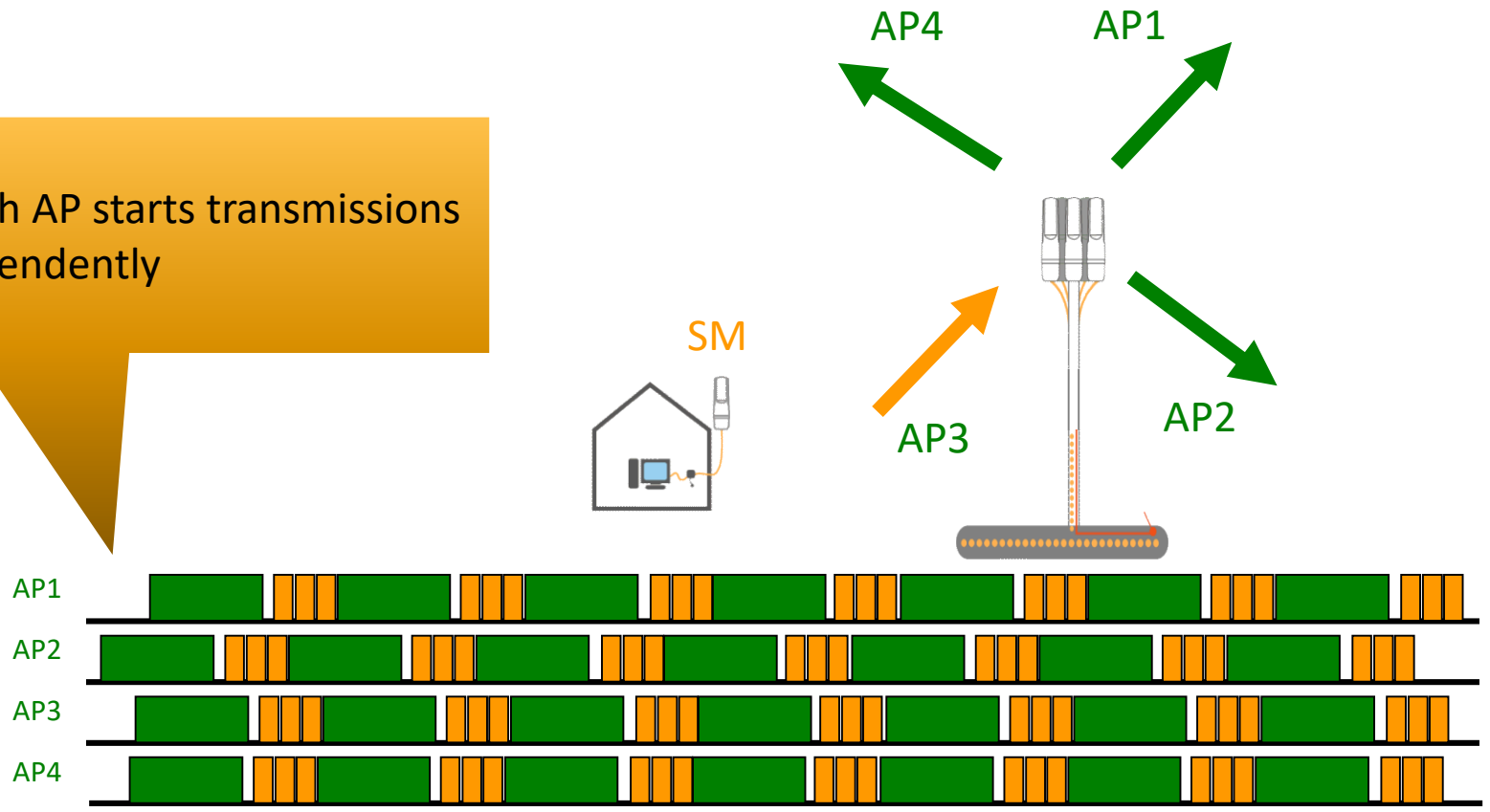
Broadcast message – the schedule to many SMs

Data, ACKs, Retries from different SMs scheduled and "tightly packed" in uplink

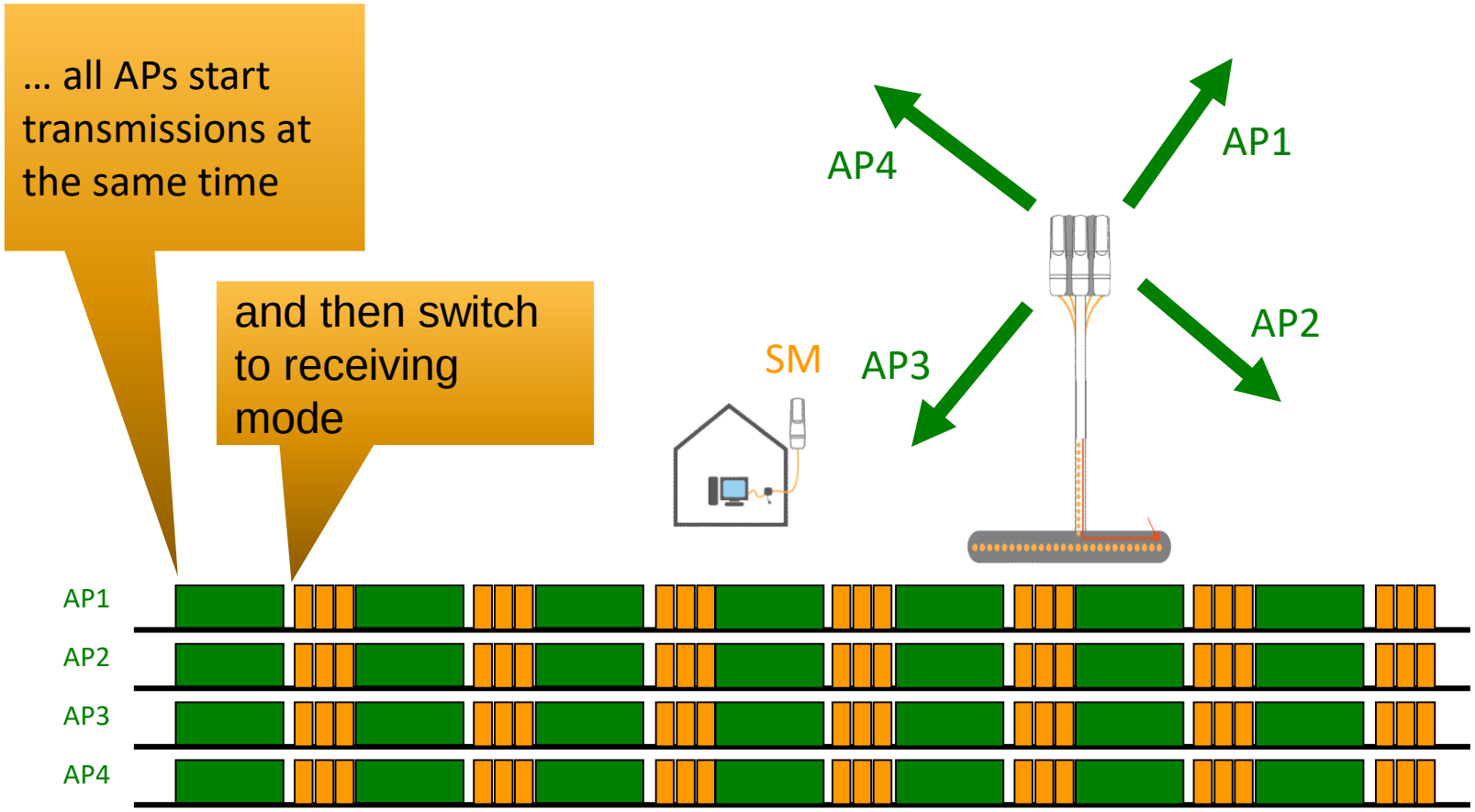
- Efficient Use of RF Capacity
- Allows for High SM Scalability
- Allows for Consistent Performance even in High Interference Environments

Without sync…

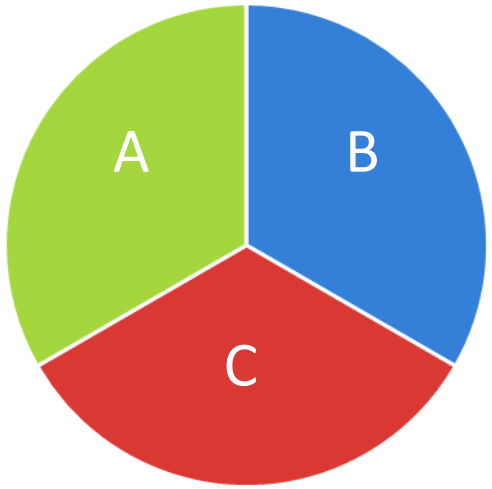
… each AP starts transmissions independently



With sync…

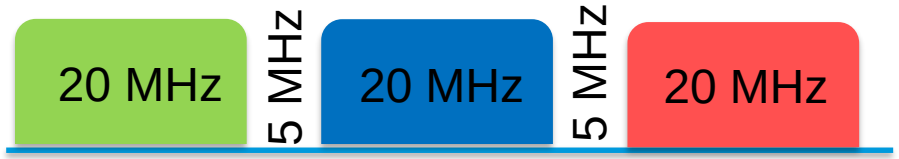

… all APs start transmissions at the same time
and then switch to receiving mode
AP4
AP1
AP2
AP3
SM
AP1
AP2
AP3
AP4

ePMP saves spectrum and money

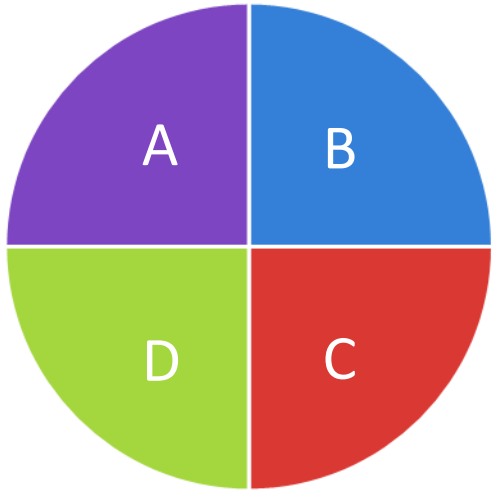


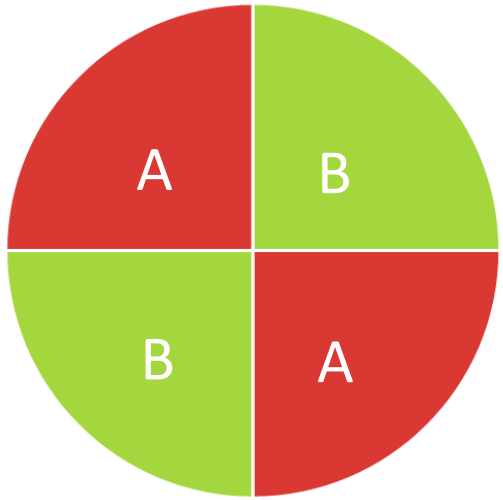
Competitors:

ePMP:

