



**Cambium Networks™**

## New Opportunities for Fixed Wireless: Spectrum Sharing and Utilizing 5G

Matt Mangriotis, Senior Director of Product Management

- **Expanding Demand and New Use Cases**

- Work/Learn/Entertain from Home
- Over-The-Top Media Access
- Industrial Automation

- **Spectrum Availability**

- 6 GHz: FCC 5.925 – 7.125 GHz
- CBRS: 3.550 – 3.700 GHz
- 60 GHz: 57 – 66 GHz
- 5G: 24.25 – 29.50 GHz

- **Supporting Standards**

- IEEE 802.11ax
- IEEE 802.11ay
- 3GPP 5G NR (Release 15 & beyond)

- **Enabling Technology**

- Massive Multi-User MIMO
- Smart Antenna
- System on Chip

- **3GPP Acknowledgment in 5G NR**



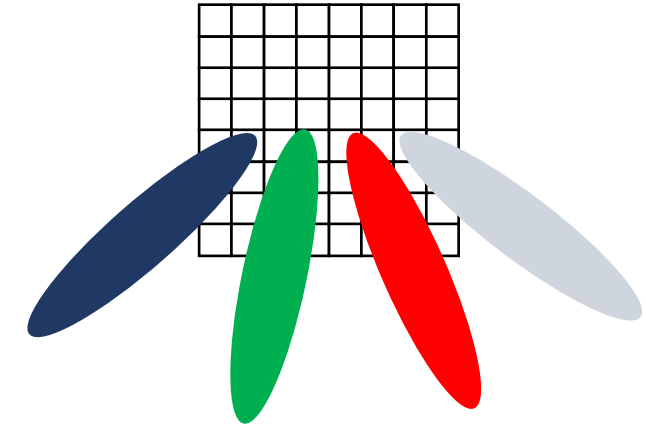
- **Release 15 Foundation / Validation**
- **Higher Data Rates**
- **Lower Latency**
- **Denser Networks**
- **Improved Symmetry**
- **Defined facilities for specific vertical applications**

## Three Defined Applications:

- **eMBB: Enhanced Mobile Broadband** progresses mobile broadband access and performance beyond 4G
- **URLLC: Ultra-Reliable Low-Latency Communications** for mission critical applications
- **mMTC: Massive Machine-Type Communications** to support IoT connections



- **Support for a large number of steerable antenna elements**
  - 100's to 1000's elements : no hard limit
  - Suitable for
    - beamforming
    - Massive MIMO
- **All physical channels and reference signals can be beam formed**
  - A necessity in mm-wave bands
    - Up to 64 SSBs (Synchronisation Signal Blocks)
  - Minimal always on transmissions : SSB and SIB1 (system information block)
    - UE can request data from additional SIBs during attachment
    - 1/100 reduction in transmissions for inactive cell
  - Front loaded DMRS (demodulation reference signals)
    - Reduced latency forming channel estimate
  - Flexible ACK timing



- **MU-MIMO users**

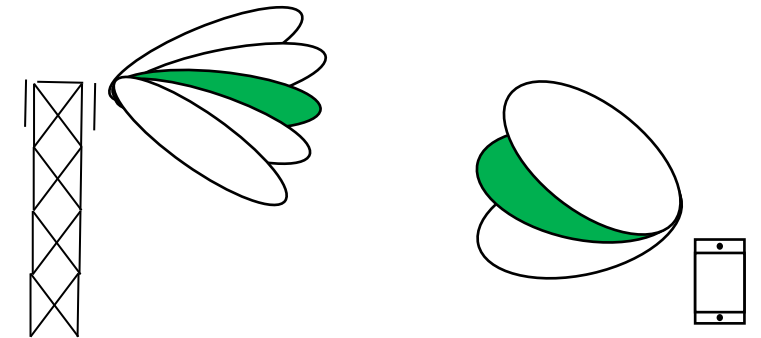
- Up to 12 layer DMRS
  - MU-MIMO channel estimates not affected by inter-beam interference

- **Channel sounding**

- Sounding : CSI-RS (channel state information RS), SRS (sounding RS)
- Type II CSI feedback targets MU-MIMO
  - UE provides high resolution mag/phase from the strongest beams
  - Low mobility
    - PMI report uses 100's bit
    - relevant to FWA

- **Extensive beam management facilities and processes**

- Support beam forming at both sides of the link
- Facilities support analog and digital domain beamforming



- **New spectrum**

- ~ 5 GHz in mm-wave bands

- Additional spectrum around 3-4 GHz

REMARKS OF FCC CHAIRMAN AJIT PAI on 21 JUNE, 2019  
"All in all, our auctions this year will free up for the commercial marketplace almost 5 gigahertz of spectrum for flexible use."

- **OFDM with flexible numerology**

- Multiple subcarrier spacing

- Steerable antenna support

- Phase Tracking Reference Signals

- mm-wave compromise at high SNR

subcarrier spacing	Max bandwidth	Min bandwidth	symbol duration	cyclic prefix	slot time
kHz	MHz	MHz	us	us	us
15	50	3.6	71.35	4.69	1000.00
30	100	7.2	35.68	2.34	500.00
60	200	14.4	17.84	1.17	250.00
120	400	28.8	8.92	0.59	125.00

# Release 15 for Fixed Wireless Access

## April 2019

Attribute	Benefit
Native mmWave support	<ul style="list-style-type: none"><li>• Explicit support for beamforming during acquisition &amp; operation</li><li>• Wide subcarrier spacing to mitigate phase noise degradation</li></ul>
Wide Channel Size (up to 800 MHz)	<ul style="list-style-type: none"><li>• Very high throughput</li></ul>
Flexible Frame Structure	<ul style="list-style-type: none"><li>• Support wide range of up/down asymmetric traffic</li><li>• Always On</li><li>• Well suited to FWA</li></ul>
Uplink OFDMA	<ul style="list-style-type: none"><li>• Efficient, cost effective CPE</li></ul>



