Centralized Dynamic Spectrum Access

History, Background and Details of AFC

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Mark Gibson

Sr. Director, Spectrum Regulatory & Policy

mark.gibson@commscope.com

Topics

Centralized Dynamic Spectrum Access

History up to AFC

1. A Brief History of Centralized Dynamic Spectrum Access
2. New Unlicensed Uses for 6 GHz
3. Introduction to 6 GHz Unlicensed
4. Description of Current 6 GHz Operations
5. Description of Unlicensed 6 GHz Operations
6. Automated Frequency Coordination (AFC) System
7. AFC Commercialization & Timeline

A Brief History of Centralized DSA

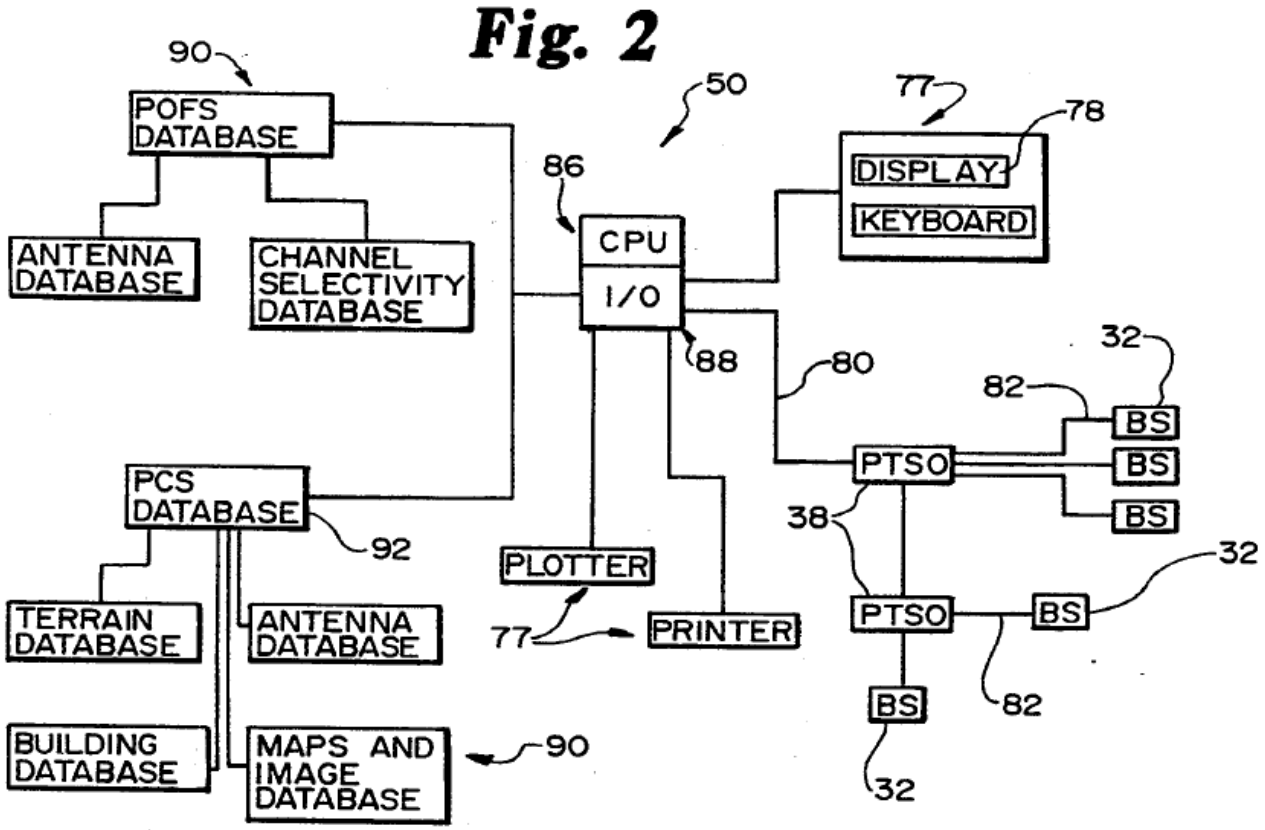
Frequency-Agile Sharing Technology (FAST)

BACKGROUND

- Proposed in 1995 by American Personal Communications (APC)
- System sensed transmit frequency and used database to determine location of potential victim receiver
- Used for PCS
- Used Comsearch Private Operational Fixed Service (POFS) databases
- Merited a “Pioneer Preference Award” from the FCC
- Deployed in the Washington DC area