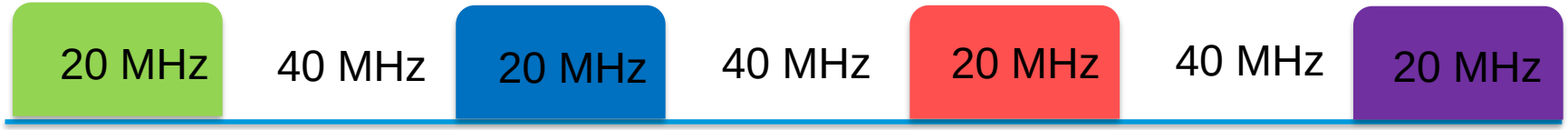


…and allows re-use the same frequency





Competitors:



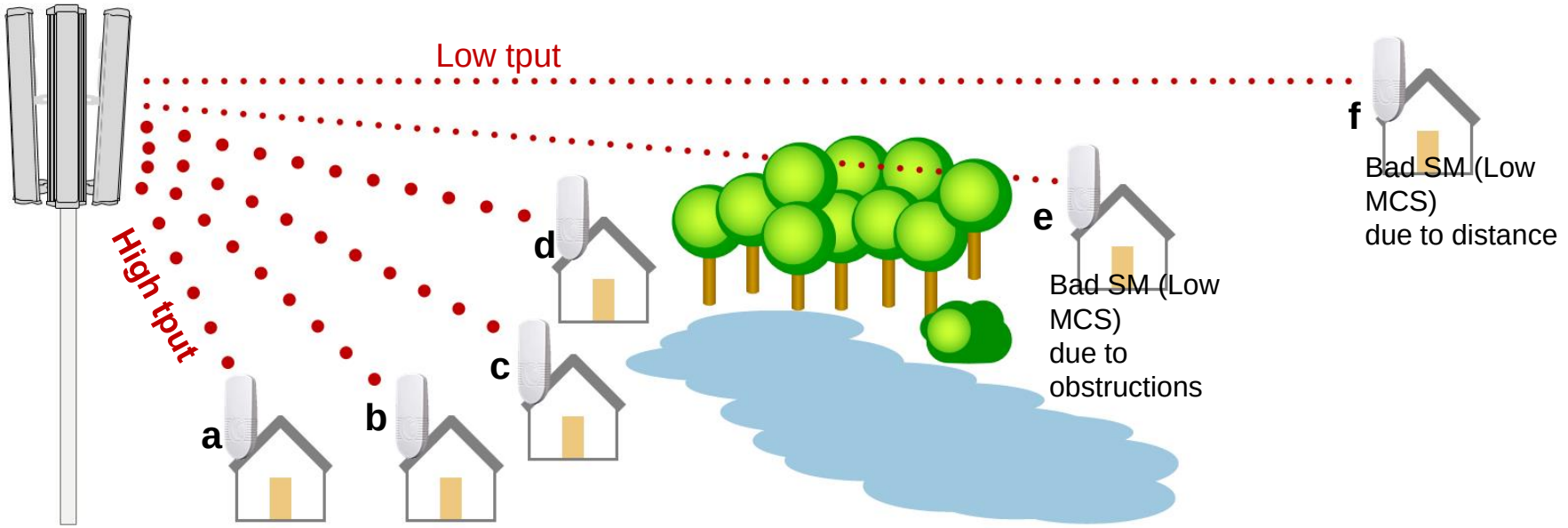
ePMP:

Benefits of Efficient Spectrum Usage

- 3X the spectral efficiency with ePMP
- 3X the number of subscribers
- 3X the monthly revenue
- Faster payback with ePMP

Air fairness adaptive scheduler

Air Fairness



- "Air Fairness" Scheduler Prevents a few "Bad" SMs from dragging down the entire Access Point
- A "Bad" SM can be a SM at lower modulation or a SM in high interference.
- Resource Allocations based on Time, not Throughput

QoS and Triple-Play support

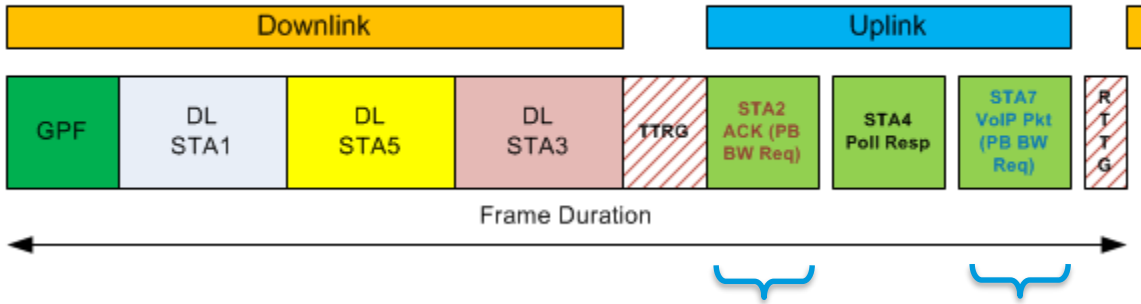
QoS, queues, and priorities

- ePMP has three queues in radio channel. Priority of packets within the radio:
  - VoIP priority (only for packets less than 220 bytes)
  - High priority
  - Low priority
- When a packet arrives with classification, it is queued in the appropriate queue.
  - L2 Markings: VLAN ID, CoS, EtherType, MAC address
  - L3 Markings: IP address, DSCP
- Broadcast/Multicast Traffic can be configured to be High or Low Priority
- When the RF pipe is overloaded and packets are dropped, consideration is given to VoIP & High priority packets over low priority packets by utilizing latency drop concept
- Prioritization happens for both DL & UL
- Prioritization can be additionally altered by SM Priority: Normal, High, Low

Additional attention to Voice

ePMP utilizes the following mechanisms for VoIP delivery

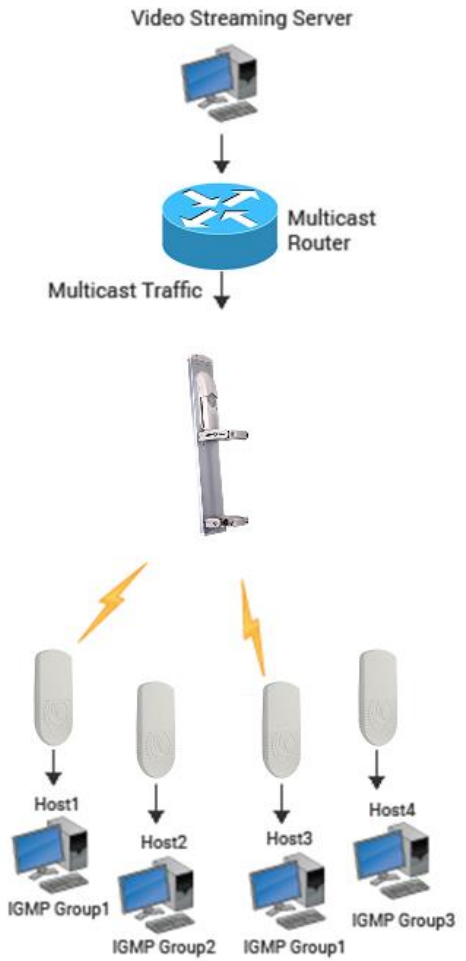
- DL/UL automatic prioritization of VoIP packets within the queues of the radio.
- High priority/ more frequent bandwidth allocation to SMs carrying VoIP traffic
- Ability transf respo ting data poll



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

Multicast in radio channel

- Multicast transmission doesn’t use ACK mechanisms, so infrastructure doesn’t know if the packet has been delivered, or not
- Different SMs, “watching” the same channel, usually work in different radio conditions: distance, interference, obstacles. It means different MCSs and BERs.
- Thus “one to many” concept doesn’t work in radio, as it’s impossible to guarantee, that video translation will be delivered to all mcast group members with a good quality.
- Our approach is Reliable Multicast, which means converting multicast into unicast using IGMP snooping mechanism.
- Goals
  - ACKs in radio channel
  - Retransmissions are possible
  - Transmitting at SM’s current MCS



High sector capacity

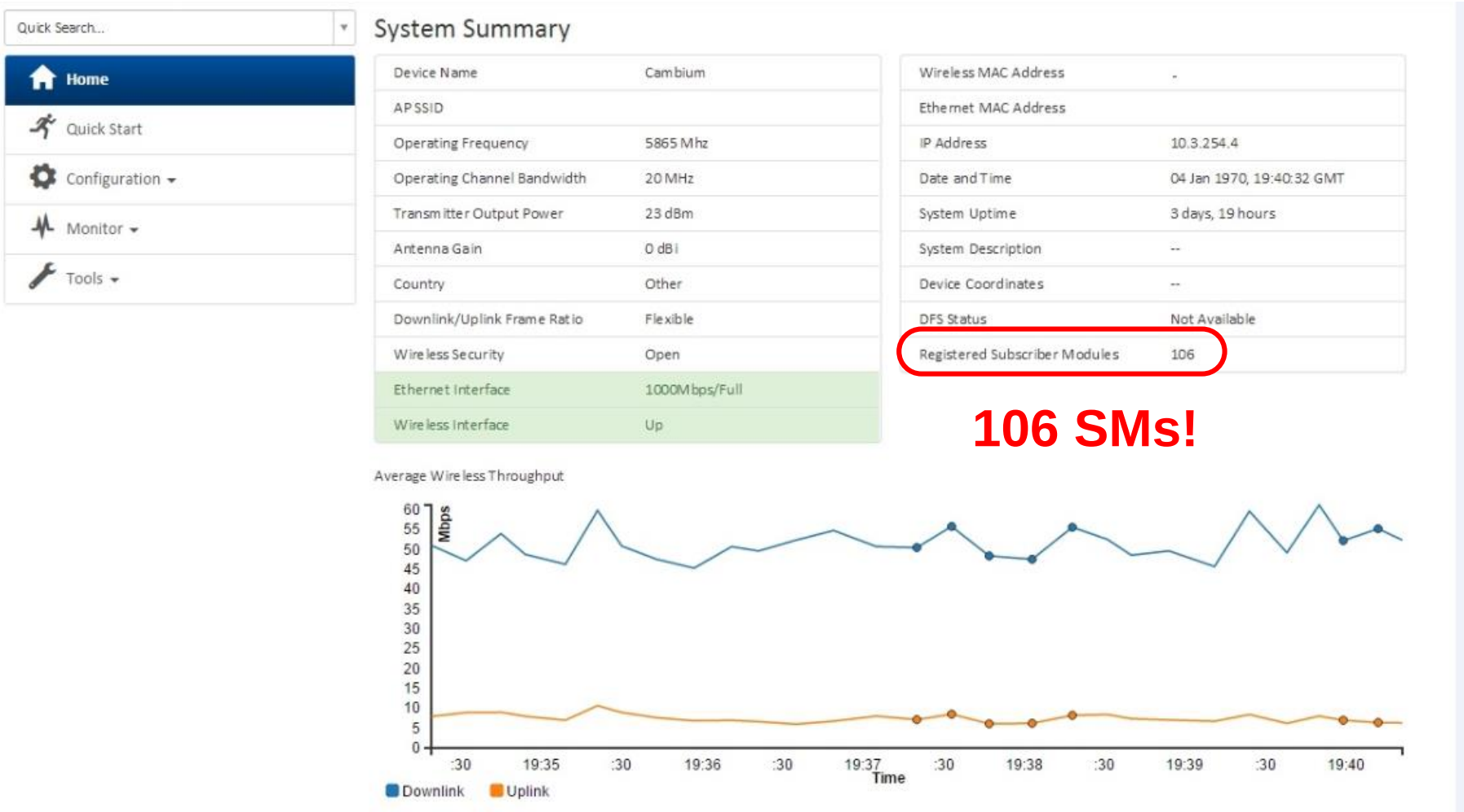
What solution is scalable?