# Release 16 for Fixed Wireless Access

## July 2020

Attribute	Benefit
Unlicensed Spectrum Support	<ul style="list-style-type: none"><li>Provides ubiquitous access to 5G NR technology by lowering the high cost of acquiring licensed spectrum</li></ul>
Coexistence with non-3GPP systems	<ul style="list-style-type: none"><li>Opportunity to access/share spectrum</li></ul>
Enhancements to Ultra-Reliable Low Latency Communication	<ul style="list-style-type: none"><li>Support for mission critical applications</li></ul>
Industrial IoT	<ul style="list-style-type: none"><li>Opening up IIoT Use Cases</li></ul>





# Release 17 for Fixed Wireless Access

## December 2021

Attribute	Benefit
52.6~71 GHz support	<ul style="list-style-type: none"><li>• Standard air interface for 26/28/39 and 60 GHz</li></ul>
Dynamic Spectrum Sharing	<ul style="list-style-type: none"><li>• More efficient use of available spectrum</li></ul>
Low complexity NR devices	<ul style="list-style-type: none"><li>• Cost optimized CPEs</li></ul>
Integrated Access & Backhaul enhancements	<ul style="list-style-type: none"><li>• Lower cost, faster deployment, “all wireless” networks</li></ul>
Coverage Enhancements	<ul style="list-style-type: none"><li>• More cost-effective networks</li></ul>



- ITU has been working on identifying and assigning spectrum for “5G” use
- WRC-19 has designated more than 17 GHz of spectrum for this purpose
  - <https://news.itu.int/wrc-19-agrees-to-identify-new-frequency-bands-for-5g/>
- **However, implementing this globally is quite challenging**

- How can connecting more people be easier?
- Regulating telecommunications and spectrum use is difficult
- Internationally this is even more complex
  - Need local understanding of:
    - Policy
    - Local Market
    - Existing licenses and incumbent users
- **Spectrum Sharing can provide an avenue to avoid long, complex licensing schemes releasing more spectrum to more users, while protecting incumbents**

- **TVWS:** TV Whitespace – Shift to digital TV transmission freed up spectrum, but protection for existing users is required.
- **CBRS:** Success story in the US so far, attractive mid-band spectrum that is licensed but under-utilized in many geographies
- **WiFi 6e (6 GHz):** Additional (potentially unlicensed) spectrum that could be very quickly and widely adopted by many users, but again requires incumbent protection methods.
- **mmWave:** Short range but very high bandwidth means sharing could be easier to implement.



# TVWS



# Where are the Opportunities for TVWS



Source: Dynamic Spectrum Alliance

# Why no Cambium Product for TVWS?

- Cambium had a product in 2009 that could operate in TVWS bands
- Regulations made deployment and operation very difficult
  - Extremely tight emissions mask
  - Deployment height restrictions
  - Channel size limitations
  - Lack of Database (for sharing administration)
- Discrete nature of products makes it expensive to produce
- Antennas are large, cumbersome and expensive
- This is all getting better though – Future is brighter



# CBRS





# CBRS – Why does anyone care?

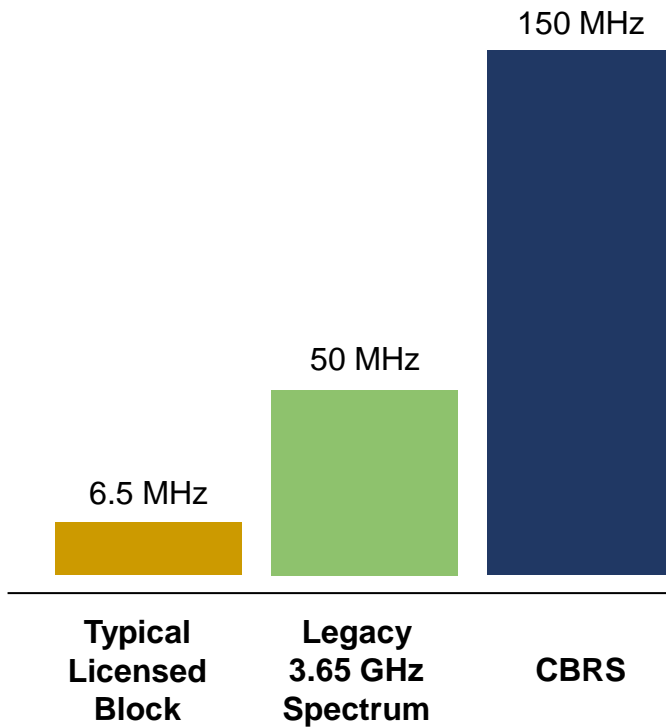
- Dynamic Spectrum Sharing model can be applied to any spectrum globally
  - Tiered approach to protect several classes of users of the spectrum
  - Allows sharing of unused portions of spectrum, while mitigating interference caused
- **CBRS** itself is quite complex

Pros	Cons
Lower Frequency than unlicensed 5 GHz (better penetration)	Spectrum sharing has a cost
Higher EIRP allowed	Hype around uses could cause congestion
Spectrum is actively managed	Equipment in this band slightly more expensive than traditional unlicensed
Incumbents protected	Standards-based (LTE) kit is predominant, and top of mind
Option to purchase license for priority use	Rules and requirements very complex