LESSONS LEARNED

- No incentive to continue with technology



From APC Patent Application

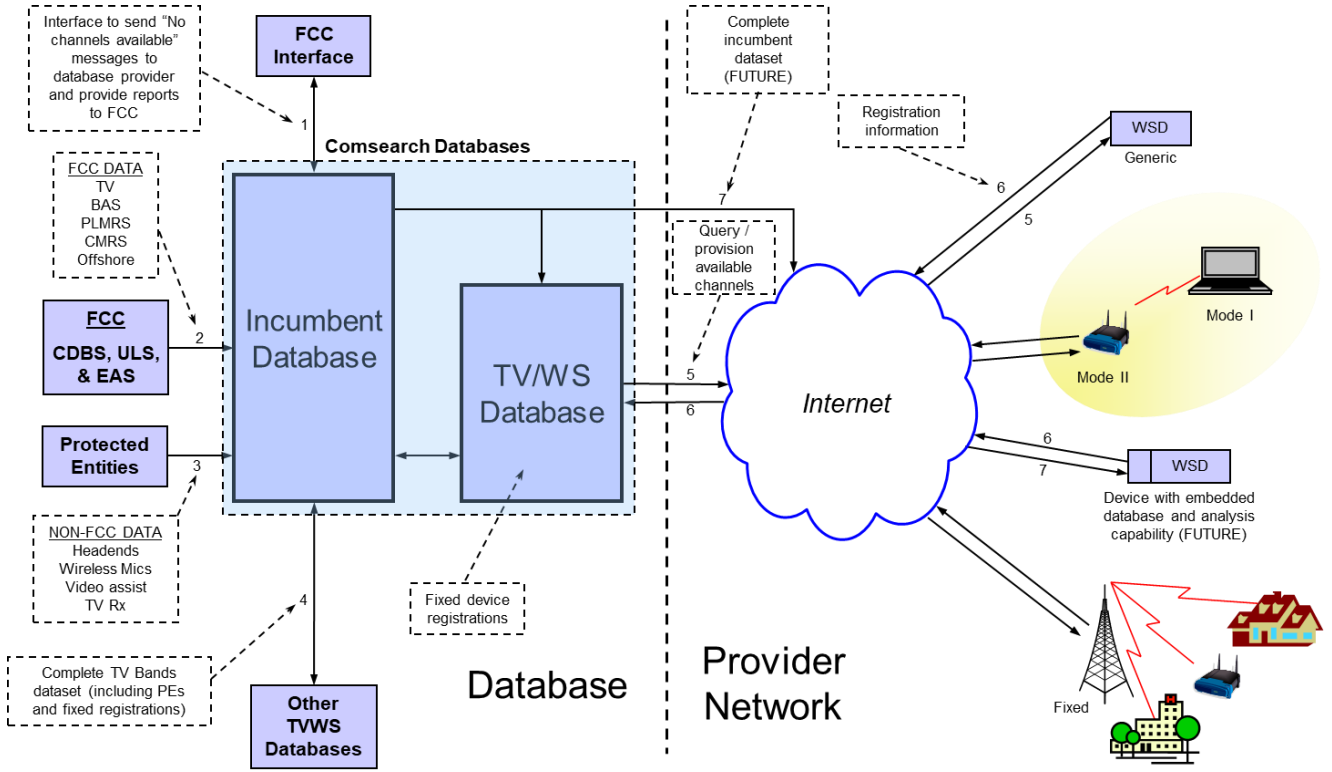
TV White Space

BACKGROUND

- Established by FCC in 2007
- Commercial TVWS database administrators built and operated databases that allow unlicensed devices to share unused TV channels at specific locations
- FCC selected ten TVWS database administrators
- Upper portion of the TV band in the U.S. reallocated to mobile, severely limiting remaining TV White Space and market
- TVWS database testing done serially by FCC took several months
- RED took over all database operations
- Fewer than 300 TVWS deployments
- Several international TVWS applications

LESSONS LEARNED

- Band plagued by regulatory uncertainty
- FCC database testing delayed rollout
- Never really addressed Enforcement



From Comsearch TVWS DBA Proposal

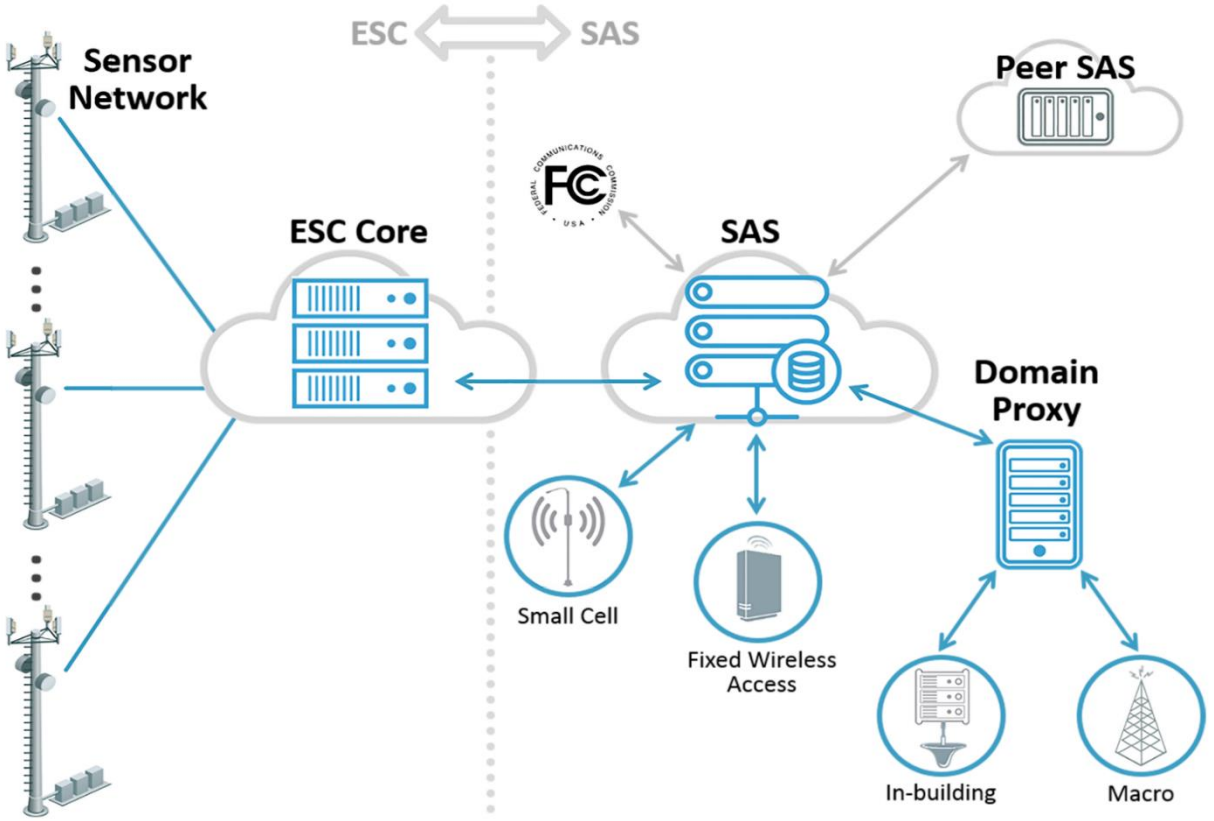
Citizens Broadband Radio Service (CBRS) Spectrum Access System (SAS)