Competitor’s BS

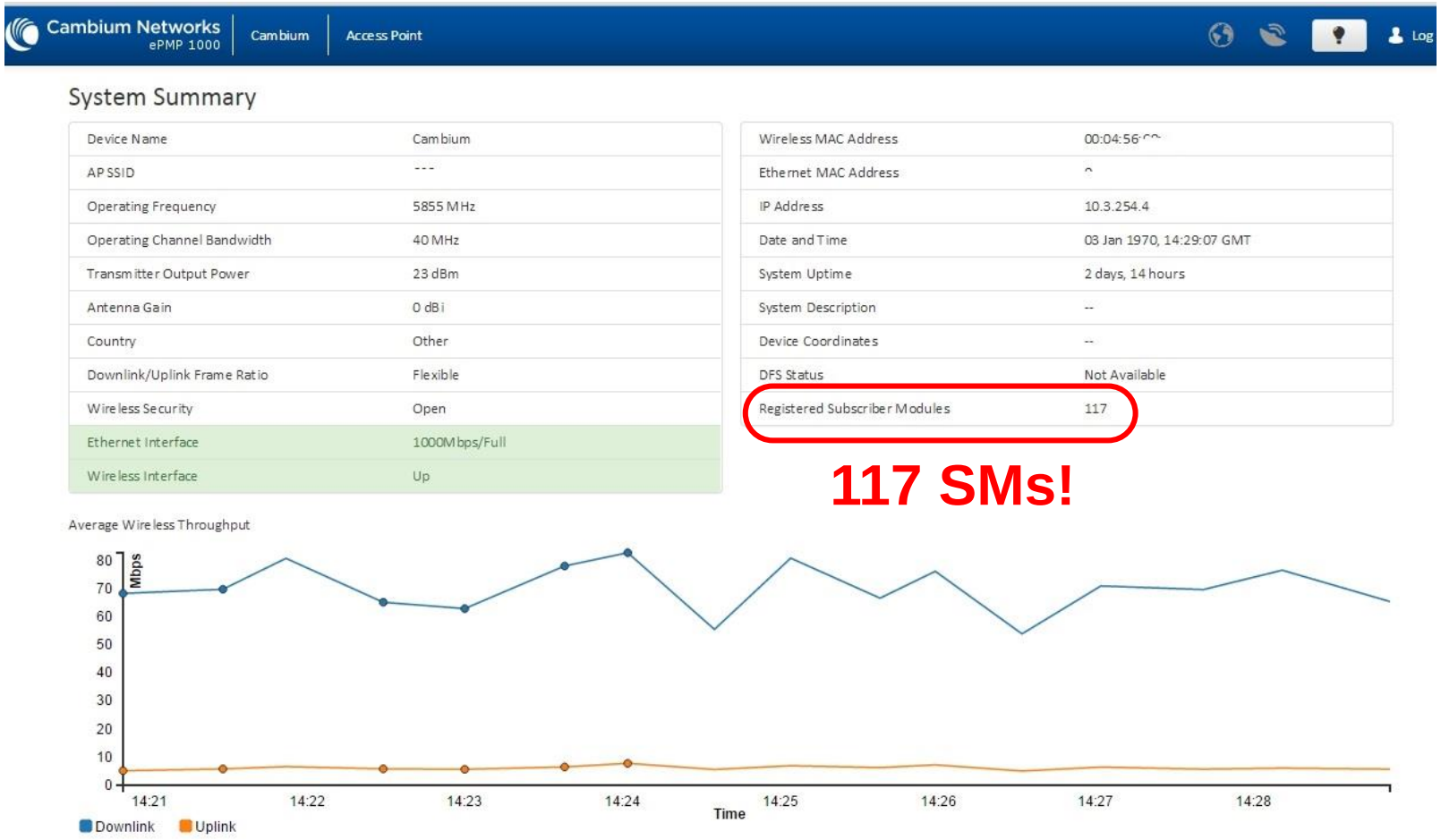
ePMP BS

120 SMs per sector!

106 SM


Quick Search...
Home
Quick Start
Configuration
Monitor
Tools
System Summary
Device Name Cambium
AP SSID
Operating Frequency 5865 Mhz
Operating Channel Bandwidth 20 MHz
Transmitter Output Power 23 dBm
Antenna Gain 0 dBi
Country Other
Downlink/Uplink Frame Ratio Flexible
Wireless Security Open
Ethernet Interface 1000Mbps/Full
Wireless Interface Up
Wireless MAC Address -
Ethernet MAC Address
IP Address 10.3.254.4
Date and Time 04 Jan 1970, 19:40:32 GMT
System Uptime 3 days, 19 hours
System Description --
Device Coordinates --
DFS Status Not Available
Registered Subscriber Modules 106
106 SMs!
Average Wireless Throughput
Mbps
60
55
50
45
40
35
30
25
20
15
10
5
0
:30
19:35
:30
19:36
:30
19:37
:30
19:38
:30
19:39
:30
19:40
Time
Downlink
Uplink

117 SM

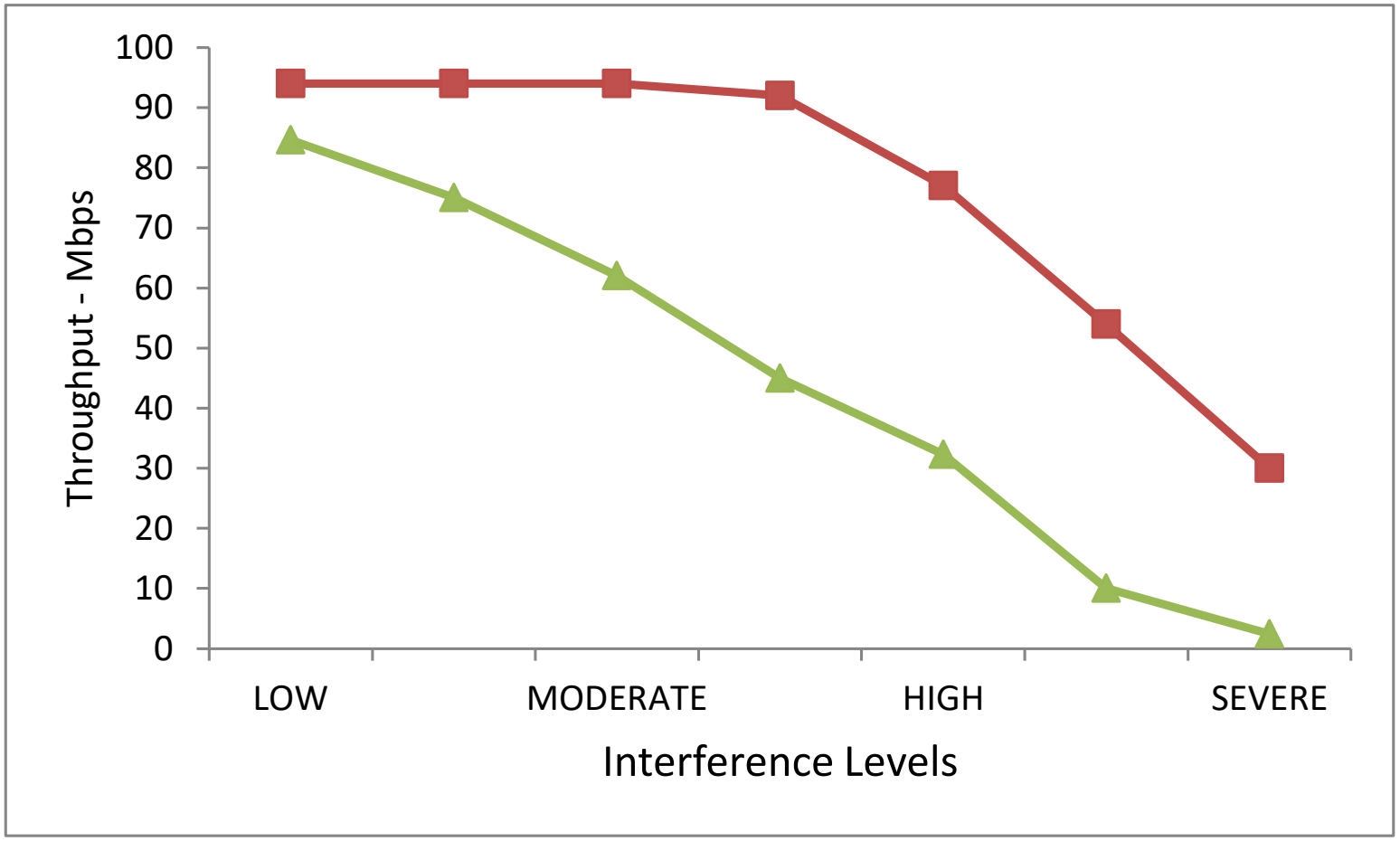

Cambium Networks
ePMP 1000
Cambium
Access Point
Log
System Summary
Device Name
Cambium
AP SSID

Operating Frequency
5855 MHz
Operating Channel Bandwidth
40 MHz
Transmitter Output Power
23 dBm
Antenna Gain
0 dBi
Country
Other
Downlink/Uplink Frame Ratio
Flexible
Wireless Security
Open
Ethernet Interface
1000Mbps/Full
Wireless Interface
Up
Wireless MAC Address
Ethernet MAC Address
IP Address
10.3.254.4
Date and Time
03 Jan 1970, 14:29:07 GMT
System Uptime
2 days, 14 hours
System Description
--
Device Coordinates
--
DFS Status
Not Available
Registered Subscriber Modules
117
117 SMs!
Average Wireless Throughput
Mbps
80
70
60
50
40
30
20
10
0
14:21
14:22
14:23
14:24
14:25
14:26
14:27
14:28
Time
Downlink
Uplink

