Cambium Networks™

New PMP Solutions

Matt Mangriotis
Director of Product Management

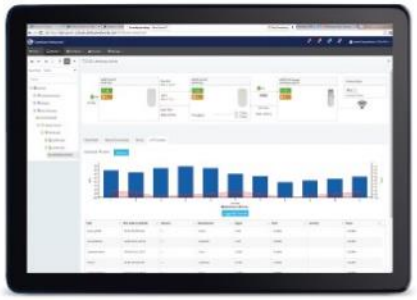
Affordable, Reliable Wireless Connectivity

World-class Wireless Networks

cnPilot™ R190W

E600

E501S



cnMaestro™

Wi-Fi

*e*PMP™ 2000

PMP 450m

PTP 700

Distribution Access & Backhaul

Cambium Networks – 2 meters to 245 kilometers

Cloud Management
cnMaestro
AutoPilot

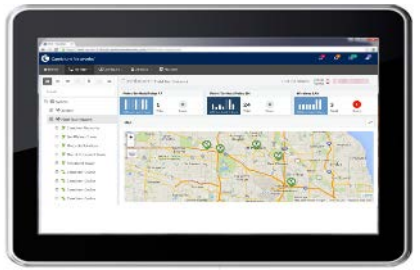
Backhaul
Point-to-Point
PTP820, PTP670, PTP450/450i, ePTP
900 MHz, 2.4, 4.9, 5, 6-23 GHz

Access
Point-to-Multipoint
PMP450b/d/i/m, ePMP
900 MHz, 2.4, 3, 4.9, 5, GHz

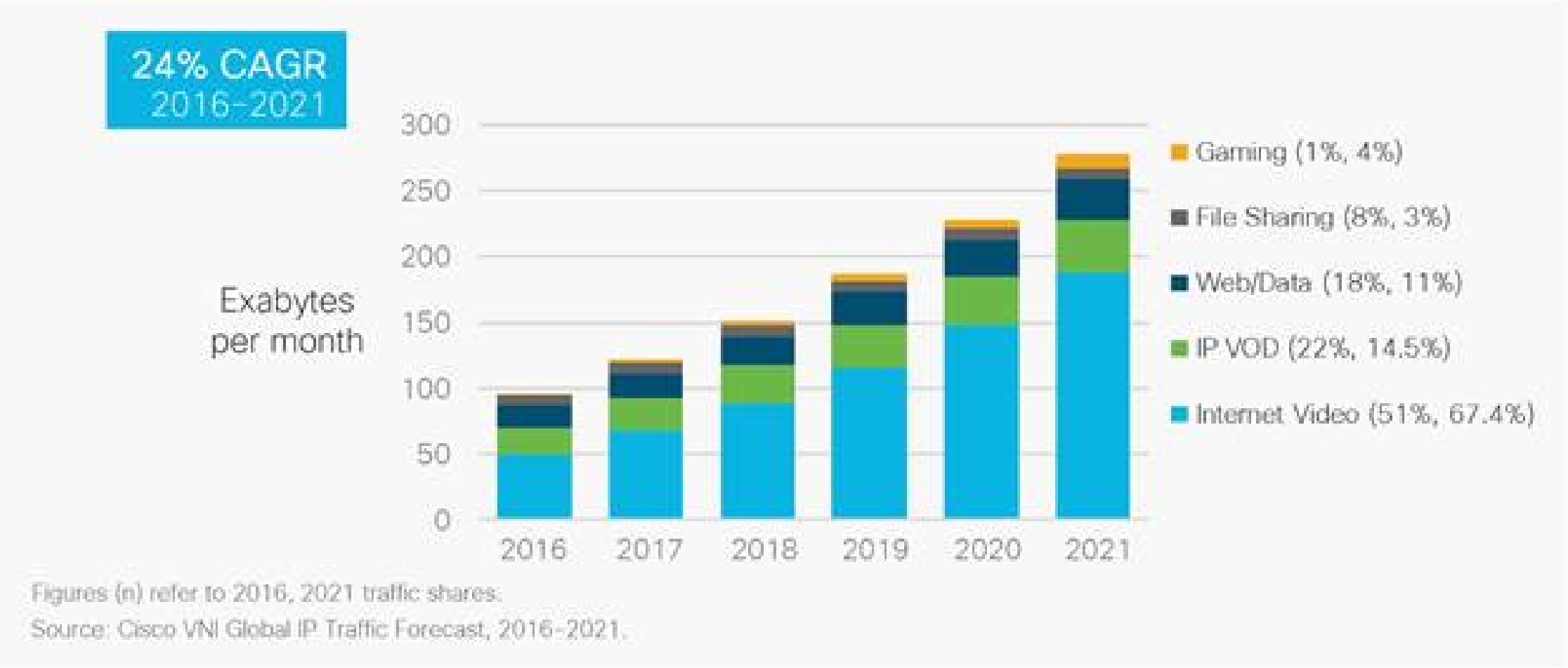
WiFi
Residential/Small Office - R190/200/201
Enterprise - E400/410/600/500/501S
802.11n & 802.11ac