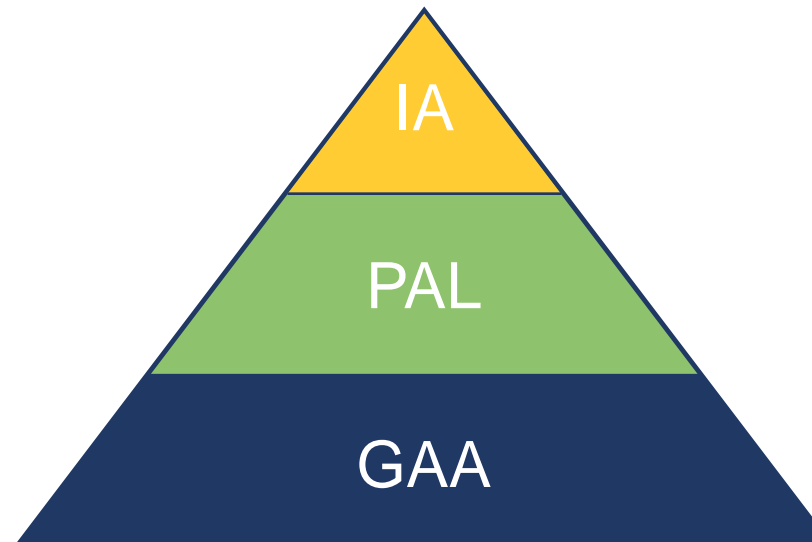
- Success being demonstrated now - many other regions and bands in process of adopting similar models

# CBRS and New 3 GHz Spectrum

## Opportunity



## Tiered Flexible Use



### Incumbents

- DoD Radars (coastal areas)
- Satellite Earth Stations

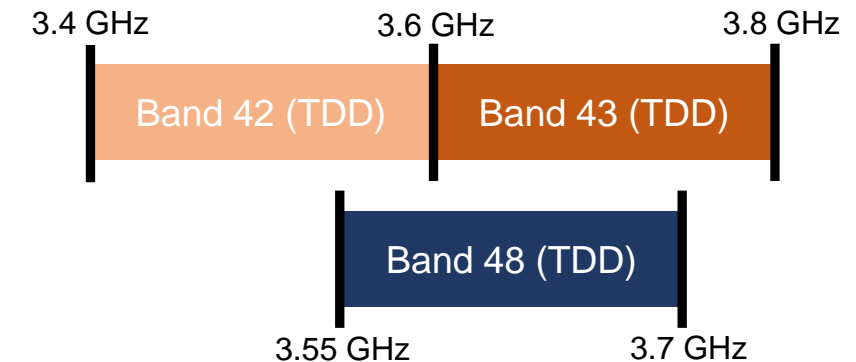
### Priority Access Licenses (PAL)

- Up to 70 MHz of spectrum licensed by auction

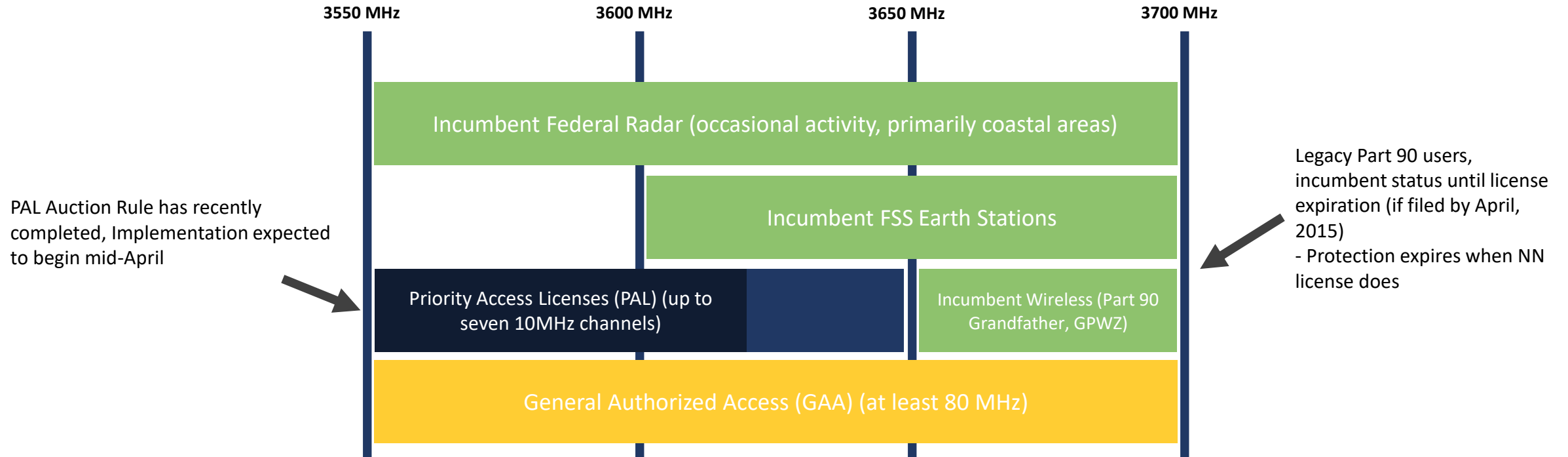
### General Authorized Access (GAA)

- At least 80 MHz nationwide

## Establishing a New Common Band



# CBRS – Frequency



Cambium expects that many of its customers have won PAL licenses in counties in which they are operating, affording them some protection in using CBRS, and assuring the continued use and expansion of their networks.

# Cambium's CBRS Solution – A Proven Winner

- 450 platform works with all major SAS providers



- Market-leading adoption:
  - Nearly 100,000 Cambium devices operating in CBRS today
- Large Ecosystem of capable products:
  - LTE-based equipment available also
- Successful auction for PALs (\$4.58 Billion)





- **450 platform works from 3.3-3.9 GHz**
- ISED has desire to move spectrum from 3.65-3.7 to 3.9-3.98 GHz, and plans to do so in 5 years
- 450 works reasonably well up to 3940 MHz.
  - From 3940-3950 MHz, ~2-3 dB loss
  - From 3950-3965 MHz, ~3-4 dB loss
  - From 3965-3980 MHz, ~6-8 dB loss
- The Good News: 450m re-design will eliminate most of this loss, due to release in Q4.