Overcome interference

Superior Performance in Real World Conditions

As interference levels increase, ePMP keeps going

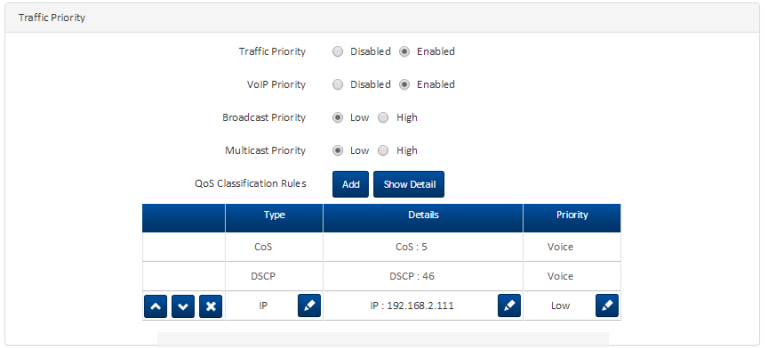


Advanced Support for Network Services

Best-in-class VoIP/Video/IPTV performance from:

- Advanced over-the-air Quality of Service (QOS) - *Assurance that critical applications are served first*
- Automatic prioritization of VOIP packets – *Traffic priority rules are automatically configured to prioritize VoIP traffic*
- Dynamic Rate Adapt mechanism – *Detect voice and minimize jitter, targeting zero packet loss*
- AP and SM perform IGMP snooping to restrict transmission to specific radio links – *Smart multicasting reduces sector radio chatter*

And more …

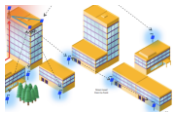


ePMP QoS Interface

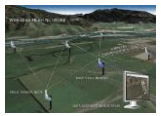
Voice over IP

Video Surveillance

IPTV



Enterprise Connectivity



Smart Agriculture through IOT

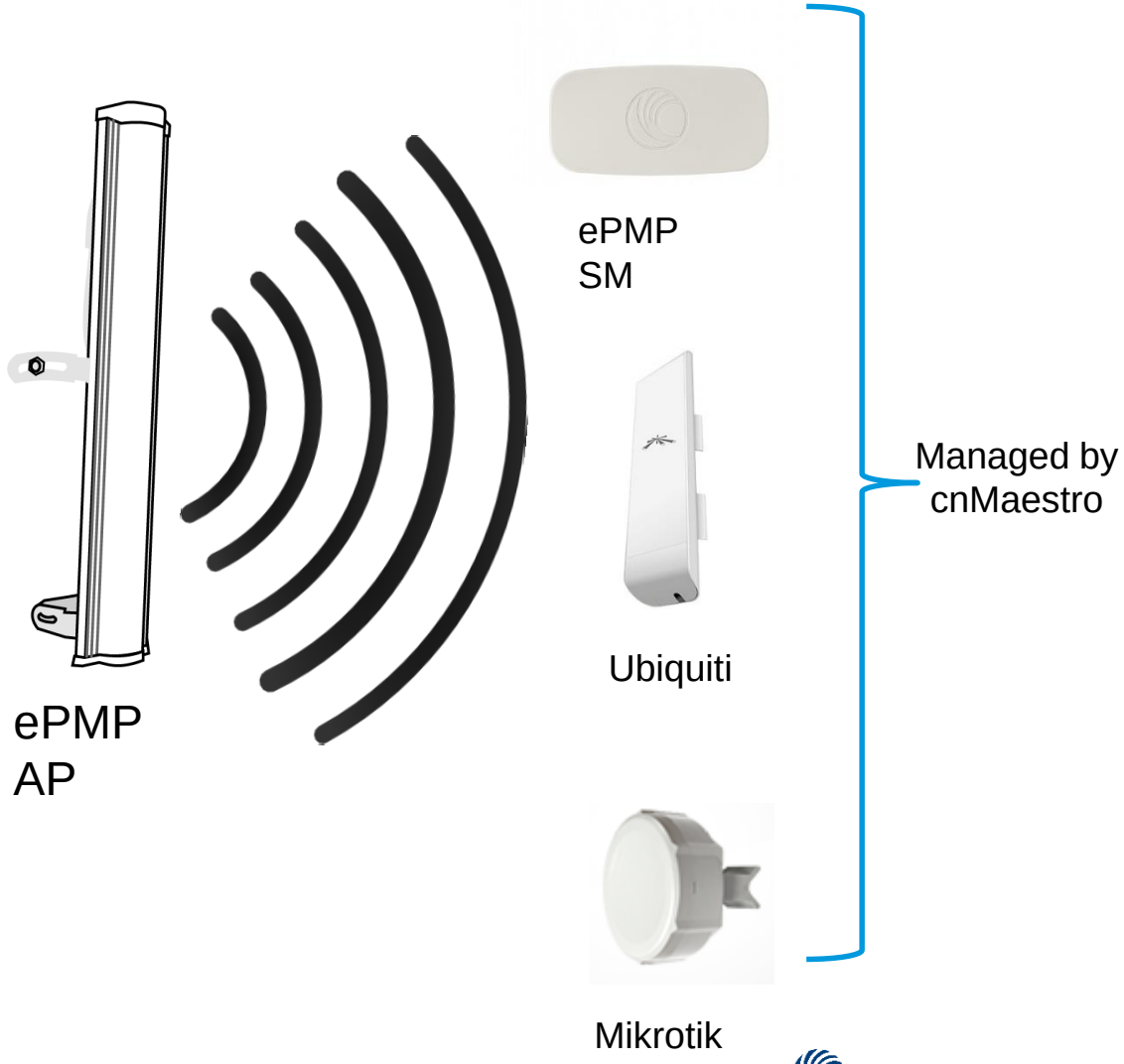
Hotspot Backhaul

Support for third-party's SMs

ePMP Elevate

ePMP Elevate

- Allows ePMP Elevate software to run on non-Cambium 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



Why Now?

- ePMP is the leading system solution for the modern WISP:
  - Industry's most affordable platform with frequency re-use enabled by GPS Synchronization
  - Highly scalable at a low price
  - Industry-leading interference mitigation with Smart Beamforming and Intelligent Filtering in ePMP 2000
- Many WISPs have older deployed gear
  - Network hardware migration remains challenging

Why Now?

- Why is network hardware migration difficult?
  - Cost of new hardware
  - Installation cost – truck rolls
  - Customer satisfaction impact
    - Service credits
    - Arranging installations where indoor access required
    - Downtime and teething troubles

Scope of ePMP Elevate

- ePMP Elevate consists of:
  - An ePMP 2000 Access Point licensed for ePMP Elevate
    - A license is purchased for a number of ePMP Elevate subscribers
  - A number of deployed non-Cambium Subscriber Modules
    - Supported model list will be shown shortly
  - ePMP Elevate software to load on the Subscriber Modules
    - ePMP Elevate software is free to download