BACKGROUND

- Established by FCC in 2015
- Used to allow for commercial access to the CBRS band and not cause interference into commercial and DoD incumbents using a SAS
- FCC selected ten SAS administrators and four ESC providers (who are also SAS admins)
- SASs have been in commercial operation since Jan 27, 2020
- SASs allow CBRS devices (CBSDs) to share spectrum with other CBRS users and incumbents
- ESC providers have built coastal sensor networks to protect Navy radar operations
- SAS testing & certification took almost two years
- Numerous engagements with DoD required
- NTIA now considering IIC

LESSONS LEARNED

- Certification process was long and complicated
- Incumbents are generally over-protected
- Concerns about role of SASs in Enforcement
- Future sharing needs to be more forward-thinking considering imminent replacement of ESC with IIC



CommScope SAS Architecture

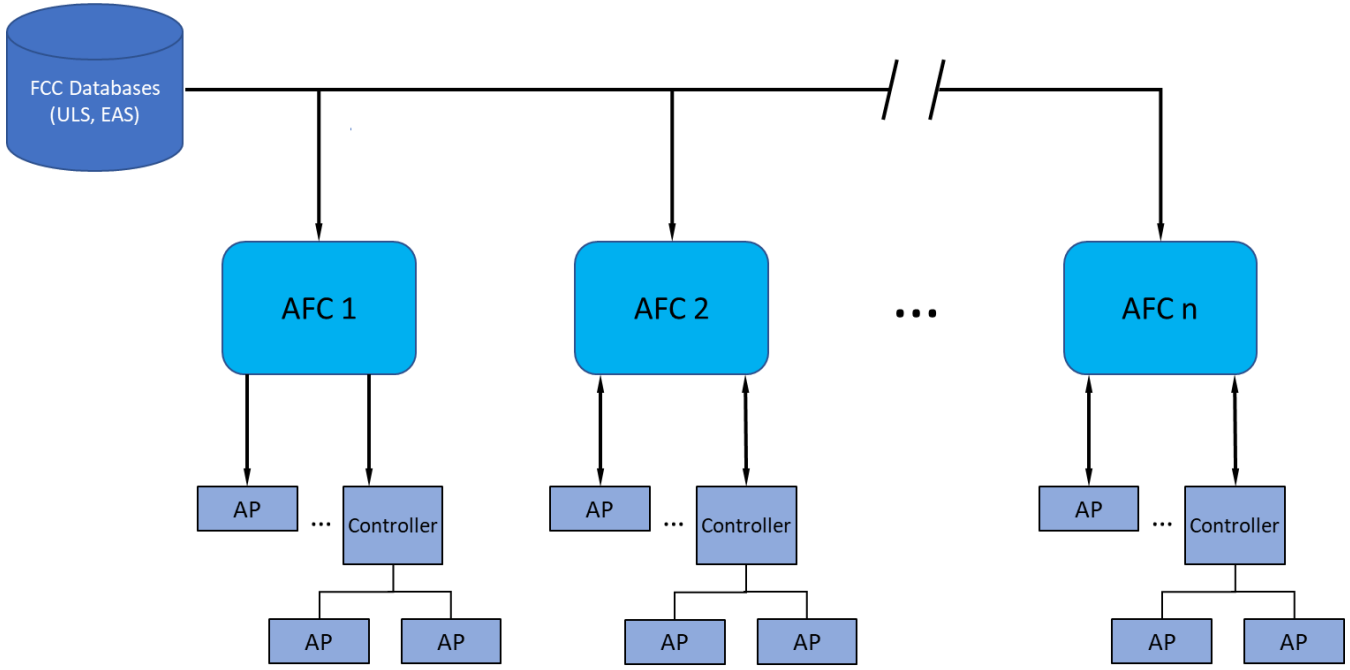
Automated Frequency Coordination (AFC) for 6 GHz

BACKGROUND

- Established by FCC in 2020
- Used to allow for standard power unlicensed devices to operate in 6 GHz band and not cause harmful interference into incumbents using the AFC
- WInnForum & Wi-Fi Alliance developed specifications and recommendations
- FCC directed formation of a Multi-stakeholder Group (MSG) to address issues specific to technical and operational aspects of the AFC
- Several open issues: testing, certification, enforcement, etc.
- AFC systems should be certified for commercial operation very soon