# 6 GHz

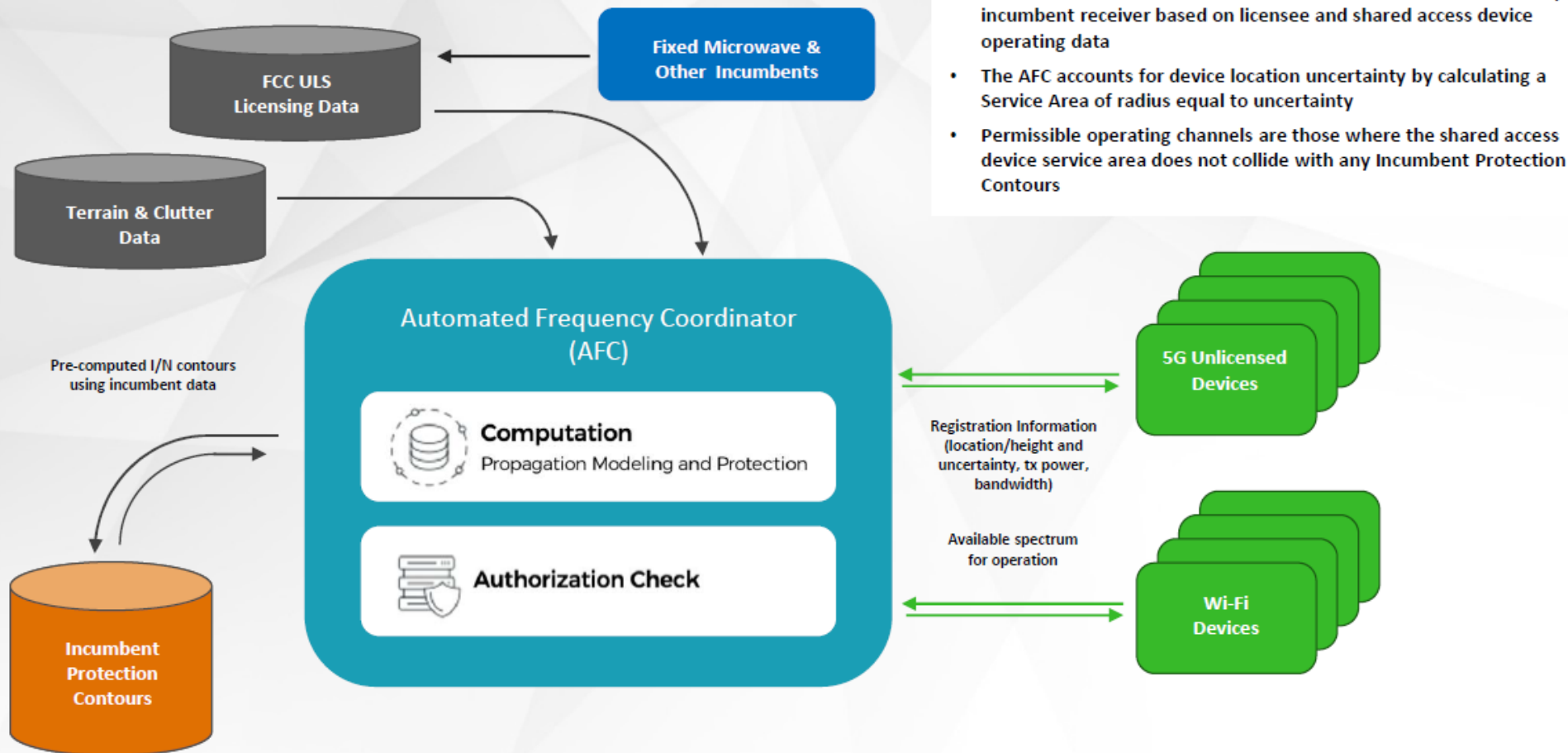


# What makes 6 GHz unique?

- Typically Wi-Fi is used in unlicensed bands
- This requires self-coordination to effectively use spectrum
  - Cambium does this using GPS Synchronization
  - Further complicated in many regions because of license holders that demand protection
- **Wi-Fi 6 and 6e provide a standard for efficiency and performance gains and will likely be the predominant technology used in the band**
  - Alternative technologies, such as the SDR protocols utilized by the 450 platform will also work quite well in this band
- **Incumbent License holders need to be protected, hence AFC**