WiFi Access - cnPilot™

Intelligently managed, Affordable, Quick to deploy & Easy to Operate

Wi-Fi for

Enterprise
Indoor, Outdoor

Service Providers
Indoor

Industrial
Indoor, Outdoor

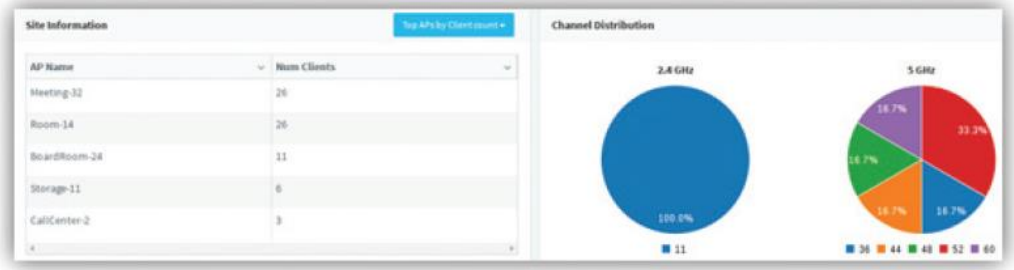
The Cambium Value Proposition

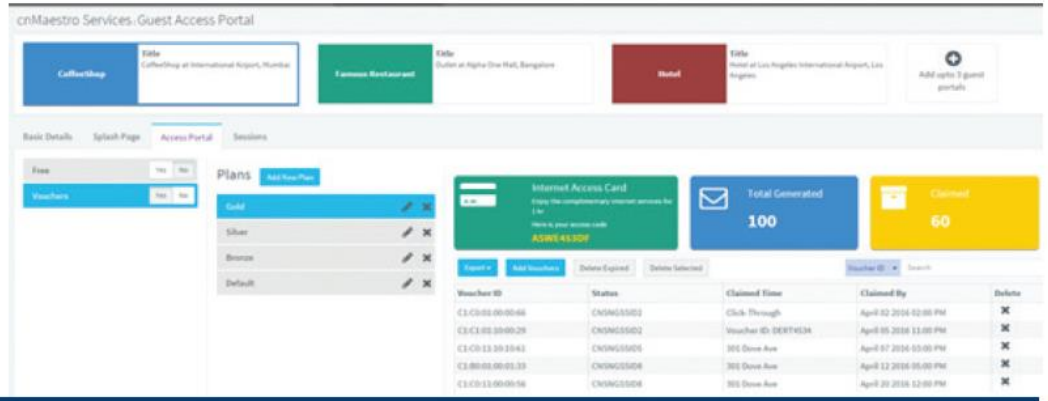
QUICK INSTALL

EASY TO MANAGE

GUEST PORTAL ACCESS
VOUCHERS

MONETIZE WIFI

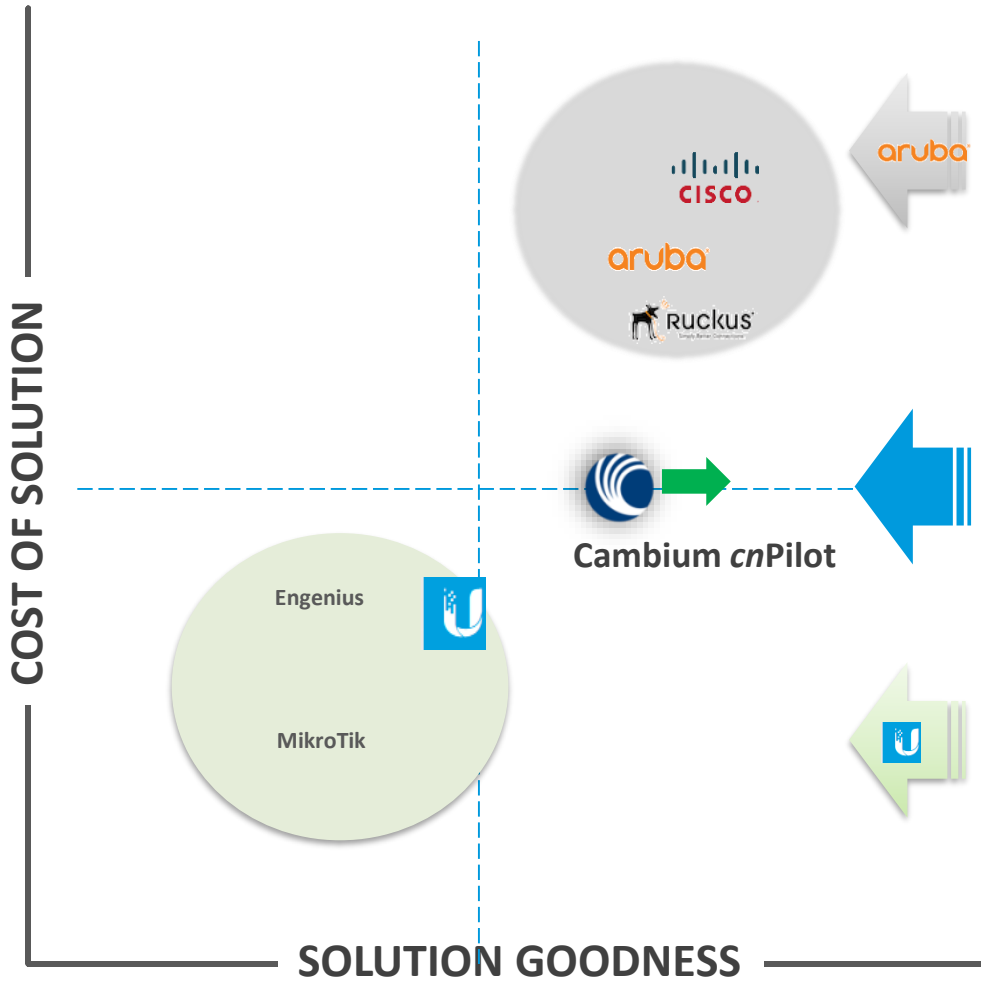




"Free WiFi is the #1 hotel amenity"
– HOTELS.COM SURVEY

"96% of customers prefer stores that offer free WiFi"
– YANKEE GROUP SURVEY

The Cambium differentiation



Large carpeted Enterprises

- Complex features
- No integrated wireless backhaul options
- ASPs of $500 ~ $1000

Price for Performance

- **High Performance for Price**
- **Wireless Backhaul integration**
- **Rich support – 24x7, Community**

Entry level capabilities

- Self support. Lack of field support
- Wireless backhaul. Distinct
- Not scalable

The cnPilot Solution

INDOOR 802.11ac ENTERPRISE

OUTDOOR 802.11ac ENTERPRISE

Enterprise Access Points

E400
2x2 Omni
802.11ac wave1

E410
2x2 Omni
802.11ac wave2

E600
4x4 Omni
802.11ac wave2

E430W
2x2 Wall Plate
802.11ac wave2

E500
2x2 Omni
802.11ac wave1

E501S
2x2 120° Sector
802.11ac wave1

E502S
2x2 30° Sector
802.11ac wave1

Controller

cnMaestro Cloud Controller

cnMaestro On-Premises

autoPilot AP controller

ISP Managed Residential Routers

R201/P 802.11ac Dual band Router

R200P 802.11n single band PoE Router

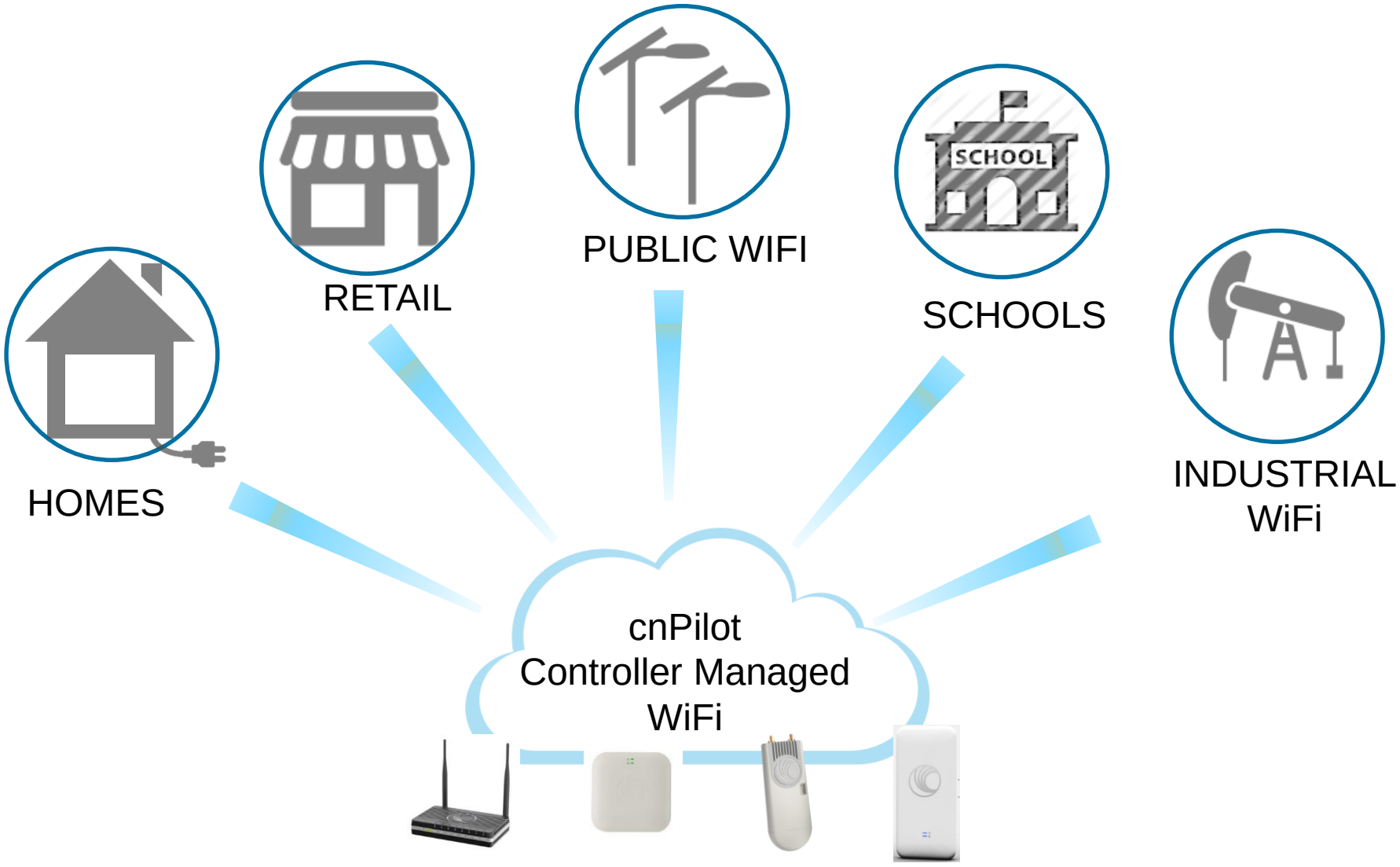
R190W, R190V
802.11n single band Router

Taking on the completion…

Functionality highlights

- Multi-hop MESH with recovery
- Fast Roaming (802.11r, OKC)
- Auto RF – dynamic interference analysis / frequency selection / output power control
- Band steering (client distribution 2.4 → 5 GHz)
- Passpoint (Hotspot 2.0) – 3G/4G offload
- Airtime Fairness (optimizing throughput with legacy and slow client online)
- L2TP/GRE/EoGRE tunnels (traffic aggregation in central point, including the controller)
- Gateway Monitoring (turning off SSID when connection loses)
- LDAP Authentication (Windows Active Directory or OpenLDAP)
- One-time SMS-passwords authentication
- APIs for equipment and controller (positioning services, management, integration)
- Integration with 3rd parties captive portals
- Autopilot – embedded controller (up to 32 APs)
- Embedded captive portal with voucher support
- Payment gateway integration

cnPilot Applications



Achieving Success in Targeted Verticals

Education
Schools
Universities

India – 540 University deployment
USA – Plymouth School Dist., WI

Hospitality
Resorts
Hotels
RV parks

Bali – Holiday Inn (Indoor & outdoor)
Kenya – End to end Wireless

Events
InfoGamer
U.S. WISP

Croatia – High capacity Event WiFi

Public Wi-Fi
Govt. Public Wi-Fi
Internet.org

India – First Express Wi-Fi (XWF) vendor
Over 1,000 APs deployed

Colombia – 500+ APs deployed

Retail
Impax Media
Southern Rework

Impax Media – Canada
Retail chain rollout with video streaming

Solutions in some interesting places.

IIoT Connectivity - cnReach™

Narrow-Band Applications

- Oil & Gas
  - Well-head sensors and automation
- Electric Utilities
  - Distribution and substation automation
  - SCADA monitoring and control
  - Grid sensors
- Water & Wastewater
  - Flow & level sensors
  - Quality sensors

cnReach Narrow-Band Platform

Deployment Flexibility	• PTP/PMP/Store-and-Forward Relay • Optional digital / analog I/O • Dual-band 900 MHz (MAS / ISM) • Dual-radio options
Reliability	• 100% factory testing over temperature • ATEX/HAZLOC • Made in the USA
Low Power Consumption	Simple integration with existing power (including solar)
Scalable	Access Point synchronization Adaptive modulation
Secure	128/256-bit AES encryption
Manageable	• Cloud or NOC-based cnMaestro • LINKPlanner planning and BOMs

cnReach Physical Interfaces

- 2 x 10/100 Ethernet
- 2 x serial interfaces
  - RS-232/-422/-485
- 1 or 2 radios
- Optional 8-ports analog/digital I/O

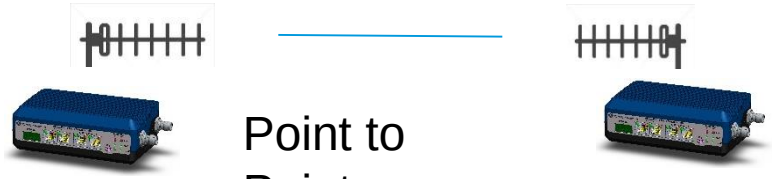
cnReach 900 MHz Narrow-Band Radio

	MAS Licensed	ISM Unlicensed
Frequency	928 – 960 MHz	902 - 928 MHz
Power	10 mW to 3W	10 mW to 1W
Channel Sizes	12.5 / 25 / 50 kHz	76 / 154 / 207 / 310 / 600 / 900 / 1200 kHz
Capacity	10 kbps – 210 kbps	57 kbps – 4.4 Mbps
Modulations	Up to 32QAM	Up to 64QAM
Range	Up to 70 miles	
Encryption	128/256-bit AES	
I/O	2 x 10/100 Ethernet 2 x Serial Port Optional Digital/Analog I/O	