IIoT
Industrial Internet of Things
cnReach
450, 700, 900 MHz

On-Premise Management

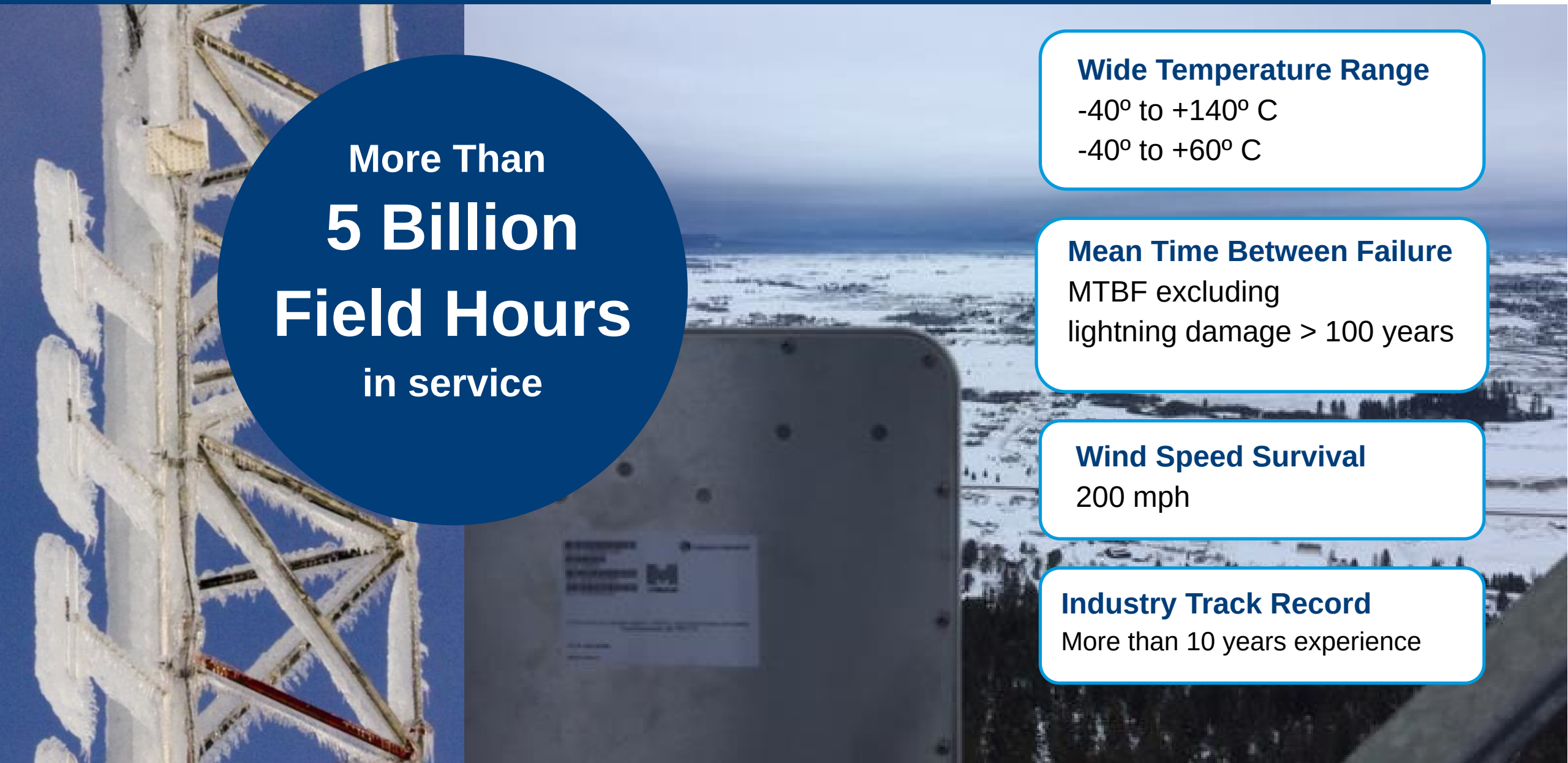


Ever Increasing Bandwidth Demand



….Especially Video Traffic

Cambium Networks - BUILT TO RUN, BUILT TO LAST



More Than
5 Billion
Field Hours
in service

Wide Temperature Range
-40º to +140º C
-40º to +60º C

Mean Time Between Failure
MTBF excluding
lightning damage > 100 years

Wind Speed Survival
200 mph

Industry Track Record
More than 10 years experience

PMP 450m

- **Leading-Edge Technical Innovation**
  - **More than 3x Capacity vs. 450/450i**
    - *cn*Medusa™ Massive MU-MIMO technology allows simultaneous communication with up to seven SMs
  - **Supreme Spectral Efficiency**
    - Achieve over 400 Mbps in a 20 MHz channel
  - **Protect Your Investment**
    - Continue using existing SMs
  - **Enhanced Link Stability**
    - Uplink Interference mitigation due to beamforming
    - Uplink Rx Sensitivity improvements (5-6 dB better)
  - **Advanced Processing Capability**
    - >100k PPS

- **One Simple device to install**
  - Simple Installation and Increased Reliability
  - Integrated 90° sector beam-forming array, **ZERO** RF cables to connect or weatherproof
  - A single Ethernet cable to connect
  - 20” x 25” x 4” (52x65x11 cm)
  - 40 lbs. (18.3 kg)

cnMedusa™

R16.0 Features

- Beta Released October 11, 2018 (expect to release officially by end October)
  - https://support.cambiumnetworks.com/files/pmp450/beta

- Incredible new Features:

  - Uplink MU-MIMO!
    - Something nobody can do today – Not 802.11, not LTE
    - Further increase total bandwidth and support high uplink requirements

  - AUX port support on 450m, PoE and/or bridging to another device

  - PTP 450b support
    - A PTP 450b can operate as PTP link or SM with software GUI change

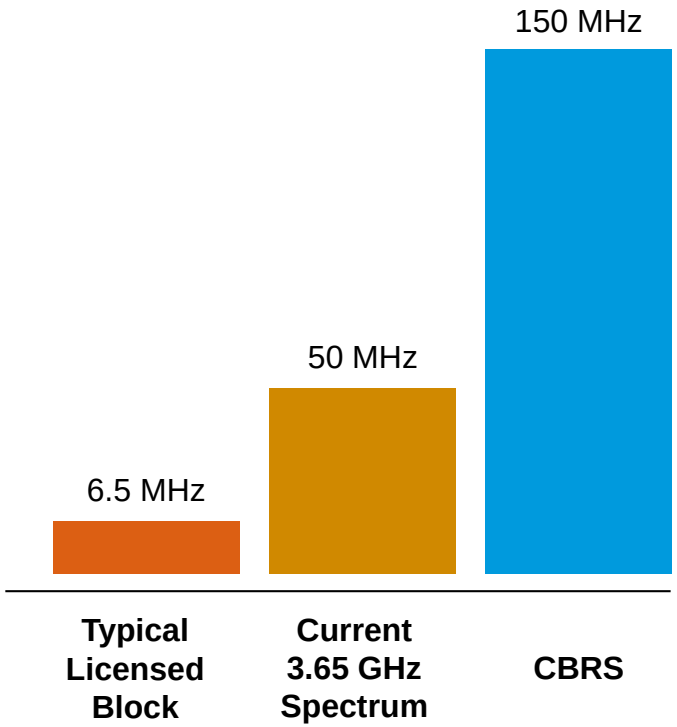
Cambium Networks™

3 GHz 450m

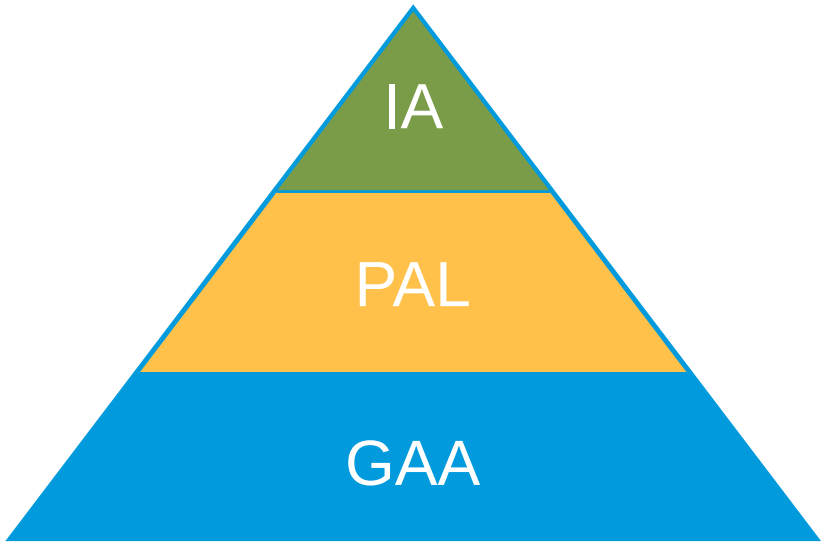
Matt Mangriotis
Director of Product Management