## Automated Frequency Coordinator (AFC)

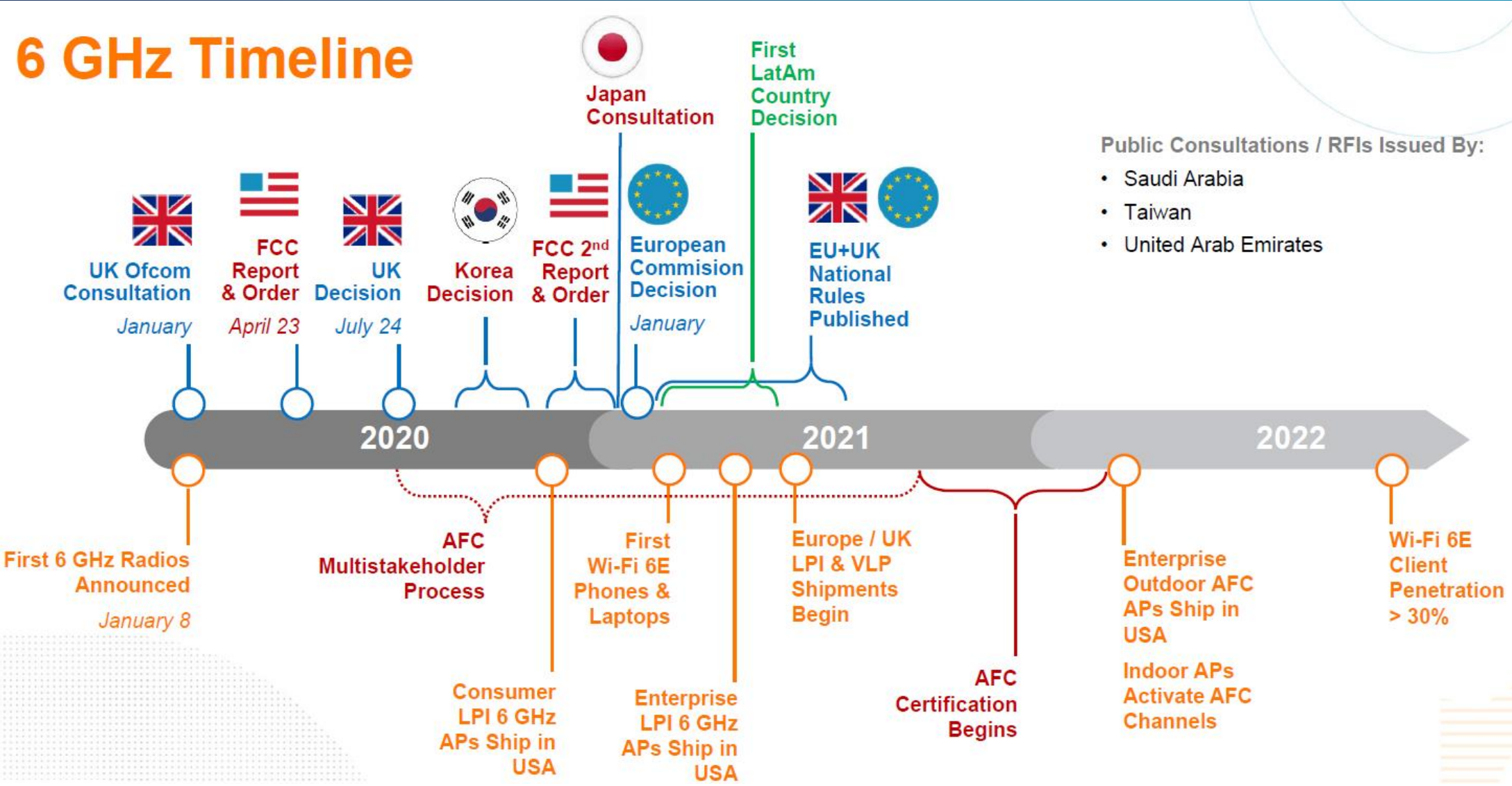
### Cloud Automation for 6 GHz Sharing



Source: Federated Wireless



## 6 GHz Timeline

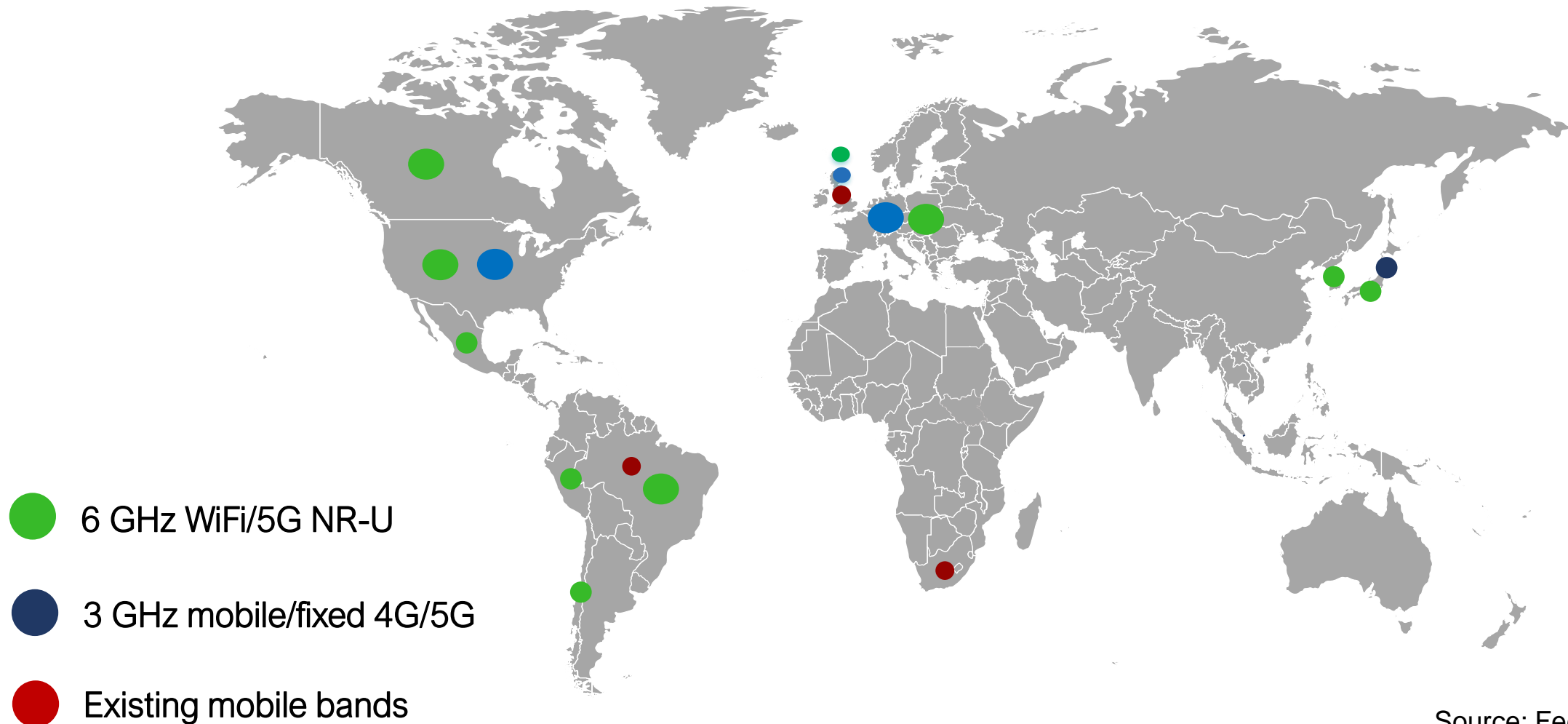


- Public Consultations / RFIs Issued By:
- Saudi Arabia
  - Taiwan
  - United Arab Emirates