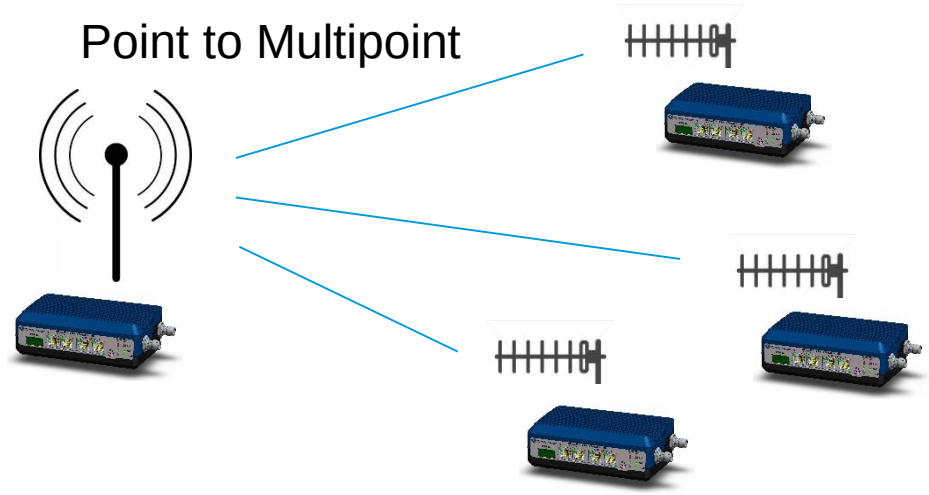
*cn*Reach™ 450 MHz Narrow-Band Radio

	Licensed
Frequency	406 – 430 MHz & 450 – 470 MHz
Power	50 mW to 8 W (17 dBm to 39 dBm) FCC 50 mW to 2 W (17 dBm to 33 dBm) ETSI
Channel Sizes	12.5 / 25 kHz
Capacity	10 kbps to 76 kbps FCC 9 – 102 kbps ETSI
Modulations	Up to 32QAM FCC Up to 64QAM ETSI
Range	70 miles
Encryption	128/256-bit AES
I/O	2 x 10/100 Ethernet 2 x Serial Port Optional Digital/Analog I/O

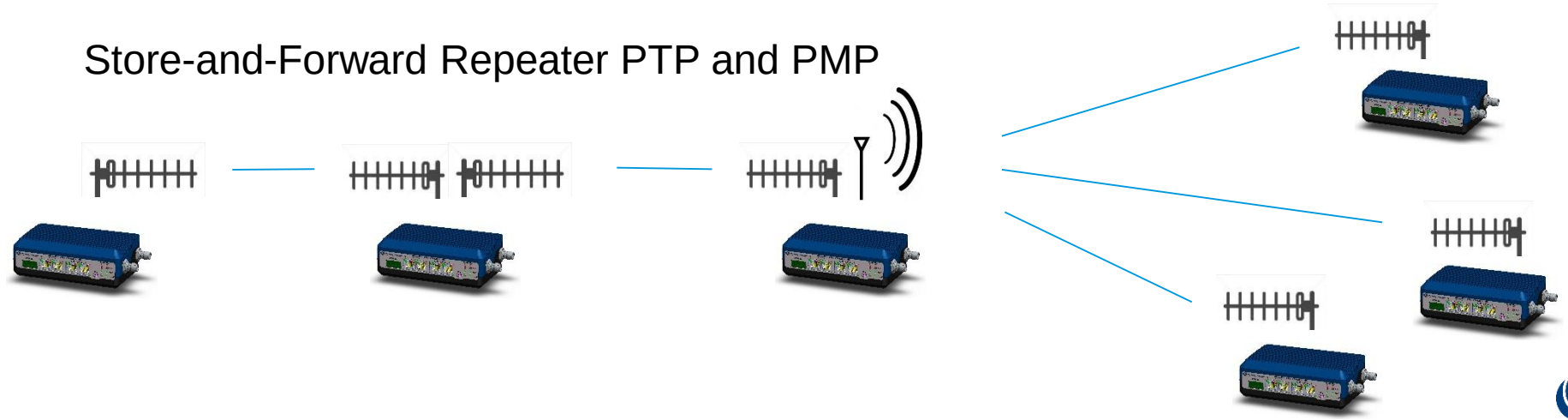
cnReach Deployment Topologies – Single/Dual Radios



Point to Point



Store-and-Forward Repeater PTP and PMP

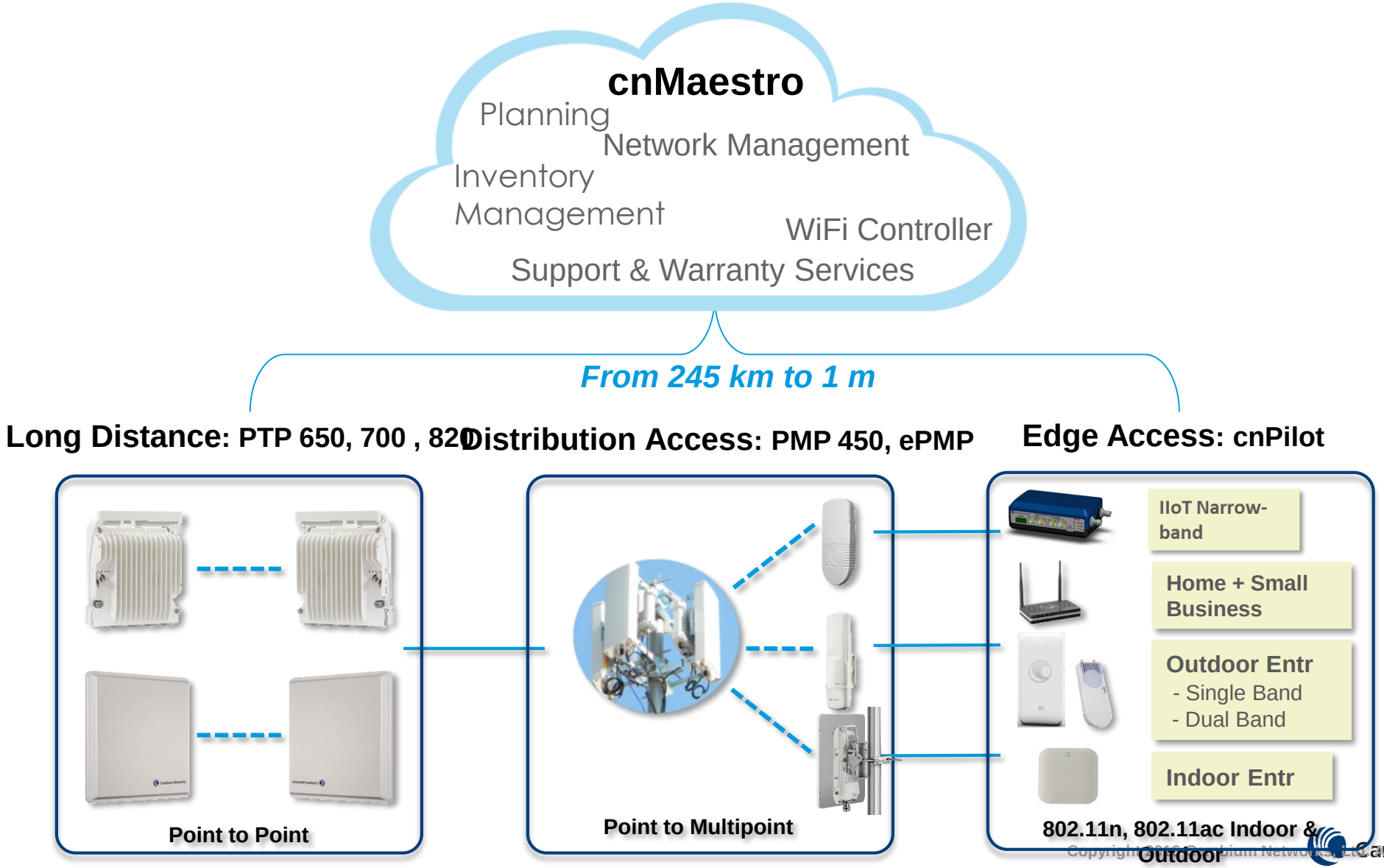


cnReach Data Capabilities

- Switching Fabric
  - Integrated Ethernet switch
  - Static layer 3 routing
- OR
  - Layer 2 flat network
  - VLAN tagging support

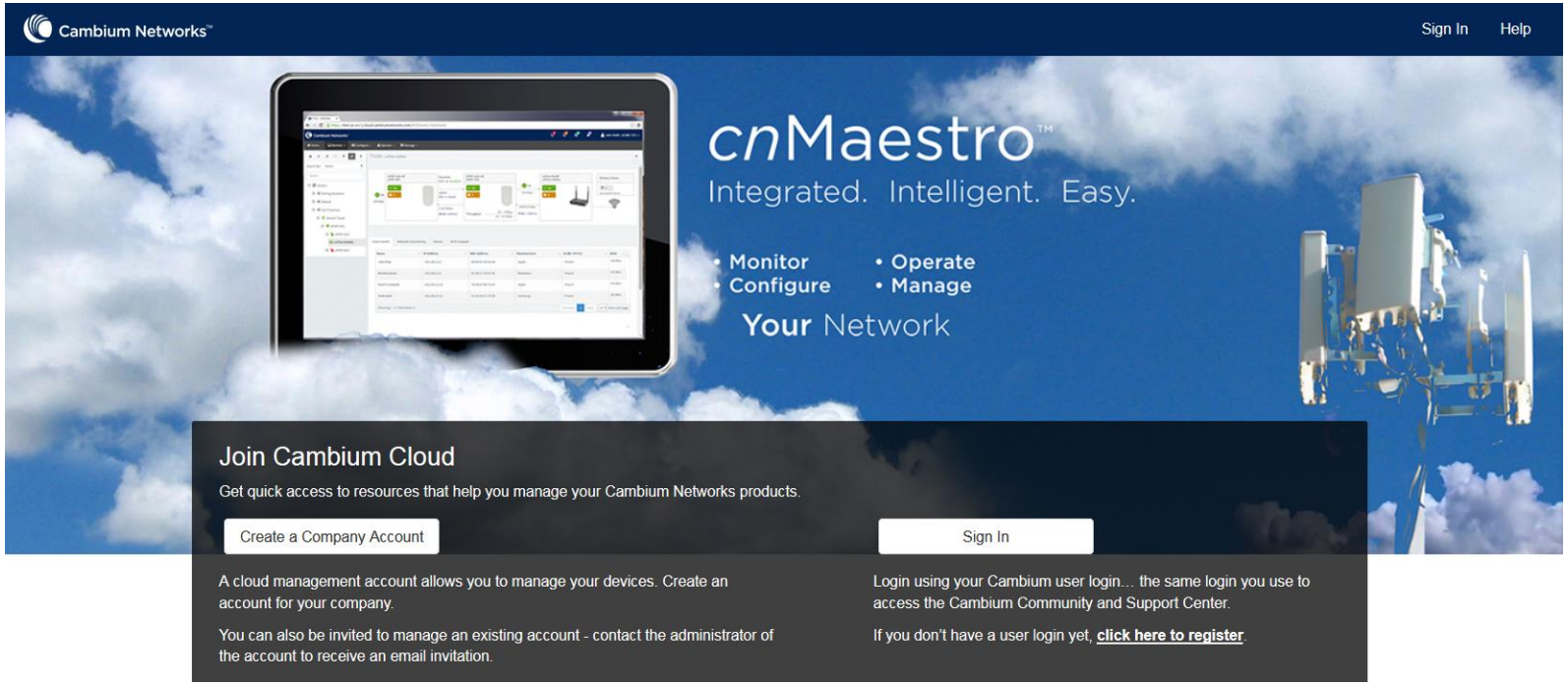
- Benefits
  - Keep licensed and unlicensed traffic separate
  - Prevent broadcast data from using narrow-band channels
  - Store-and-forward
  - Shared Serial / IP network
    - Terminal server
    - Terminal client
    - MODBUS RTU server
    - MODBUS TCP
    - DNP3