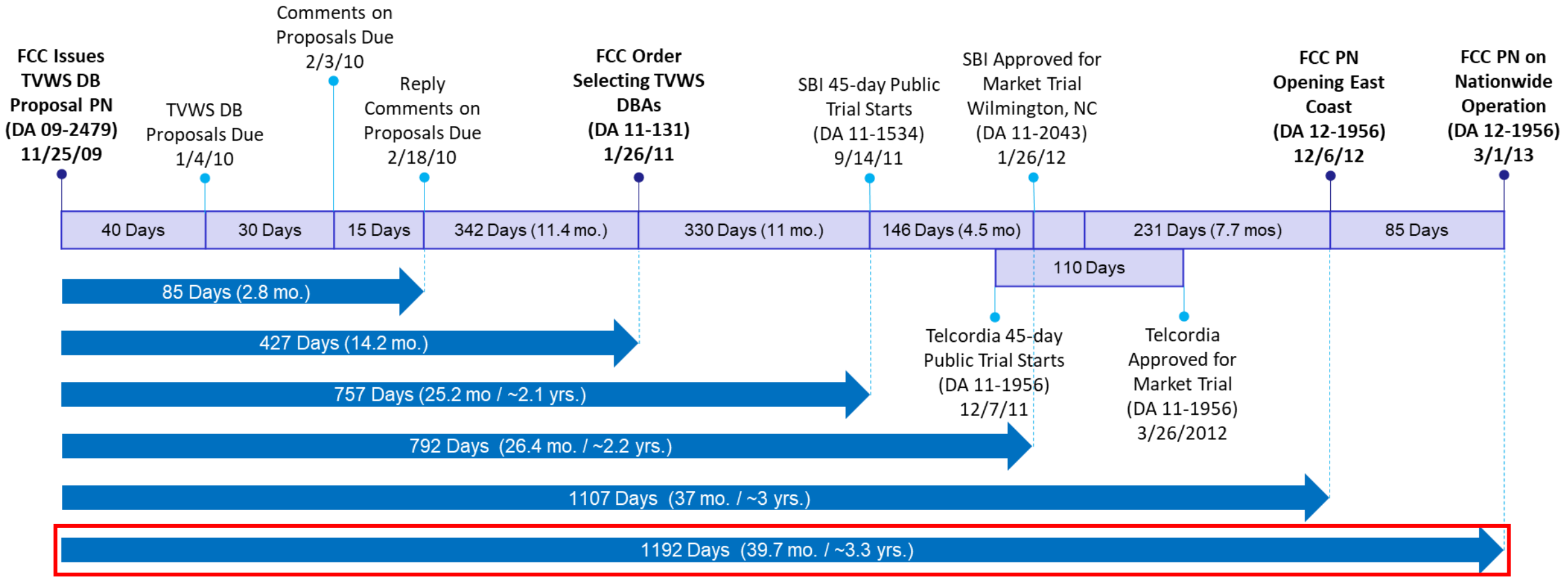
LESSONS LEARNED (so far)