Source: Aruba



# Many Countries Have Begun Evaluation

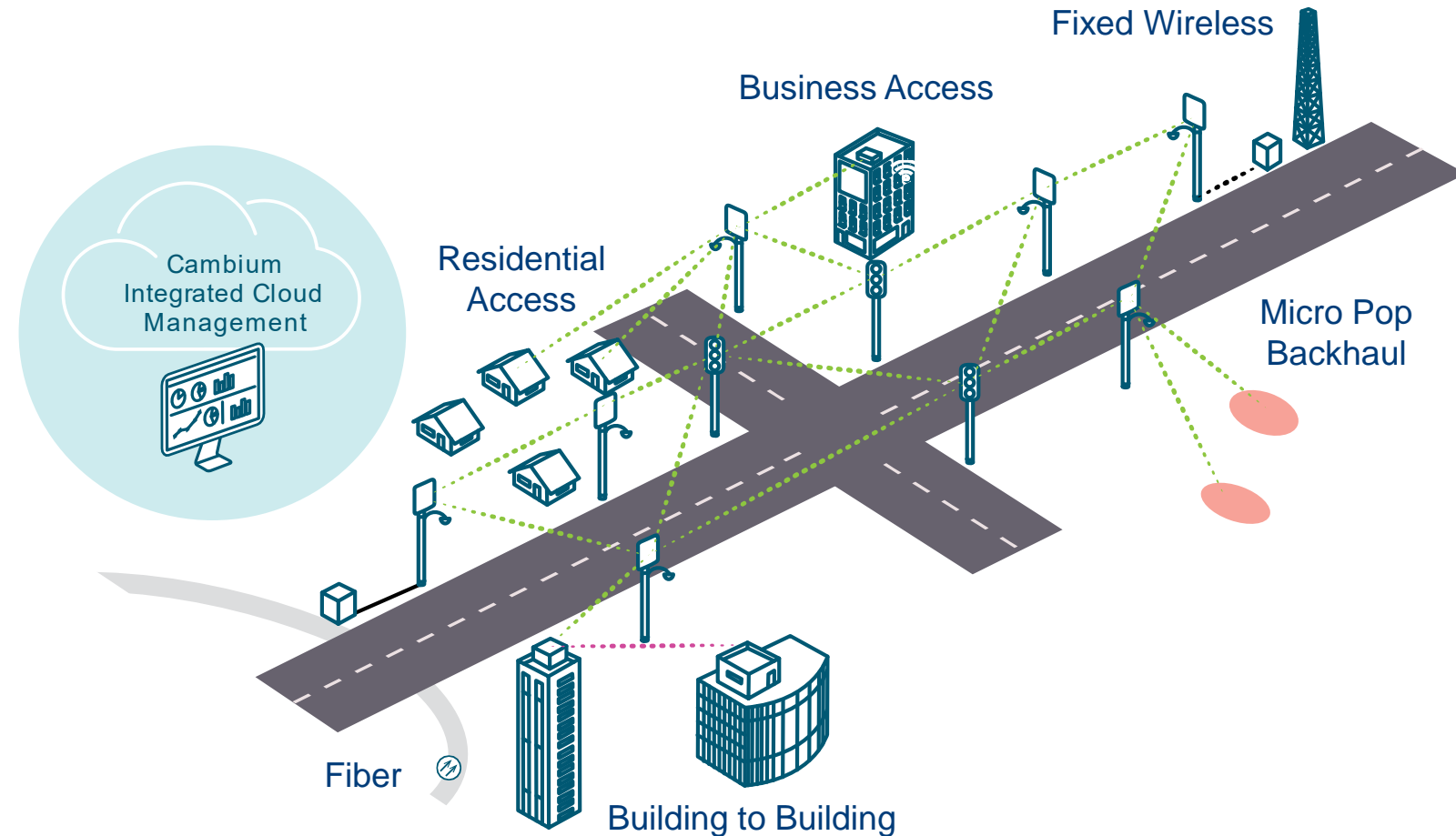


Source: Federated Wireless

\* Sharing rules adopted, consultations launched and/or trials planned

# mmWave





- **WTTH – Wireless To The Home**
  - Providing Wireless Broadband access directly to the home.
- **WTTB – Wireless To The Building**
  - Wireless Broadband access provided to rooftops or side of buildings, which then get distributed to individual offices and homes via wire.
- **RTTTRT – Roof-Top To Roof-Top**
  - Long range Point to Point with high gain dish
  - Multi Dwelling Distribution
- **Fiber Extension**
- **Backhaul** for 5G Small Cell, outdoor Wi-Fi, MicroPoP and CCTV

- **Provide high capacity wireless solution to resident, enterprise and backhaul for Wi-Fi or small cell**
- **PMP, PTP and Mesh configurations**
- **Terragraph Certified**
- **Highlights**
  - 802.11at based
  - Auto-alignment
  - TDD / TDMA channel access and scheduling
  - Support network synchronization through 1 PPS
  - Up to 15 Gb Aggregate Capacity
  - Support 30 CPE
  - Comprehensive network design tools
  - cnMaestro Integrated Management