Complete Network Lifecycle Management – one Manager



cnMaestro Account

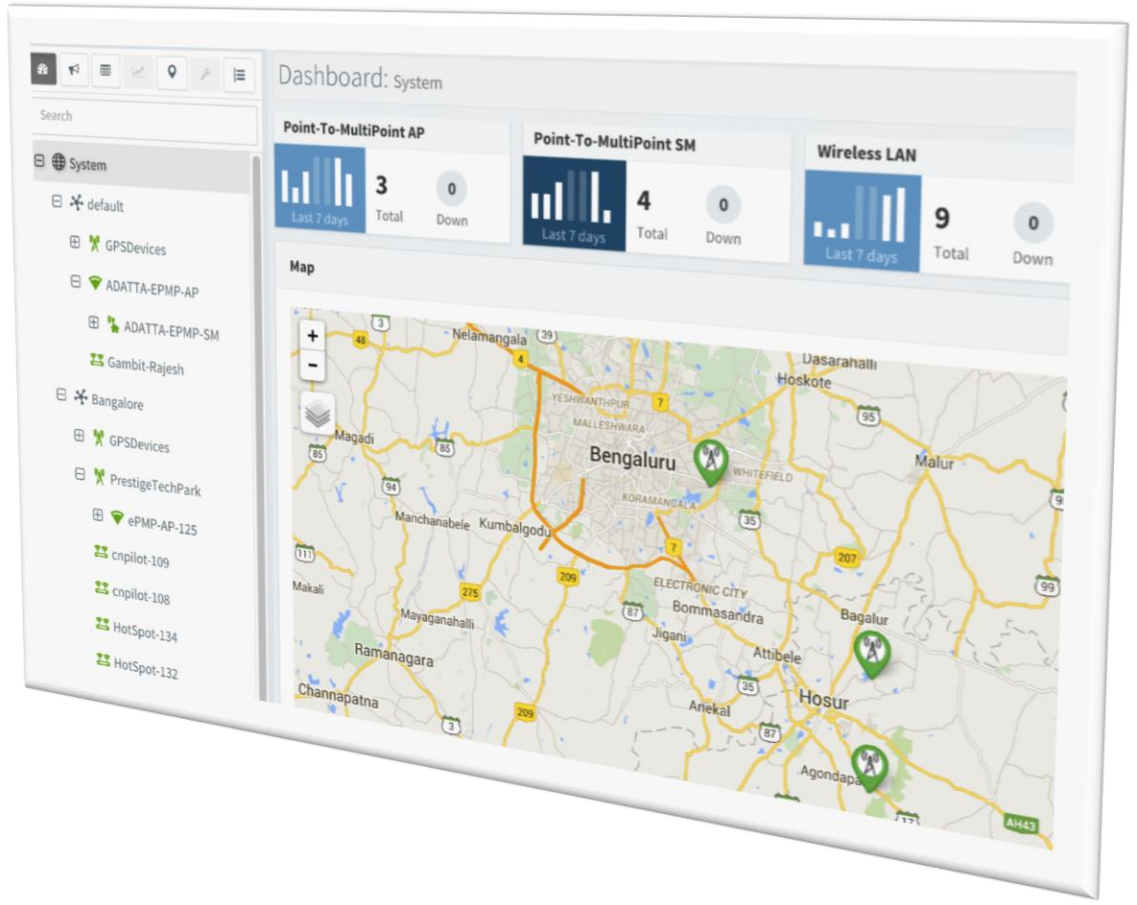
- Access from anywhere with a standard web browser
- Login with your Cambium Support Center email



Get started at https://cloud.cambiumnetworks.com

cnMaestro – End-to-End Management

- Unified way of managing backhaul and WiFi
- Map location of ePMP Access points, SMs and WiFi APs
- Hierarchical device organization
- Summary view of UP & DOWN devices
- Sticky Alarms – Critical, Major & Minor



cnMaestro Frictionless Deployment

Pull Config,
Upgrade

Auto Registration

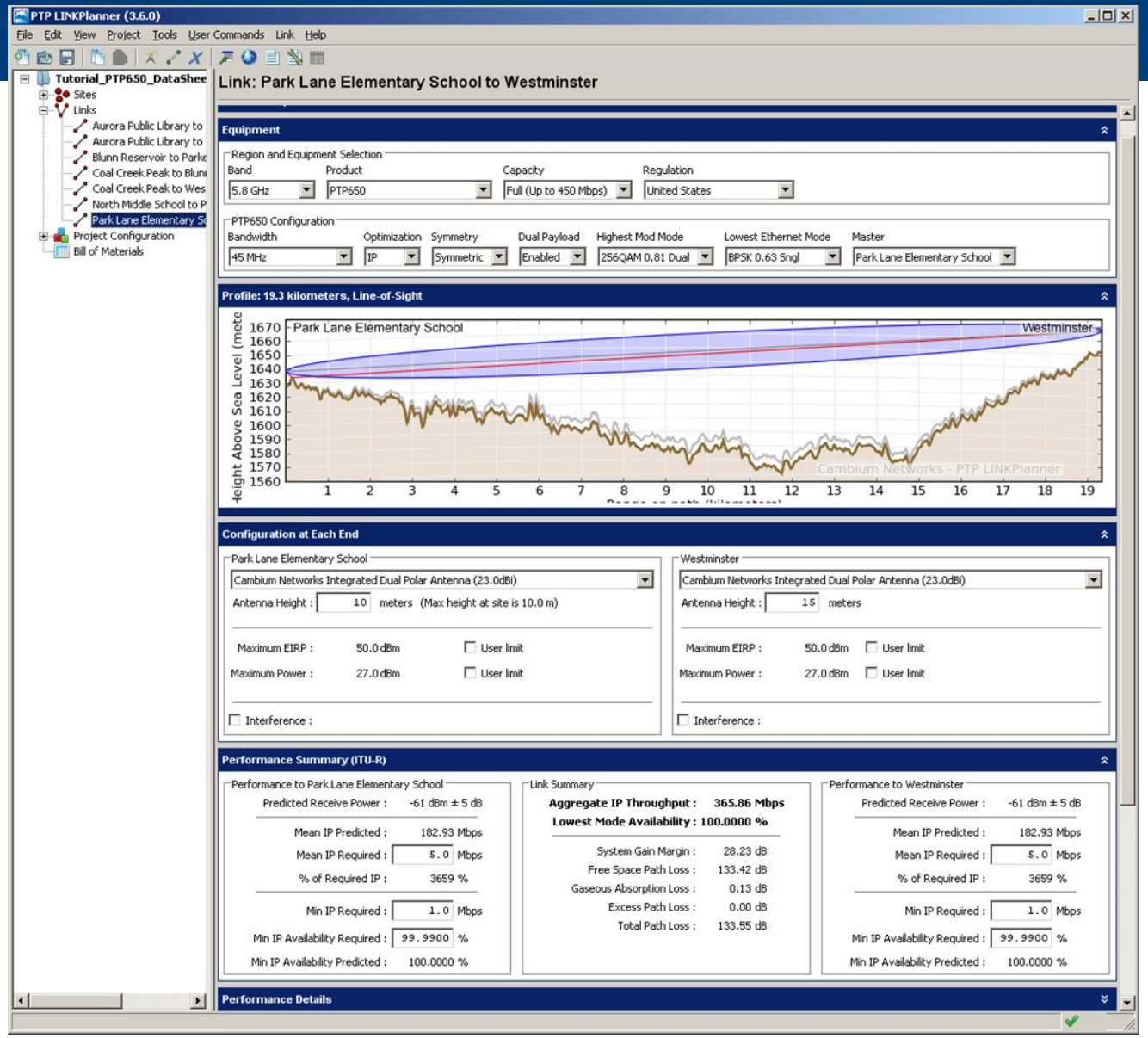
***cn*Pilot** Enterprise
& Home
Access Points