- MSG didn't work out
- Enforcement is afterthought



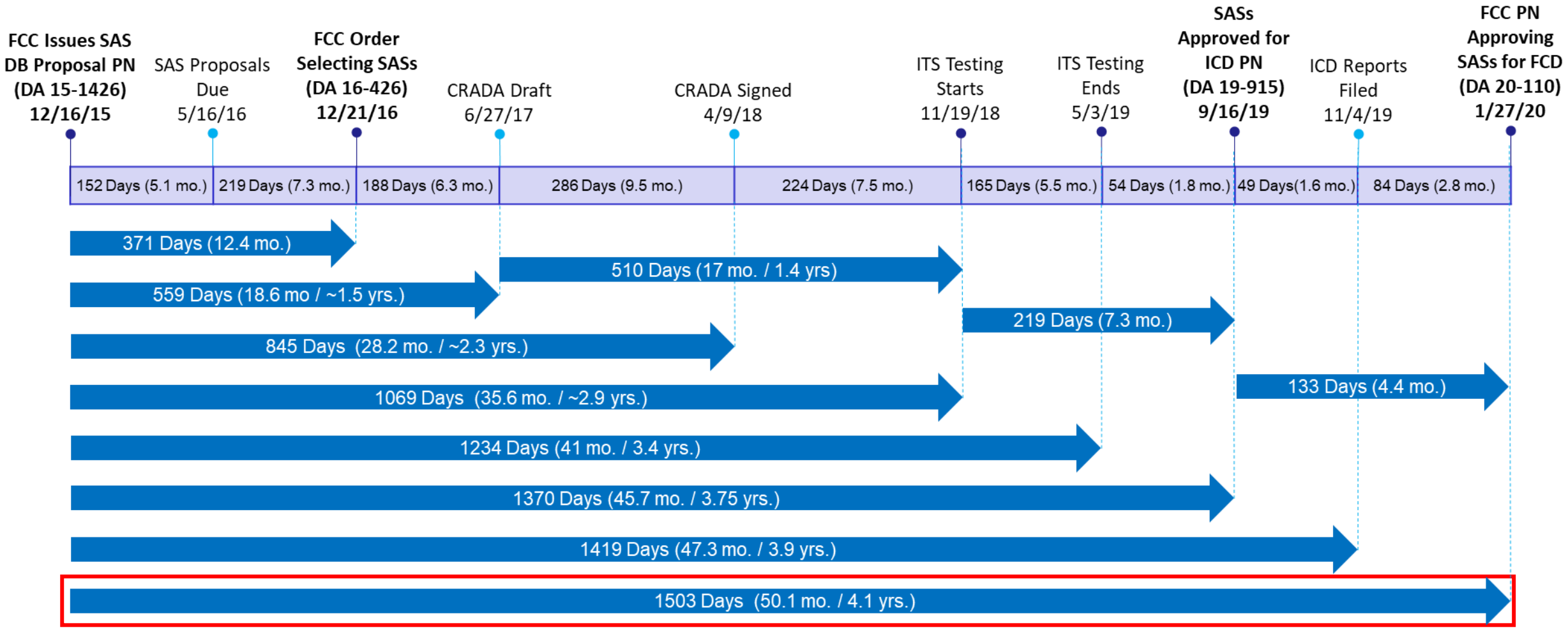
AFC Functional Architecture

TV White Space Database FCC Testing & Certification Timeline



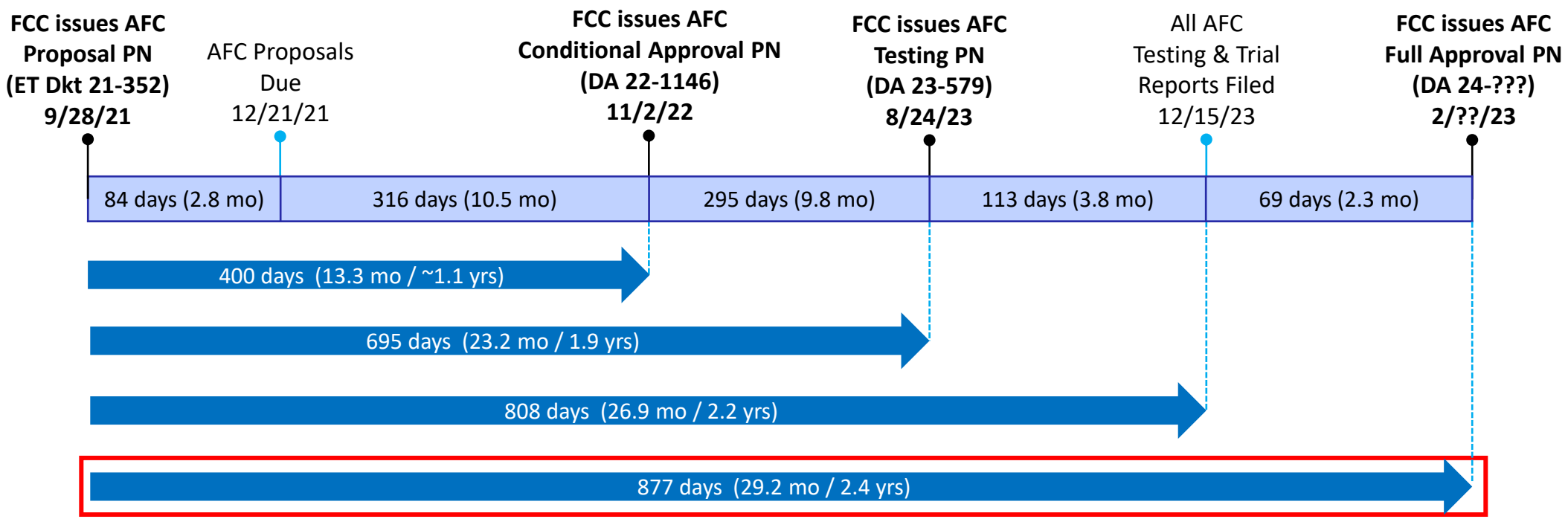
Challenges: TVWS Certification Timing & Complexity

CBRS SAS FCC Testing & Certification Timeline



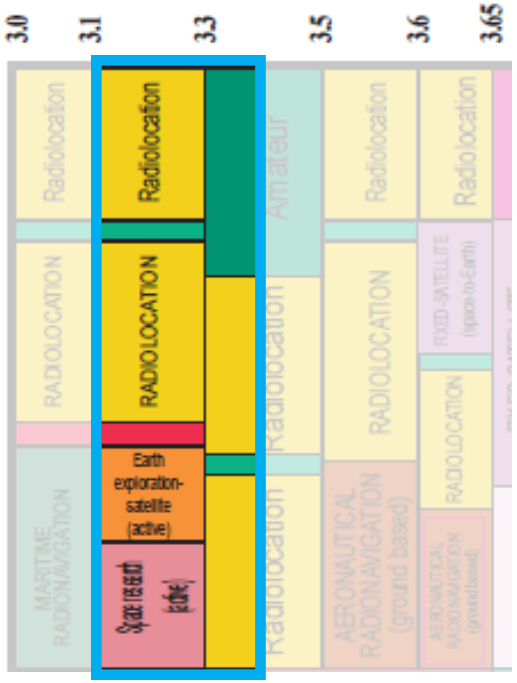
Challenges: SAS Certification Timing & Complexity