# 802.11ad vs. 802.11ay

	Product 802.11ad based	Product 802.11ay based
Protocol	802.11ad (2016)	802.11ay
CPE per Sector	8	15
Sector Maximum Throughput (L1)	5 Gbps	10 Gbps
Maximum Channel Width	2160 MHz	4320 MHz with Channel bonding
Channel Access	CSMA	TDMA
Network Synchronization	No	TDD
Configuration	PTP, PMP	PTP, PMP, Mesh

# Using 24 GHz to 30 GHz band for Fixed Wireless Access

- **Most common 5G NR band worldwide**

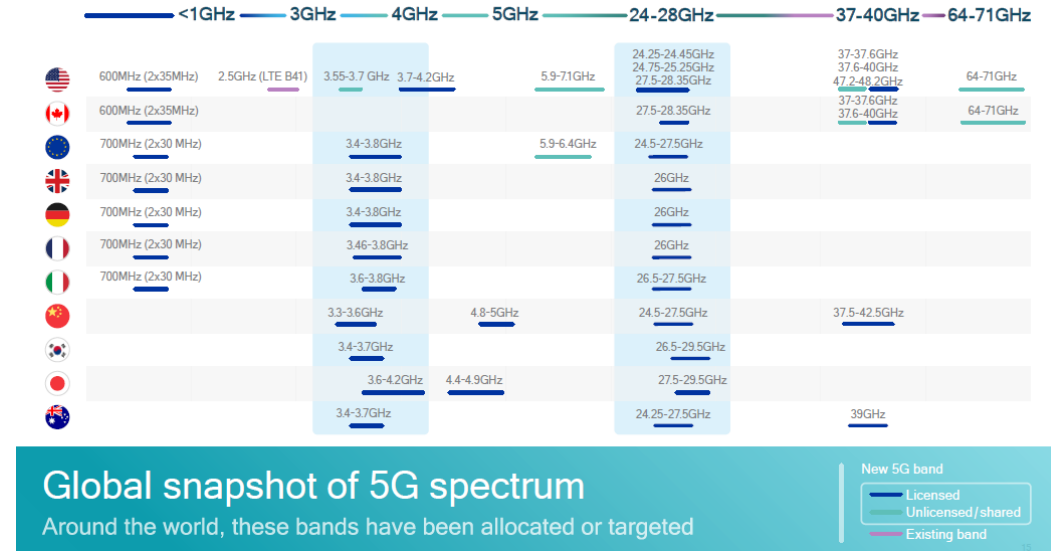
- 24.25 - 29.50 GHz (TDD)
  - n257 (26.50 - 29.50 GHz), 28 GHz, TDD
  - n258 (24.25 - 27.50 GHz), 26 GHz, TDD
  - n261 (27.50 – 28.35 GHz), 28 GHz US, TDD

- **Commercially**

- Wide spectrum enables high-capacity network
- Security of **licensed** spectrum
- **5G NR** has driven investment in cost optimized, integrated RF front-end modules (chipsets)

- **Technically**

- Propagation allows **5+ km range** even in rain condition
- Medium antenna aperture results in high antenna gain → better range/coverage





- **Future proof investment**

- Standard rather than vendor proprietary air interface
- Cambium **SDR architecture** enables future enhancements

- **5G NR / 3GPP Release 15**

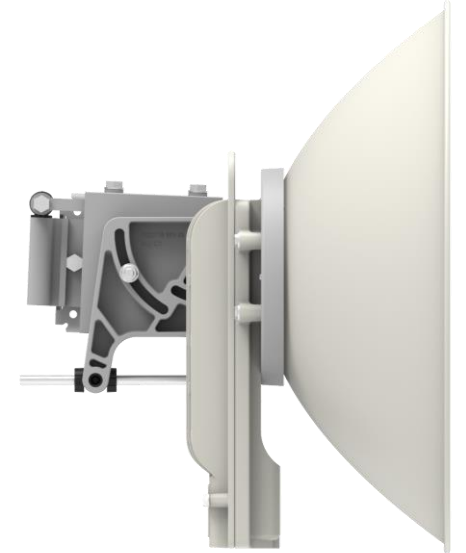
- Designed for mmWave frequency (“FR2”)
- More suited to FWA than 4G / LTE

- **Enables cost effective CPE based on 5G chipsets**

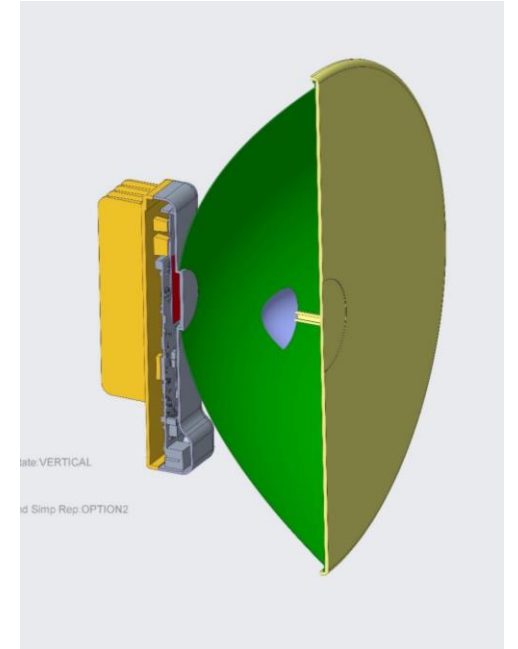
- Cambium BTS will support Cambium & third-party 5G NR CPEs
- Multiple types of CPEs can co-exist in same sector



- **Optimized End-to-End for Fixed Wireless Access**
  - Benefits from cnMedusa™ world-class MU-MIMO expertise and field-proven performance
  - Lower cost & complexity solution by targeting FWA only (no mobility)
  - Optimized to exploit good signal quality & provide high throughput
- **Simple to deploy and operate**
  - Cambium 5G NR network infrastructure is as simple as 450 Series!
  - BTS can be stand-alone, no SIM card required on CPE
  - Mobile operator core network not required!