CBRS and New 3 GHz Spectrum

Opportunity



Tiered Flexible Use



Incumbents

- DoD Radars (coastal areas)
- Satellite Earth Stations

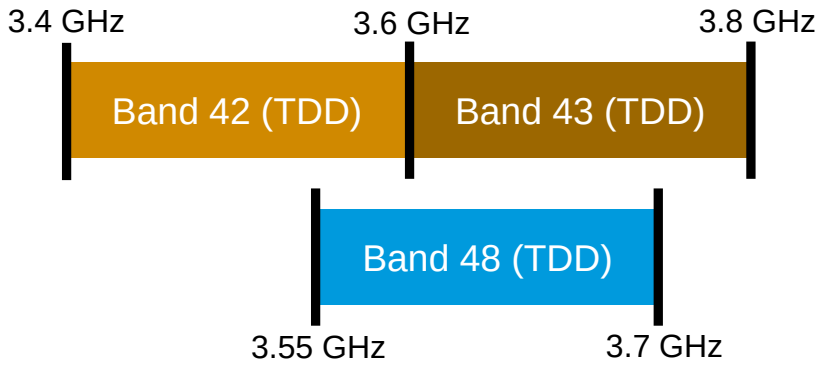
Priority Access Licenses (PAL)

- Up to 70 MHz of spectrum licensed by auction

General Authorized Access (GAA)

- At least 80 MHz nationwide

Establishing a New Common Band



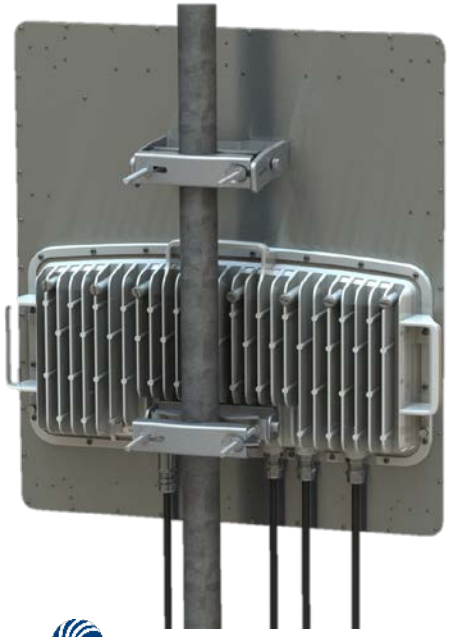
CBRS and New 3 GHz Spectrum - Strategy

- Ensure 450 platform readiness by working with several SAS providers

federated wireless COMMSCOPE® Google

- cnMaestro will bridge the communication from Radio to SAS
- Several questions exist on competitive equipment being able to meet more stringent CBRS emissions masks (and at what Tx powers)
- Shipping 3 GHz 450m in Q4, 2018
  - Supporting 8x8 MU-MIMO (up to 500 Mbps)
- Release of 3 GHz 450b SM in Q2, 2019
- Complete 3 GHz portfolio capable of graceful migration
  - Continue to operate under Part 90 subpart Z until license expires
  - Easily transition to Part 96 (CBRS) without changing equipment

cnMedusa



3 GHz - PMP 450m

Shipping in October

- **Leading-Edge Technical Innovation**
  - **More than 3x Capacity vs. 450/450i**
    - *cn*Medusa™ 8x8 MU-MIMO technology allows simultaneous communication with up to four SMs
  - **Supreme Spectral Efficiency**
    - DL and UL MU-MIMO supported
    - Achieve up to 750 Mbps in a 40 MHz channel
  - **Protect Your Investment**
    - 3.3GHz to 3.9GHz range
    - >47dBm EIRP
    - Continue using existing SMs
  - **Enhanced Link Stability**
    - Uplink Interference mitigation due to beamforming
    - Uplink Rx Sensitivity improvements (4-5 dB better)
  - **Advanced Processing Capability**
    - >200k PPS

- **One Simple device to install**
  - Simple Installation and Increased Reliability
  - Integrated 90° sector beam-forming array, **ZERO** RF cables connect or weatherproof
  - Direct DC powering
  - SFP and Gigabit Ethernet Support
  - 27” x 24” x 7” (70x61x17 cm)
  - 44 lbs. (20 kg)

Under test in the Lab – May 2018

Current Results Status

Test Duration: 8 Pkt Length: 1500 Test Direction Downlink

Link Test with Multiple LUIDs

Subscriber Module	LUID	Priority Channels	Throughput	Efficiency	Fragments		Downlink Rate
					Transmit	Received	SU-MIMO
			123.95 Mbps	**99%**	**1939784**	**1936758**	
SM 106 - [0a-00-3e-42-9a-11]	004	Low Priority	10.71 Mbps	99%	167806	167472	8X/8X MIMO-B
SM 107 - [0a-00-3e-42-98-d1]	005	Low Priority	8.96 Mbps	99%	140667	140139	8X/8X MIMO-B
SM 108 - [0a-00-3e-42-9c-7c]	006	Low Priority	9.86 Mbps	99%	154186	154074	8X/8X MIMO-B
SM 109 - [0a-00-3e-42-99-70]	007	Low Priority	10.83 Mbps	99%	169400	169335	8X/6X MIMO-B
SM 110 - [0a-00-3e-42-9b-99]	008	Low Priority	10.64 Mbps	99%	166550	166313	8X/8X MIMO-B
SM 111 - [0a-00-3e-42-99-d0]	009	Low Priority	8.49 Mbps	99%	133577	132793	8X/8X MIMO-B
SM 100 - [0a-00-3e-42-9c-a7]	010	Low Priority	10.24 Mbps	99%	160589	160114	8X/8X MIMO-B
SM 101 - [0a-00-3e-42-9b-c3]	011	Low Priority	10.97 Mbps	99%	171554	171489	8X/8X MIMO-B
SM 102 - [0a-00-3e-42-9c-1a]	012	Low Priority	11.02 Mbps	99%	172313	172252	8X/8X MIMO-B
SM 103 - [0a-00-3e-42-9b-c4]	013	Low Priority	10.82 Mbps	99%	169176	169124	8X/8X MIMO-B
SM 104 - [0a-00-3e-42-9c-9c]	014	Low Priority	10.49 Mbps	99%	164130	163991	8X/8X MIMO-B
SM 105 - [0a-00-3e-42-9c-95]	015	Low Priority	10.85 Mbps	99%	169836	169662	8X/8X MIMO-B

Slot Grouping

Group Size	% Distribution	Average Slot Count
1 (ungrouped)	100.0	75
2	0.0	0
3	0.0	0
4	0.0	0
5	0.0	0
6	0.0	0
7	0.0	0