AFC FCC Testing & Certification Timeline

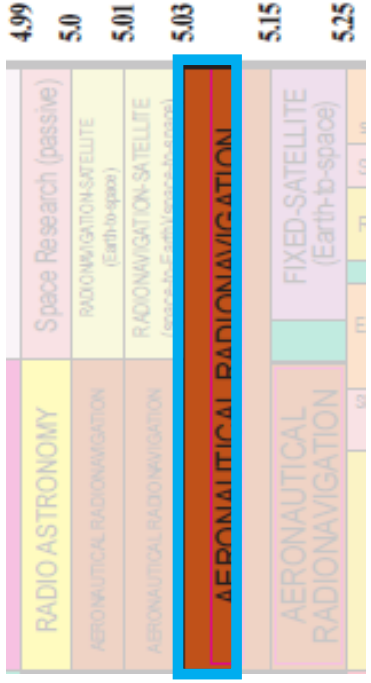


Challenges: AFC Certification Timing & Complexity

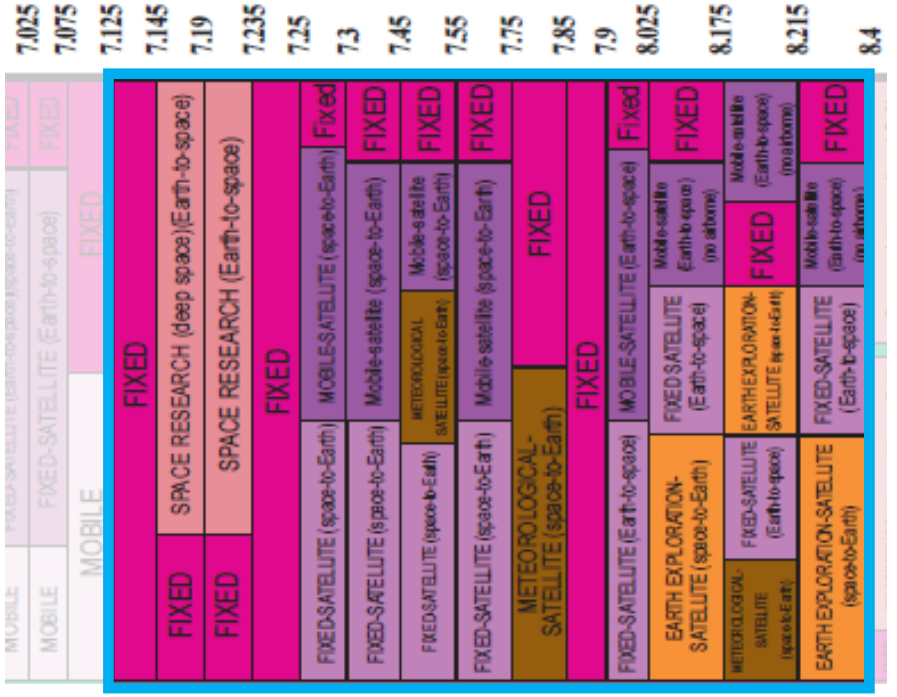
Sharing in the Spectrum Pipeline



3100-3450 MHz

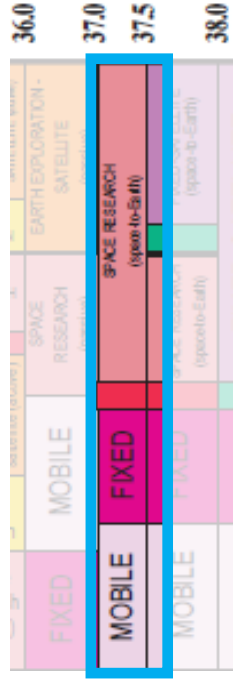


5030-5091 MHz



7125-8400 MHz

18.1-18.6 GHz



37-37.6 GHz

"… the U.S. will set measurable goals for advancing the state of technology for spectrum access, with an emphasis on dynamic forms of sharing." *National Spectrum Strategy*