- **Optimised for long range access**
  - Typically 5km, but can support up to 10km cell size
  - Cell size depends on availability target and rain region of deployment
- **Optimised for Line-Of-Sight, professional installation**
  - CPE has high gain dish antenna
  - Fine-tune mounting hardware available for precise alignments
  - Beam steer capability to ease installation (Patent submission pending)
- **CPE optimized for high throughput in clear sky conditions**



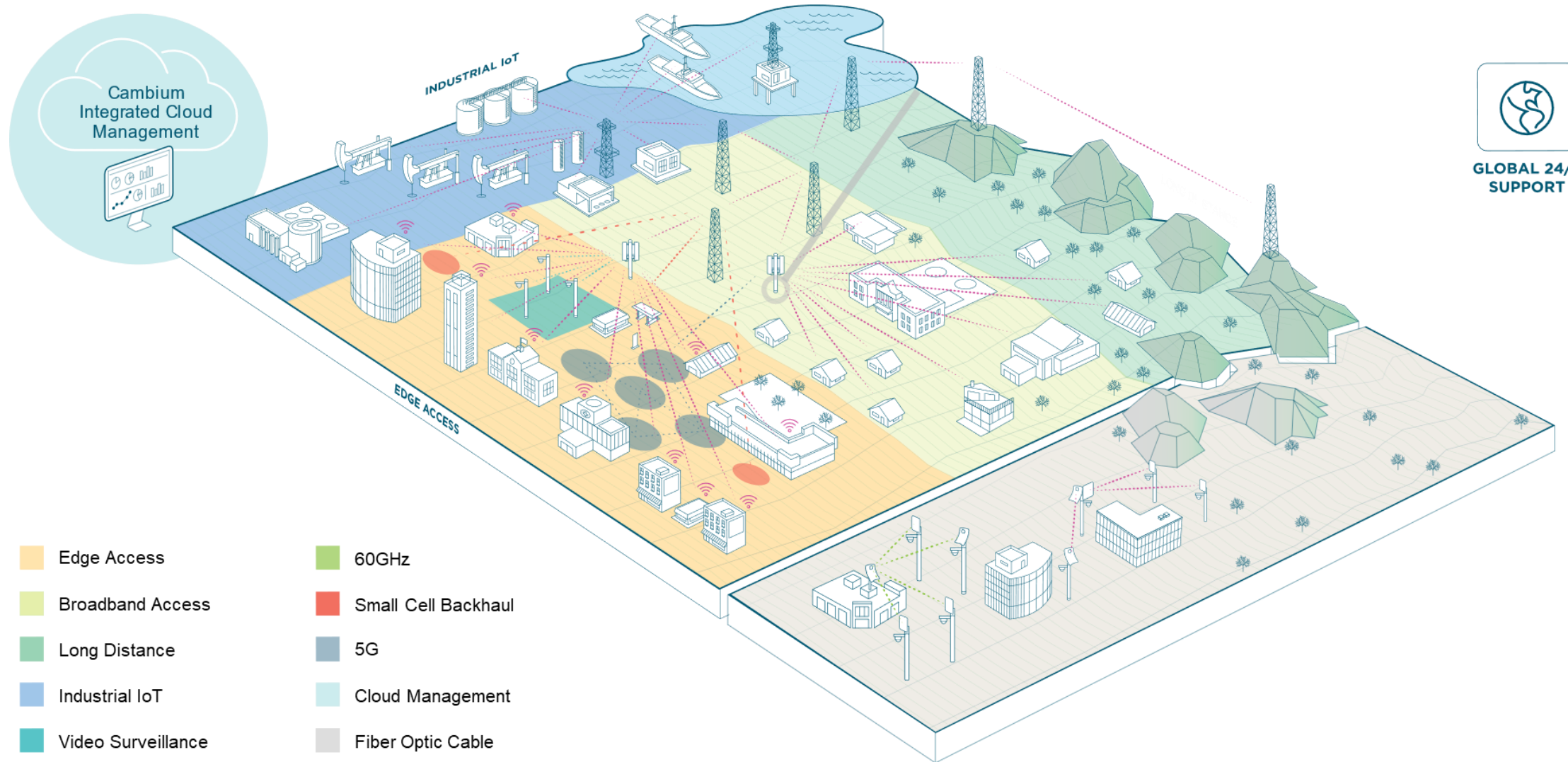
- **Cambium solution is based on PMP450m (“cnMedusa”) MU-MIMO expertise**
  - Field proven, first-in-class!
- **Air interface further optimized by 5G NR standards even compared to PMP450m**
  - Lower latency (1-2 ms vs 7-10ms), optimized for TCP/IP traffic
  - Better multi-user sharing granularity (Multiple MIMO groups in DL, OFDMA in UL)
- **Up to 240 CPEs per BTS**

# Summary





# Cambium Networks' Gb Wireless Fabric



- **Advancement of standards, including 5G, is leading to a Fixed Wireless Renaissance**
- **Spectrum Sharing will undoubtedly be a useful tool to drive economic growth and access to broadband**
- **Many technologies will help enable this growth and can be applied to Dynamic Sharing Model**
  - 3GPP 5G
  - Wi-Fi 6
  - Software-Defined Radio Systems
- **Cambium Networks is adding threads to our Wireless Fabric**
  - Adopting Standards
  - Addressing 28 GHz
  - Addressing 60 GHz
- **Leveraging Decades as a Fixed Wireless Broadband Leader**



Questions?





Cambium Networks<sup>TM</sup>