Link Test ran on 04:34:18 01/01/2016 UTC

Current Results Status

Test Duration: 10 Pkt Length: 1500 Test Direction Downlink

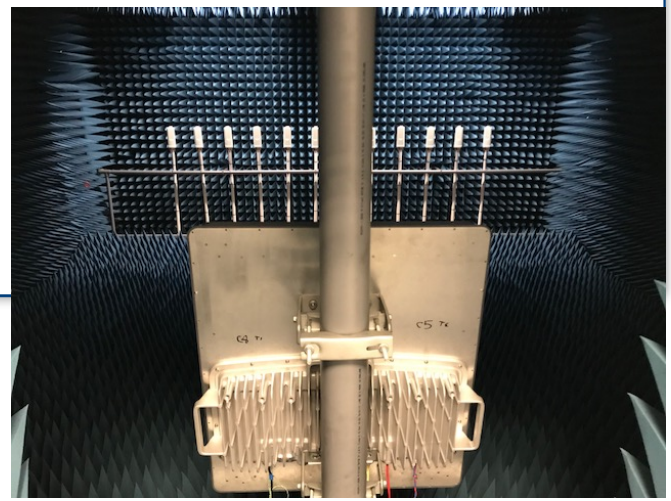
Link Test with Multiple LUIDs

Subscriber Module	LUID	Priority Channels	Throughput	Efficiency	Fragments		Downlink Rate		Grouping Ratio
					Transmit	Received	SU-MIMO	MU-MIMO	
			489.44 Mbps	**99%**	**9592489**	**9559481**			
SM 106 - [0a-00-3e-42-9a-11]	004	Low Priority	39.59 Mbps	98%	785146	773259	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 107 - [0a-00-3e-42-98-d1]	005	Low Priority	40.34 Mbps	99%	791558	788002	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 108 - [0a-00-3e-42-9c-7c]	006	Low Priority	41.17 Mbps	99%	805024	804217	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 109 - [0a-00-3e-42-99-70]	007	Low Priority	41.34 Mbps	99%	808172	807613	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 110 - [0a-00-3e-42-9b-99]	008	Low Priority	41.40 Mbps	99%	809112	808611	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 111 - [0a-00-3e-42-99-d0]	009	Low Priority	41.02 Mbps	99%	803493	801330	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 100 - [0a-00-3e-42-9c-a7]	010	Low Priority	40.09 Mbps	99%	786514	783012	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 101 - [0a-00-3e-42-9b-c3]	011	Low Priority	41.22 Mbps	99%	807076	805157	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 102 - [0a-00-3e-42-9c-1a]	012	Low Priority	41.10 Mbps	99%	803660	802755	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 103 - [0a-00-3e-42-9b-c4]	013	Low Priority	41.02 Mbps	99%	803118	801251	8X/6X MIMO-B	8X/8X MIMO-B	100%
SM 104 - [0a-00-3e-42-9c-9c]	014	Low Priority	40.39 Mbps	99%	792695	789022	8X/8X MIMO-B	8X/8X MIMO-B	100%
SM 105 - [0a-00-3e-42-9c-95]	015	Low Priority	40.71 Mbps	99%	796921	795252	8X/8X MIMO-B	8X/8X MIMO-B	100%

Slot Grouping

Group Size	% Distribution	Average Slot Count
1 (ungrouped)	0.0	0
2	0.0	0
3	0.0	0
4	100.0	75
5	0.0	0
6	0.0	0
7	0.0	0

Link Test ran on 01:13:52 01/01/2016 UTC



3 GHz PMP 450 vs. LTE Whitepaper


Cambium Networks

A COMPARISON

PMP 450 and LTE in 3 GHz

INTRODUCTION

The LTE (Long Term Evolution) standard provides for great performance and has (at some point on the roadmap) many features that make it well-suited for any use case. The 3rd Generation Partnership Project (3GPP) originally came together as an industry group to create mobile standards that would move mobile (cellular) infrastructure forward. This group has continued to evolve the standard, and is backed by the largest telecommunications groups in the world. The LTE standard has been developed by this group and has had billions of hours and dollars poured into it to create the standard protocol for mobile telecommunications. As it stands, the release definitions are frozen through Release 13, with Release 14 soon to come. Chipset manufacturers are doing their best to keep up with the release schedule, and incorporating features defined in these releases in their latest offerings.

However, just because a product utilizes the LTE standard does not inherently mean it has any of these features, or the optimal level of performance. The system implementation; that is, the application of chipset to functional system, makes all the difference. As is nearly always the case, there are tradeoffs to be made between system cost and performance. Striking the proper balance for the targeted market segment is key to creating a product that will be successfully implemented.

CUSTOMER EXPERIENCE

Globally, the 3 GHz band has been a licensed frequency band that was defined for the WiMAX standard. It is not typically available to Service Providers without having purchased or leased this frequency. However, some efforts have been made to make it more readily available in certain parts of the world. Specifically, in the United States and Canada, 50 MHz of this spectrum (3650-3700 MHz) had been available under a "lightly licensed" condition. An operator needed to obtain a nationwide, non-exclusive license at very low cost from the regulatory body, then register any equipment that would be operating in that band. This propelled the use of this band forward tremendously over the last several years.

Cambium Networks introduced the 450 platform operating in the 3 GHz band in 2014. Since then, it has been deployed in hundreds of networks globally. This represents a substantial number of operators that are helping to bridge the digital divide, and connect rural customers. Upcoming changes to this band in the United States (via the Citizens Band Radio Service (CBRS) initiative) will allow additional frequency

Paper available at:
https://www.cambiumnetworks.com/resource/comparison-pmp-450-lte-3-ghz/

In many ways, 450 outperforms any existing LTE solution

BEST ● ◓ ○ ◒ ● WORST	EXISTING LTE SOLUTIONS	CAMBIUM PMP
Customer Experience	◒	●
Range and Coverage	●	○
Interference Mitigation	○	●
Total Sector Capacity	○	●
Subscriber Bandwidth	◒	●
Infrastructure Costs	●	●
Mobility Support	●	●
Total Cost of Ownership	●	●

Cambium Networks™

Cambium Networks LTE Program

Why LTE?

Customer Perspective

- Small WISP (<2,000 subscribers)
  1. **NLOS performance, need for better range and coverage than other available solutions**
- Medium WISP (2,000-10,000 subscribers)
  - Licensed spectrum to add capacity and provide premium service
  - Investment protection
  2. **Inexpensive CPE options**
- Large WISP (> 10,000 subscribers)
  3. **Investors demand industry standard LTE**
  - Attractive Air Interface attributes
  - Inexpensive CPE

Cambium Perspective

- Adopt industry standard and innovate rather than reinvent
- Lower Cost SM: LTE chipsets are inexpensive relative to FPGA & DSP
- LTE air interface features
  - OFDMA in downlink
  - Improved receive sensitivity due to coding gains
  - Carrier aggregation and LAA
  - Frequency reuse 1 – for licensed bands
  - Inter cell interference coordination
  - Hybrid ARQ with soft combining

Why Not Use Existing LTE solutions?