Reduce TOC by

- Reducing installation time
- Low training requirements for install engineers

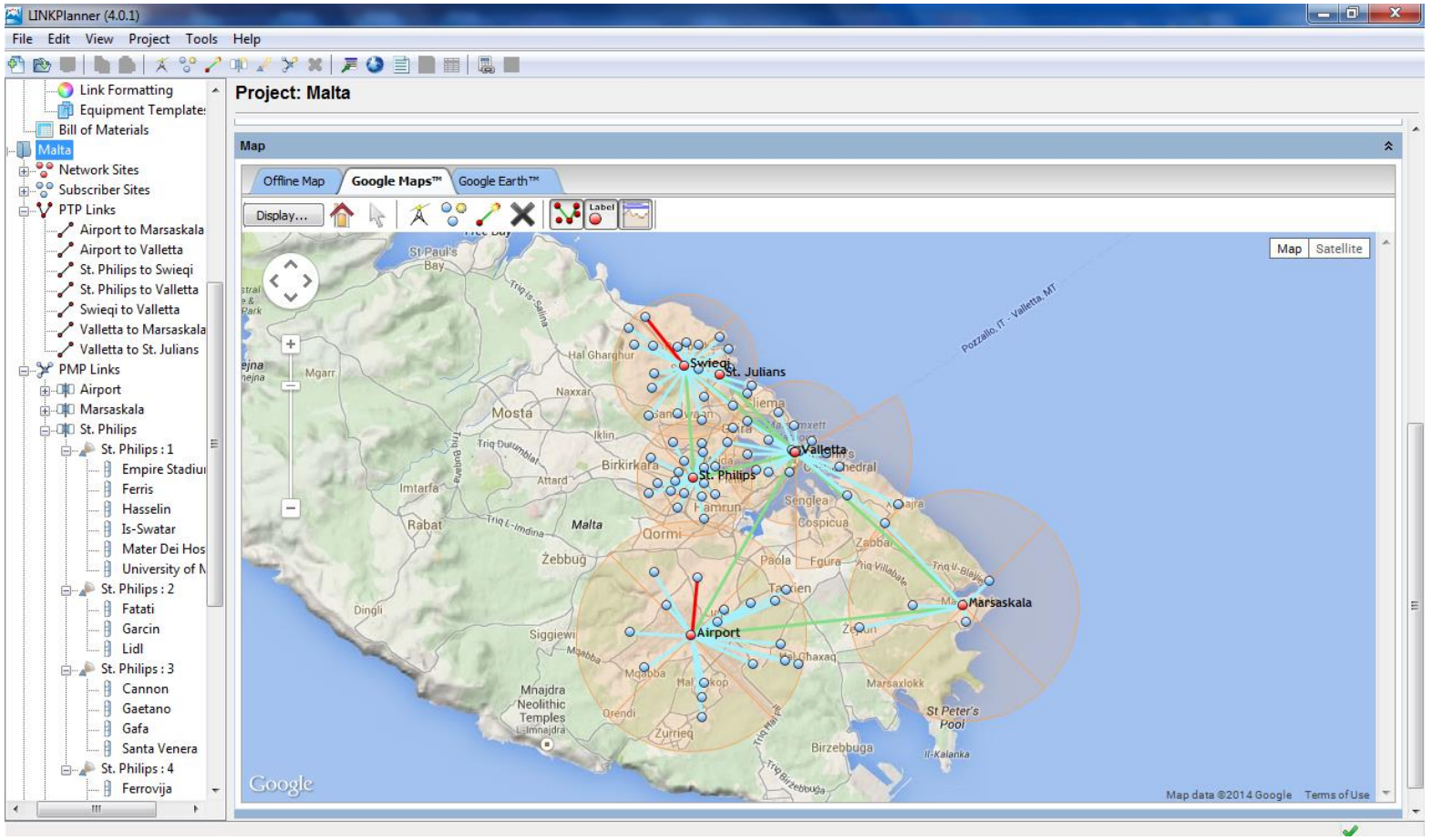
LINKPlanner

- Free network planning software improves success rate of first installation
- Path profile
- Configuration details
  - Bill of materials tailored for each link
- Performance summary



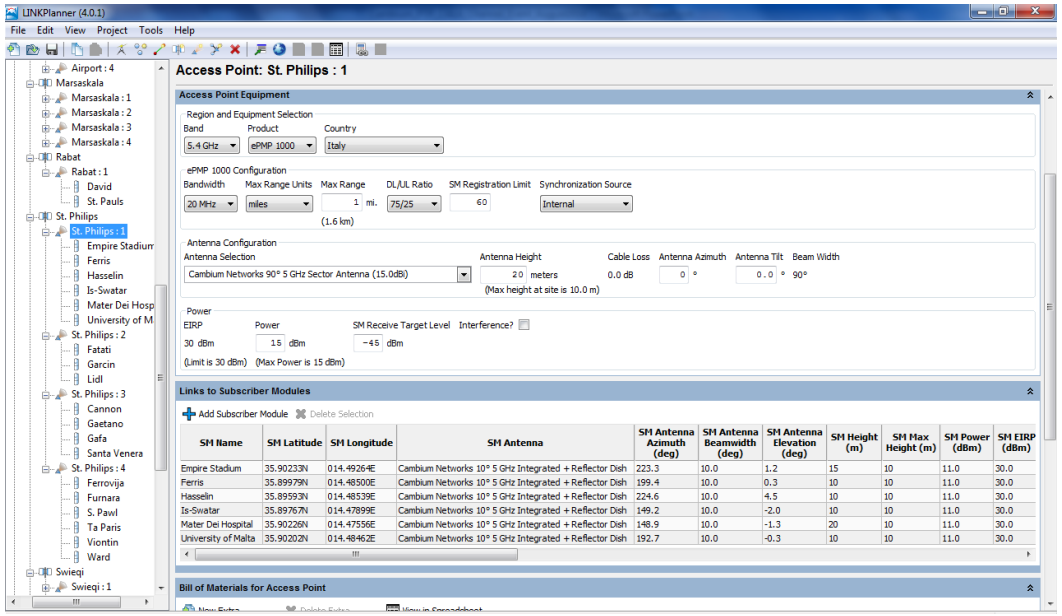
LINKPlanner

- Designs PTP, PMP, and ePMP networks
- Google earth overlays with network details
- Model the exact performance before purchasing equipment



LINKPlanner Features

- Planning
  - PTP performance and availability
  - PMP link budget
  - Scenario planning
- Reports
  - Bill of Materials
  - Proposal
  - Installation
- Products Supported
  - PTP 450i 900MHz , 450i 3GHz, 5GHz 650, 670
  - PTP 800, 810, 820
  - ePMP 1000, ePMP2000 PMP 450 and PMP 450i
  - cnReach



Support – Cambium Care

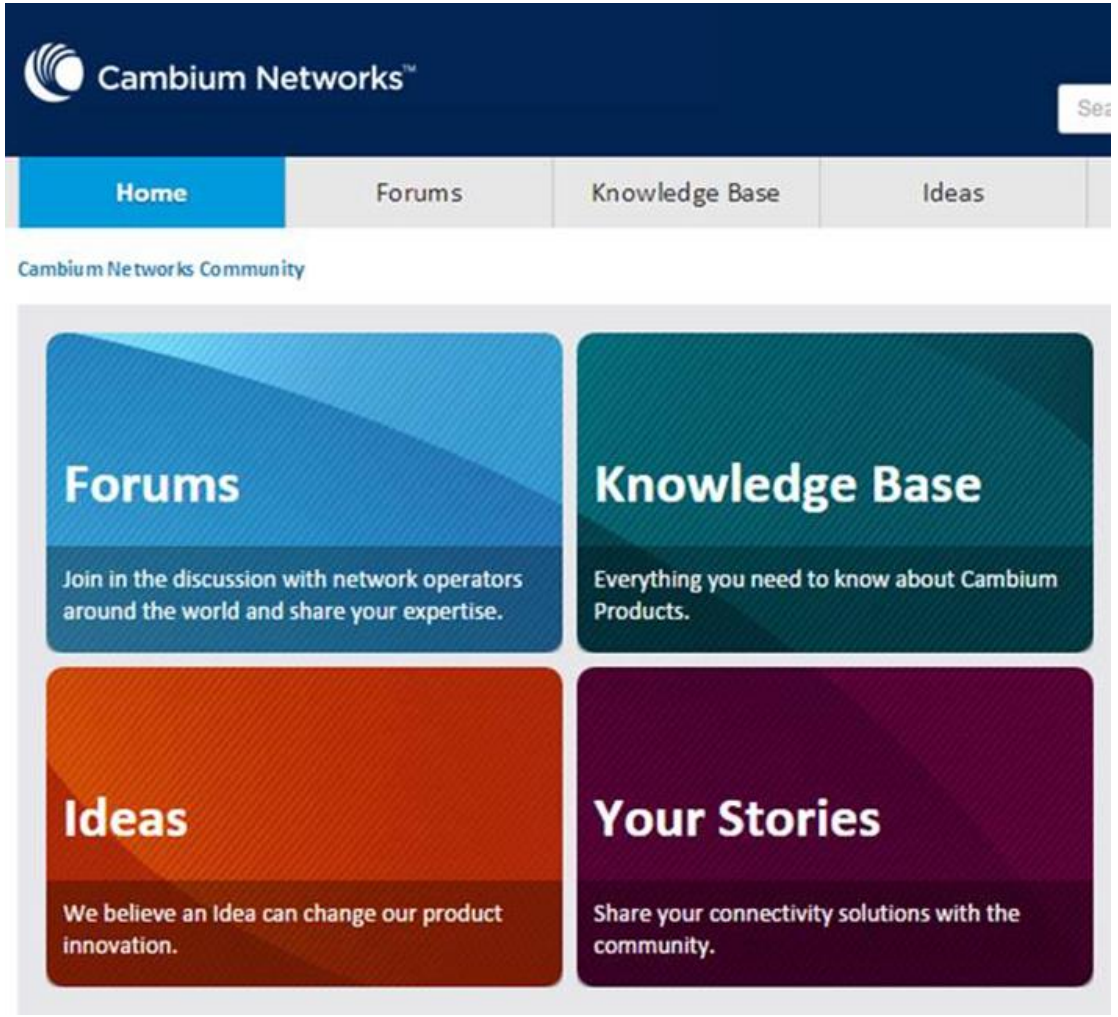
- Contact Technical Assistance Center via phone, chat, web portal
- Select the support level that meets your needs
  - Standard: 8 x 5 (customer business hours)
  - Plus: 24 x 7, accelerated access to Level 2 and Level 3
  - Prime: 24 x 7, service level agreements, All Risks repair/replace
- Extended warranty options
- Extensive knowledge base

Support – Cambium Care

FEATURE	CAMBIUM CARE STANDARD	CAMBIUM CARE PLUS	CAMBIUM CARE PRIME
8 x 5 Mon-Fri Technical Support (Phone, Chat, Web Portal/Email)	Yes	No	No
24 x 7 Technical Support (Phone, Chat, Web Portal/Email)	No	Yes	Yes
Case Management Priority	Best Effort	Accelerated	Service Level Agreements
Escalation Management	Escalation to Level 2 Engineers if Needed	Accelerated Access to Level 2 & 3 Engineers	Assigned Level 2 Engineers Escalation per SLA Matrix
Hardware Support	Based on Warranty Status	Based on Warranty Status	All Risks Repair/Replace for Infrastructure Devices
Warranty Options	Extended Warranty, All Risks Advance Replace	Extended Warranty, All Risks Advance Replace	Included (Infrastructure Devices)
Targeted Proactive Software Release Notification	No	Email Notification	Personal Advisory
Service Account Manager	No	No	Yes
Network Review	No	2 hours/year per $5K Spent on CC Plus	6 hours/year per $10K Spent on CC Prime
Training Discount	No	No	25% Discount

Cambium Community

- Learn from network operators around the world
- Community Forum
  - Products
  - Network planning
  - Languages
  - Business issues
- Knowledge Base with technical detail documents
- Submit development ideas
- Real-world connectivity stories



Technical Certification Training

- Certification on all products
- 2-Day classes
  - Certified instructors
  - Live hands-on training
  - Proficiency test
- 8 classes per month
- Courses offered around the world in multiple languages
- Option to take test online to achieve certification

Webinars

- Free interactive 1-hour sessions
- Multiple languages
- Recorded for replaying
  - Discussion on the Community
- Topics
  - New products
  - Best practices
  - Guest speakers from the industry
  - Applications
  - Industry standards
  - Regulatory issues

Connected Partner Program

A Cambium Networks Program

ConnectedPartner

- ePMP/cnPilot product discounts
- **Deal Registration**
- Access to partner portal:
  - Sales & marketing tools
  - Recorded webinars
  - Product and field images and logos
  - Partner communications
- Access to technical product training https://training.cambiumnetworks.com
- VAR Channel Account Manager / Regional Sales Manager support
- Business development support from distributors
- Invitations to channel webinars and events
- Promotions
- MDF – once certified.

http://www.cambiumnetworks.com/partners/connectedpartner-program/

Social Media

- Follow Cambium Networks to get the latest information
- Facebook
- Google+
- Instagram
- LinkedIn
- Twitter
- Weibo
- YouTube

Cambium Networks™

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Cambium Networks™
Connecting
People, Places
& Things