New Unlicensed Uses for 6 GHz

General Use Case Examples

Consumer & Enterprise Wi-Fi

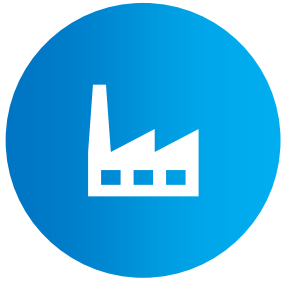
FWA

MDU applications

Whole home gigabit coverage

Carrier aggregation that can be quickly deployed

Municipal Wi-Fi



Factory and warehouse IoT

Multi-gigabit Wi-Fi venue capacity

Opportunities for Wi-Fi

Wi-Fi 6E brings Wi-Fi into 6 GHz

FEATURES

More, contiguous spectrum

Wide channels

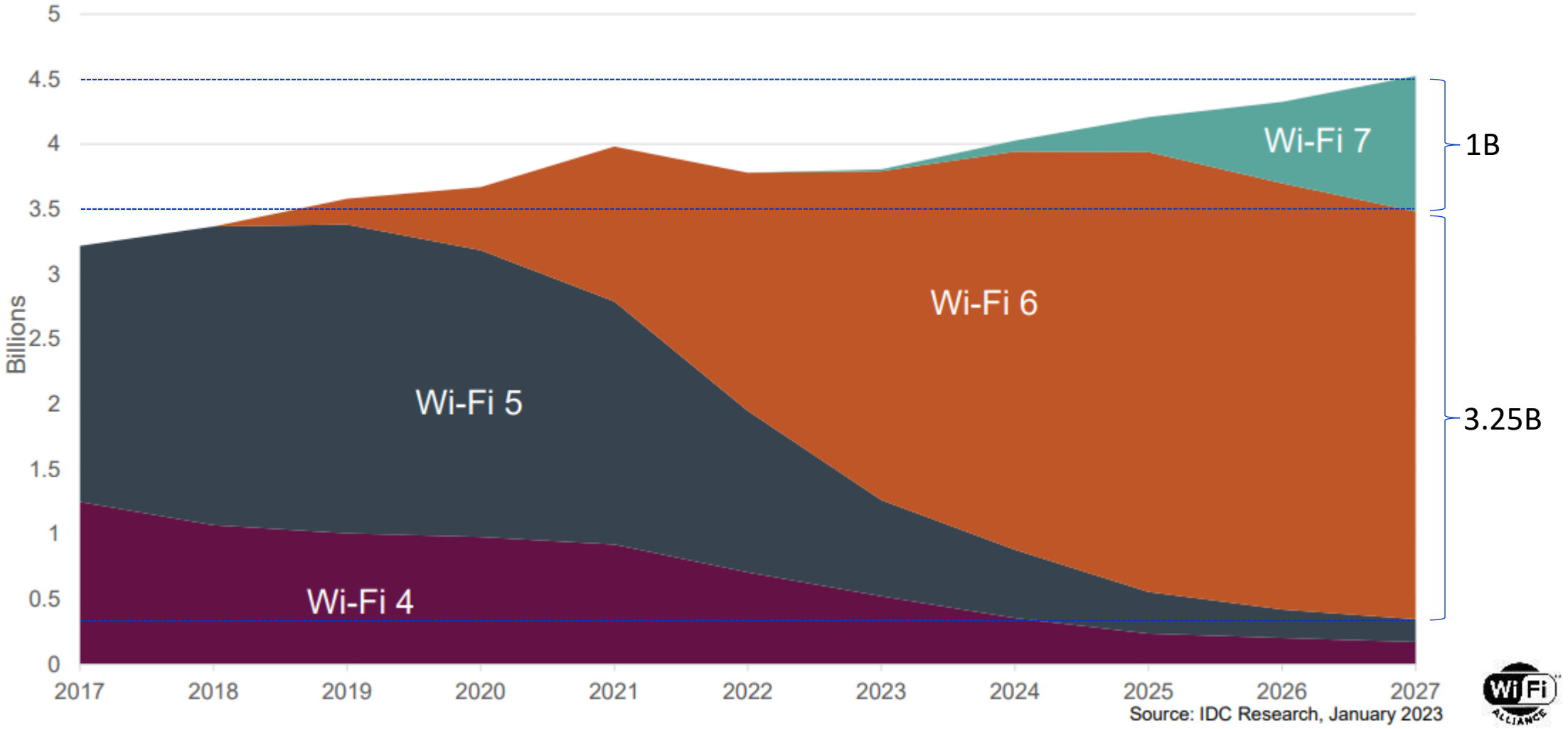
Less interference

BENEFITS

Gigabit speeds