– Too complex (EPC, SIM cards)

– Too costly

– Not Fixed Service Provider-friendly

– Products that exist are immature or “beta quality”

Cambium Networks - Differentiating on a Standard

- Remove cost and complexity typically associated with LTE
- Exploit LTE Air Interface Features
- High power radio to take advantage of higher regulatory limits in 2.5GHz
- Leverage our expertise in robust outdoor CPE design
- **Retain PMP 450 networking, QoS, security and management features**


Introducing the all new LTE platform from Cambium Networks
Bringing extreme quality, necessary features, and the focus on fixed wireless that your network deserves.
cnRanger™
TRUST SOMEONE WHO'S BEEN THERE BEFORE
Cambium Networks™

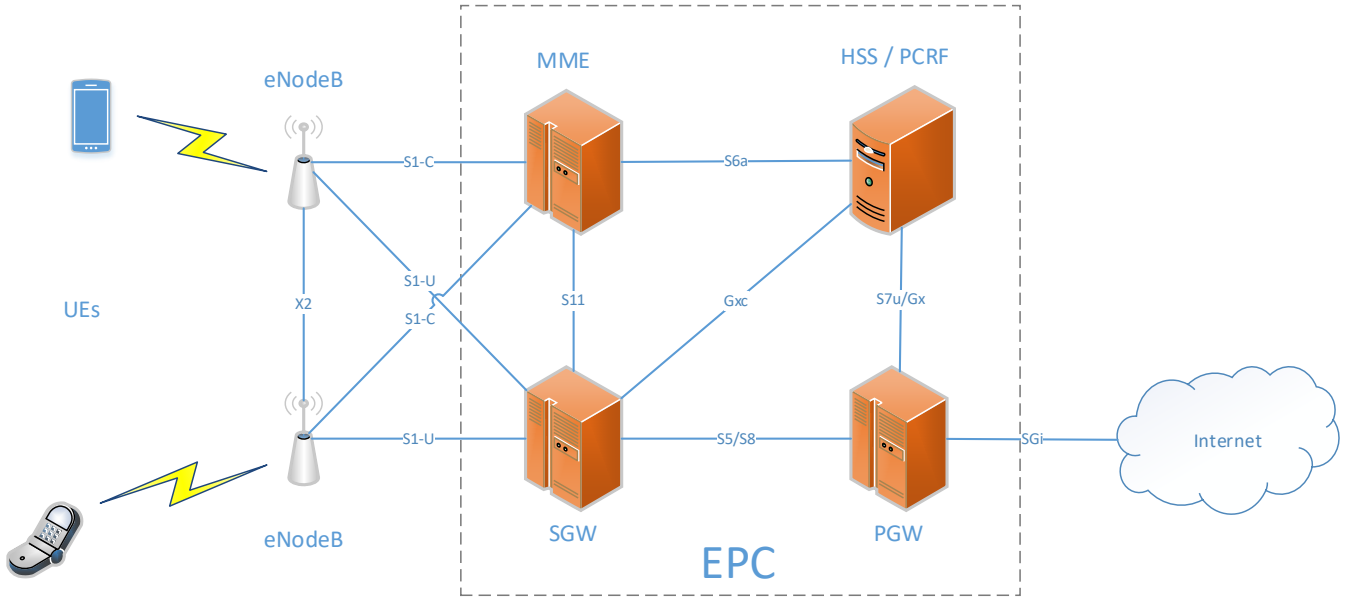
Our LTE Solution

- Building on our 450 to LTE comparison, we close the gap between the existing solutions and the Cambium LTE solution.
- 450 *still* outperforms LTE in many ways, but Cambium's LTE addresses deficiencies in alternative LTE solutions.

Best ● ◒ ○ ◒ ● Worst	Existing LTE Solutions	Cambium PMP	Cambium LTE
Customer Experience	◒	●	N/A
Range and Coverage	●	○	●
Interference Mitigation	○	●	◒
Total Sector Capacity	○	●	○
Subscriber Bandwidth	◒	●	◒
Infrastructure Costs	●	●	◒
Mobility Support	●	●	◒
Total Cost of Ownership	●	●	◒

LTE Architecture

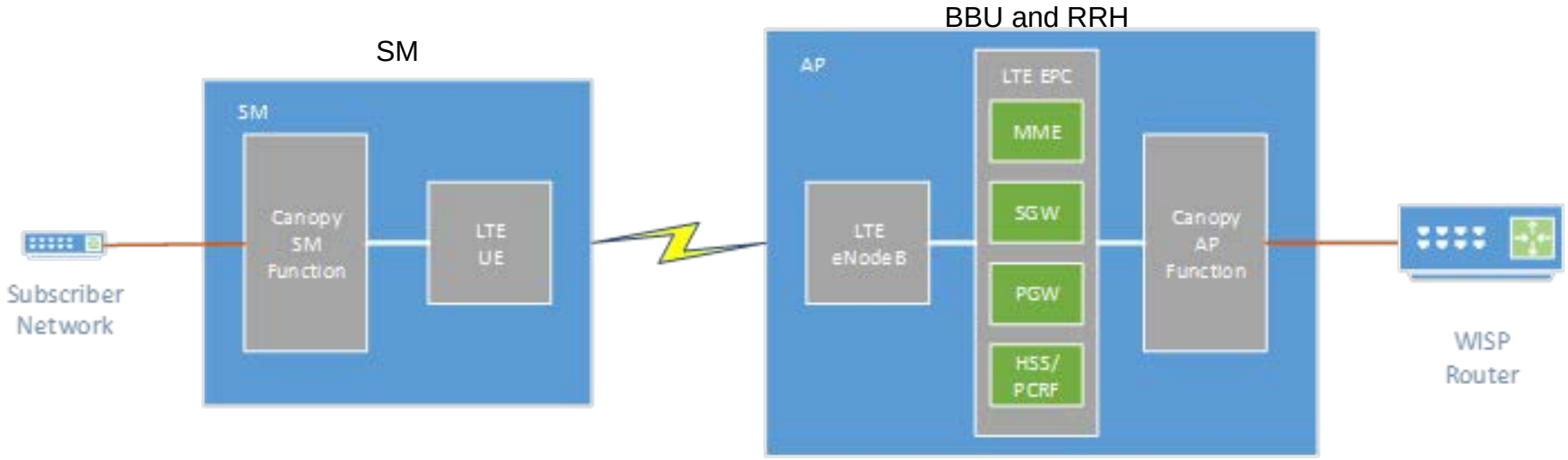
- A traditional LTE solution consists of:
  - RAN (Radio Access Network) as shown by the eNodeBs (eNB)
  - EPC (Evolved Packet Core) which has several functional entities / servers (EXPENSIVE and COMPLICATED)
    - MME (Mobility Management Entity)
    - HSS (Home Subscriber Server)
    - PCRF (Policy Control & Charging Rules Function)
    - SGW (Serving Gateway)
    - PGW (Packet Data Network Gateway)
  - SMs, also known as UEs (User Equipment)



Traditional LTE Solution

What Is cnRanger?

- cnRanger is a complete, simple, fixed LTE solution
- The BBU (Baseband Unit) and RRH (Remote Radio Head) handle *both* RAN (Radio Access Equipment) and EPC (Evolved Packet Core) functionality
  - Canopy networking (e.g. Layer 2) and management functionality are present, too
- cnRanger provides an SM with Canopy networking and management
  - Third party LTE UEs also function with the BBU and RRH

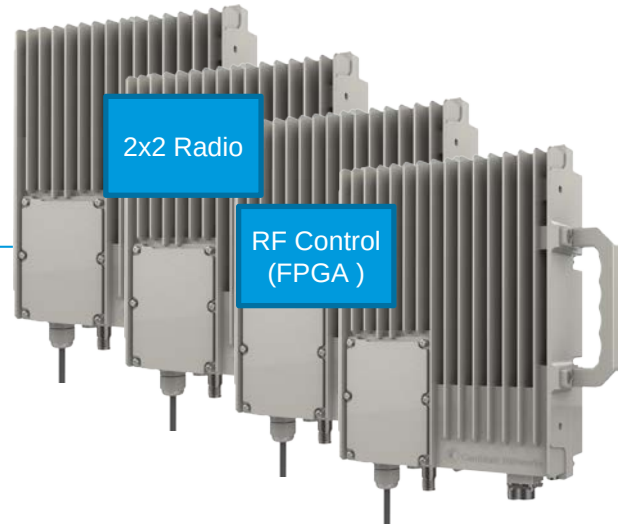


cnRanger Fixed LTE Solution

Separate Baseband and Radio
(Traditional LTE model)

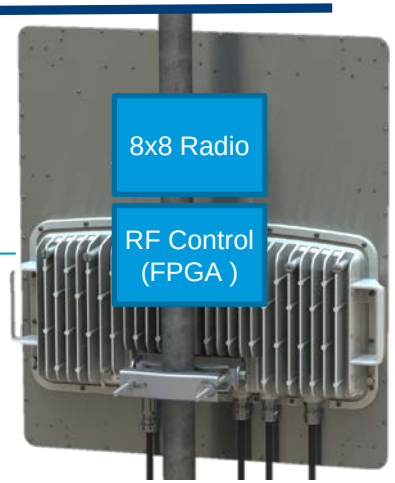
PMP450 has baseband and radio together

LTE will have 8x8 Baseband Unit (BBU) and Remote Radio Heads (RRH)



The BBU can drive 4 2x2 radios to provide 360º coverage …

… Or one 8x8 radio for a single Sector with MU-MIMO support



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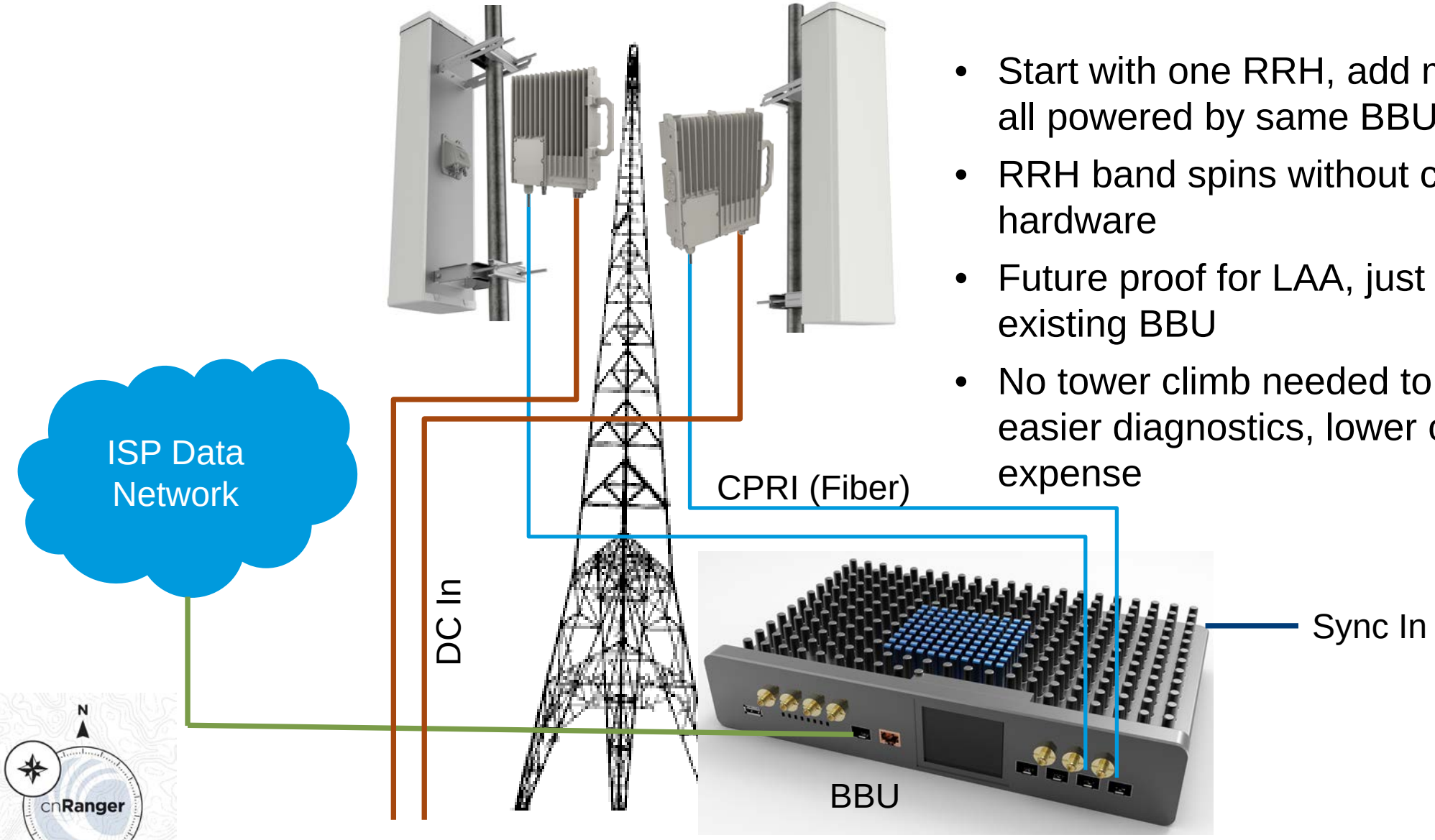
Cambium Networks™

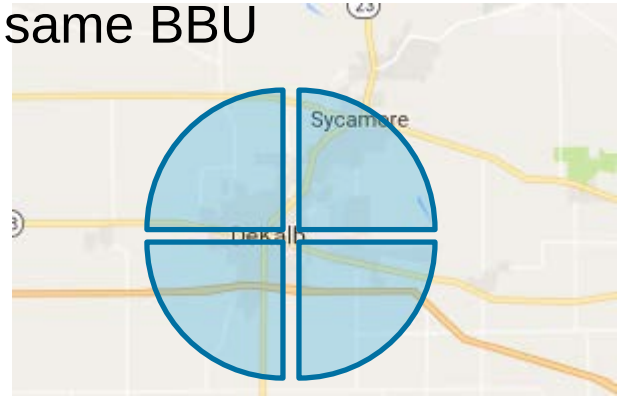
Deployment



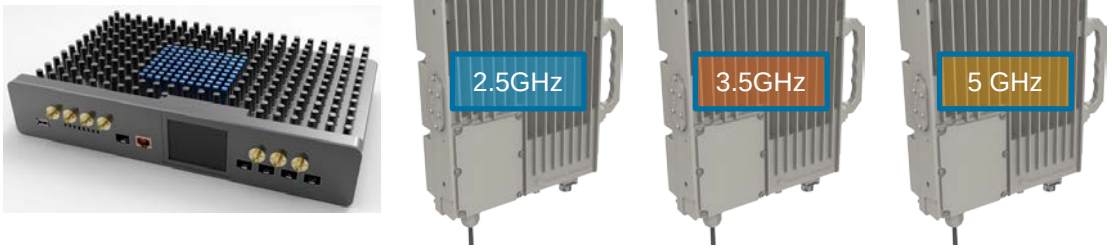
- Start with one RRH, add more as you grow, all powered by same BBU
- RRH band spins without changing BBU hardware
- Future proof for LAA, just add 5GHz RRU to existing BBU
- No tower climb needed to access BBU – easier diagnostics, lower operational expense

Flexibility by splitting Baseband and Radio

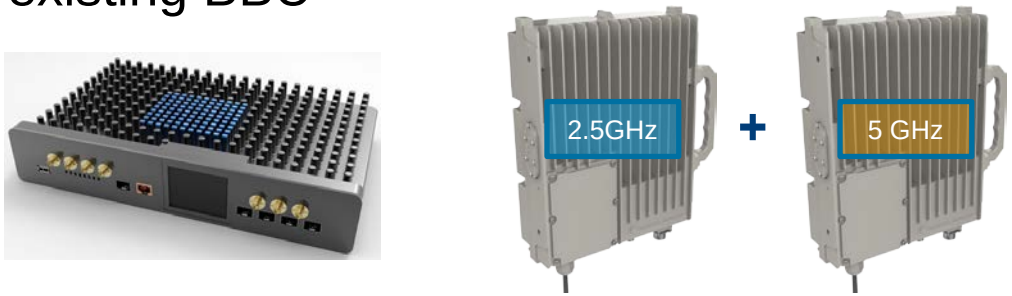
- Start with one RRH, add more as you grow, all powered by same BBU



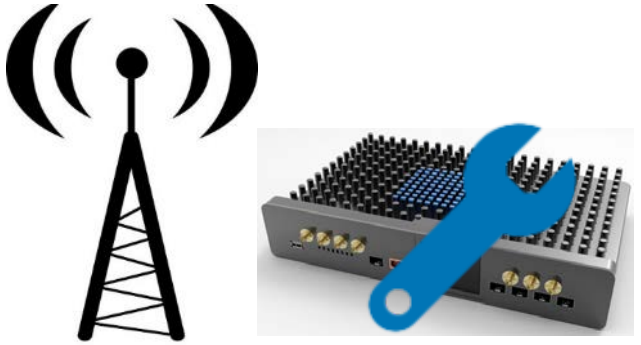
- RRH bandspins without changing BBU hardware



- Future proof for LAA, just add 5GHz RRU to existing BBU

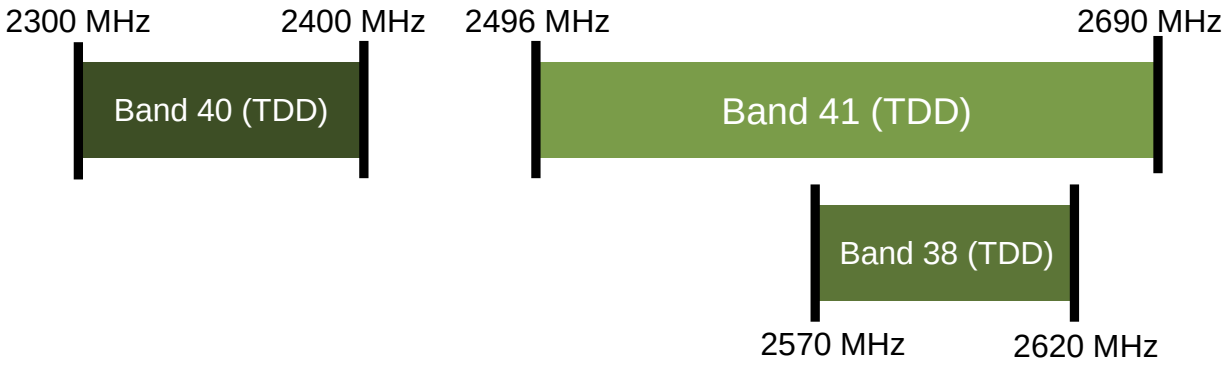


- No tower climb needed to access BBU – easier diagnostics, lower operational expense

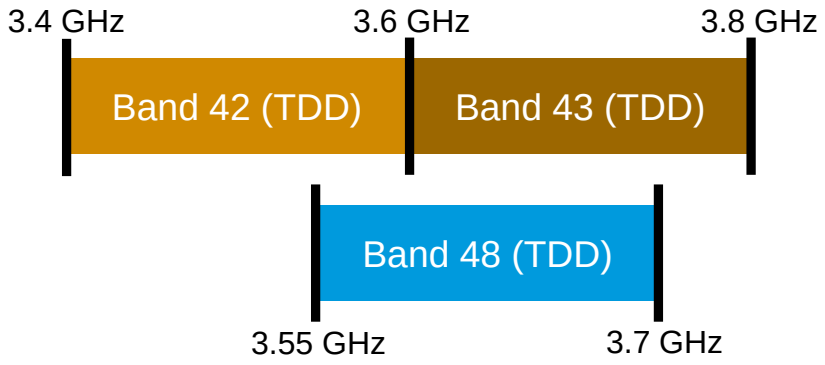


Planned Spectrum Coverage

First Release, Q1, 2019



2nd Release, Q2, 2019



What is being delivered?

Q1 2019

Baseband Unit

- ✓ LTE-A Rel 10+
- ✓ 19” rack mount unit
- ✓ 8TX, 8RX
- ✓ Drive 3 120° sectors (2x2 each) over CPRI
- ✓ 64 SM per sector
- ✓ GPS in
- ✓ 2x GigE ports
- ✓ Integrated EPC

- ➢ Future Enhancements
  - ➢ Dual sector, LAA
  - ➢ Carrier aggregation
  - ➢ 1588v2
  - ➢ 1024 SM support

- No mobility
- No roaming

Remote Radio Head

- ✓ **Band 38, 40, 41**
  - ✓ 2.3 GHz to 2.7 GHz
- ✓ 2TX, 2RX
- ✓ 2W per port
- ✓ CPRI (fiber) connection to BBU
- ✓ 90° sector antenna
- ✓ 17 dBi antenna gain
- ✓ IP66/IP67

- ➢ Future Enhancements
  - ➢ CA (20+20, 10+10)
  - ➢ Dual sector (no CA)
  - ➢ Available 8W per port version

Subscriber Module

- ✓ **Band 38, 40, 41**
  - ✓ 2.3 GHz to 2.7 GHz
- ✓ **CAT 4**
- ✓ 1 TX, 2 RX
- ✓ 100/50 Mbps
- ✓ 1x GigE port
- ✓ 30V DC Input
- ✓ 14 dBi integrated patch

- ➢ Future Enhancements
  - ➢ CAT 6
  - ➢ High Gain Integrated Dish
  - ➢ Dual-Band (2 + 3 GHz)

cnRanger

Cambium Networks™

cnRanger Differentiators

Feature	Benefit
Release Quality	Customers with experience with Cambium expect high and consistent quality, this will be a draw as other LTE vendors have had issues
Simple Set Up	LTE can be extremely complex. We are eliminating the complexity of deploying LTE (eliminating the EPC and associated infrastructure, etc.) – **Intelligent Edge, Integrated Virtualized EPC**
Provider Focused Feature Set	Bringing required features (that many LTE providers lack) to allow better monitoring and management of fixed wireless network
SM Transmit Power	Compared to most, we have 3 dB higher Tx power, so the UL is more capable with cnRanger SMs
TCO	We will produce several models against what we know about competitors, but believe we have advantage over most of competition.
Optimized use of Spectrum	Cambium-designed antenna helps optimize use of spectrum, much better than other systems in this space, optimized for N=1 deployments
Flexibility of Split Architecture	Frequency-agnostic BBU, installation at base of tower, lighter RRH than some competitors
Layer 2 Capabilities	Most providers want this for easy integration with rest of network
RRH Transmit Power (mid-tier)	At 2W per port, this is higher than “low end” competition, comparable in price, but better propagation (Higher Powered version also forthcoming)

Complete Solutions

Cambium Networks™

Support – Cambium Care

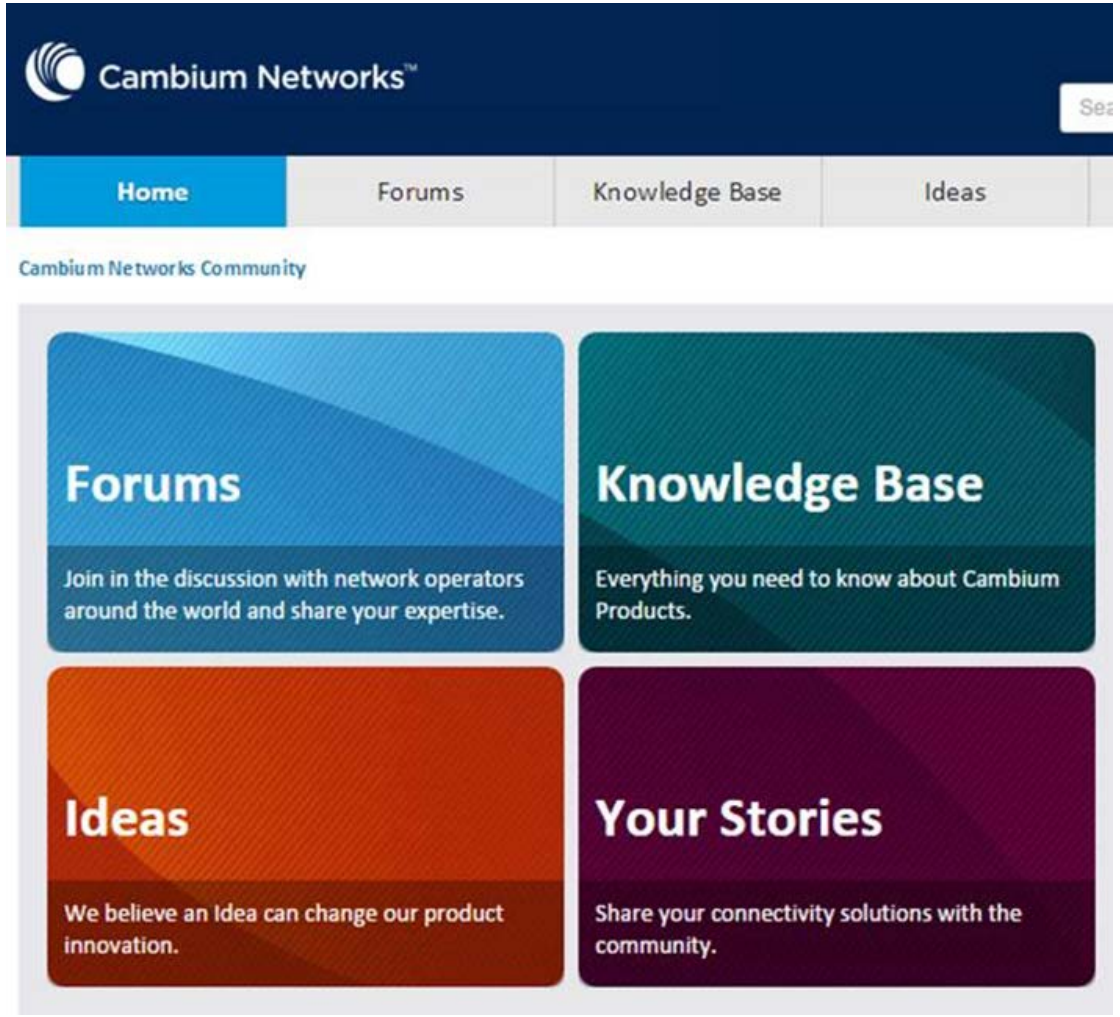
- 24x7 support
- Proactive updates
- Escalation process
- Repair and replacement services
- Select the support level that meets your needs
  - Standard
  - Plus
  - Prime

Support – Cambium Care

FEATURE	CAMBIUM CARE STANDARD	CAMBIUM CARE PLUS	CAMBIUM CARE PRIME
8 x 5, Monday-Friday Technical Support (Phone, Web Portal)/Email	Yes	-	-
24 x 7 x 365 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	Ongoing Ext. Warranty (Std) Advance Replace (Add'l)
Targeted Proactive Software Release Notification	No	Email Notification	Personal Advisory
Service Account Manager	No	No	Yes
Network Monitoring	No	Available	Available
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



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