Extremely low latency

High capacity



Wi-Fi 6 & Wi-Fi 7 Adoption

Robust 6 GHz Wi-Fi Device Ecosystem



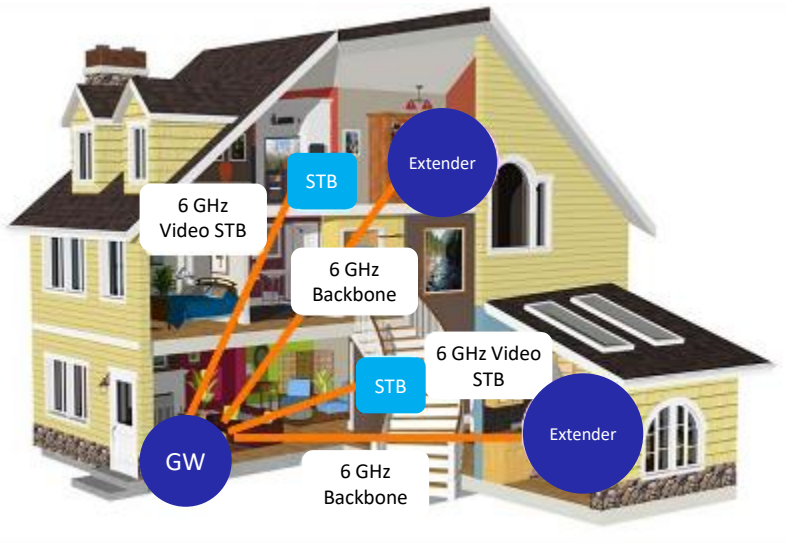




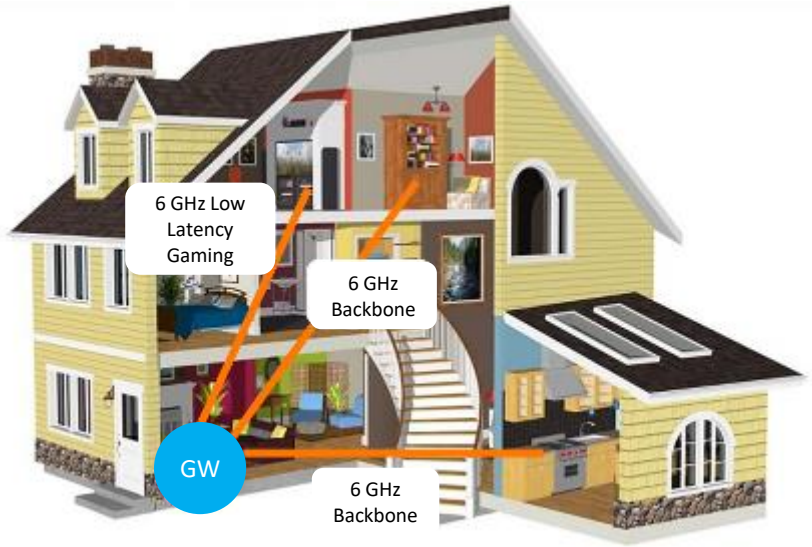




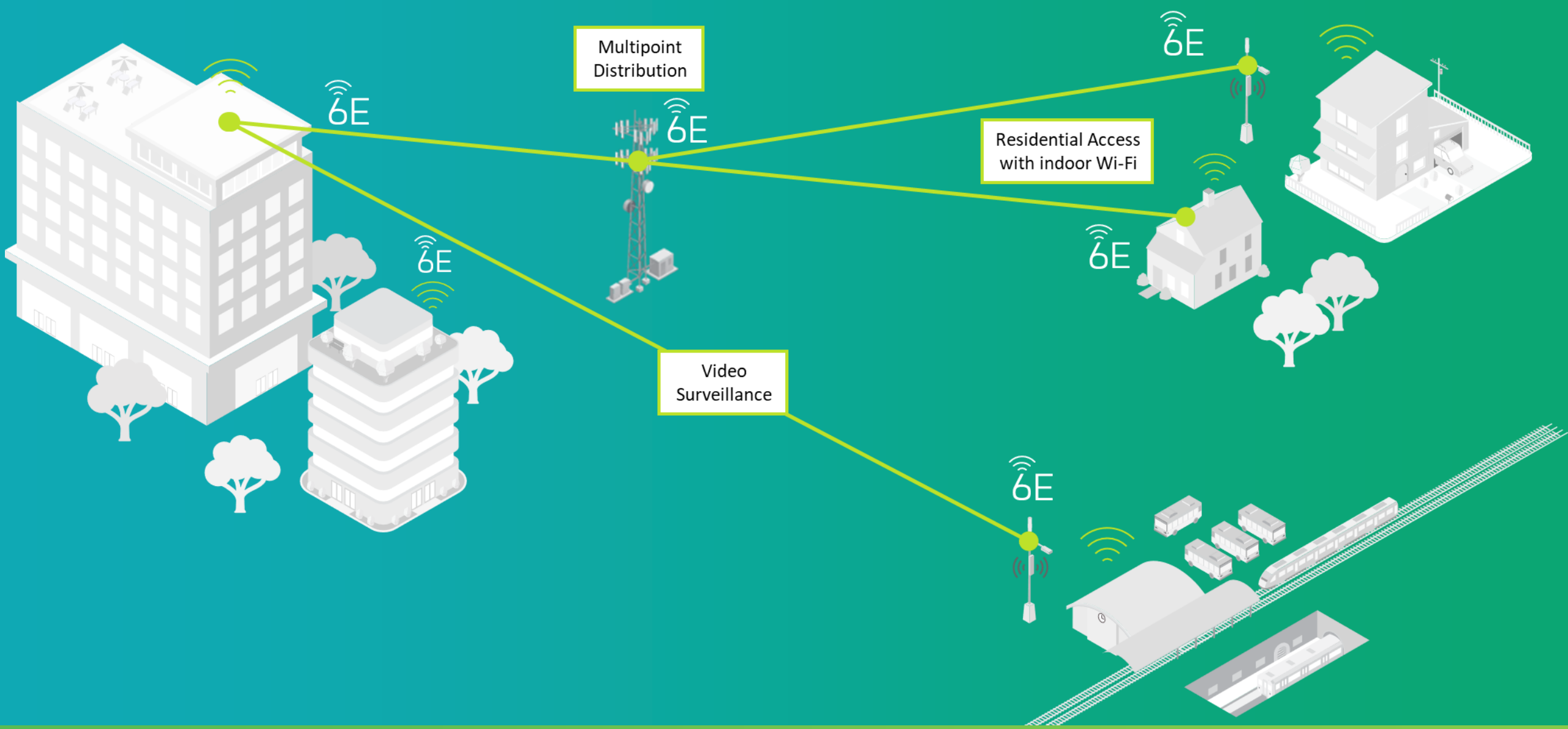




STB
Extender
6 GHz
Video STB
6 GHz
Backbone
6 GHz Video
STB
STB
GW
Extender
6 GHz
Backbone


6 GHz
Backbone
6 GHz
Backbone
EMTA
ONI with
fiGHz
6 GHz
Backbone


6 GHz Low
Latency
Gaming
6 GHz
Backbone
GW
6 GHz
Backbone

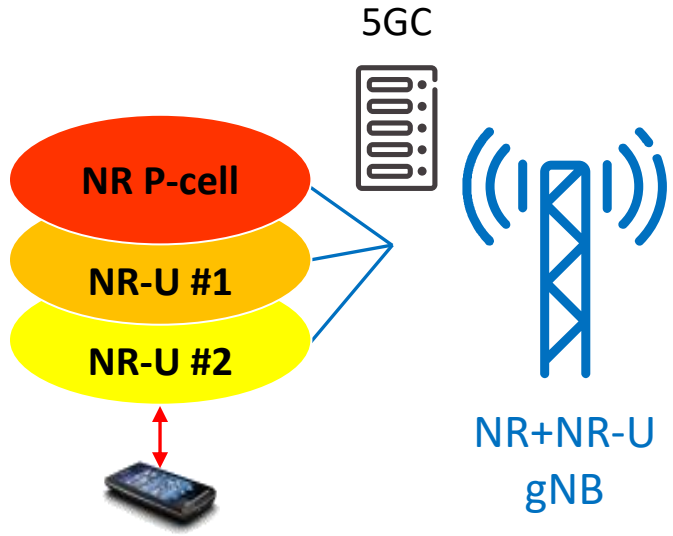
In-home Use



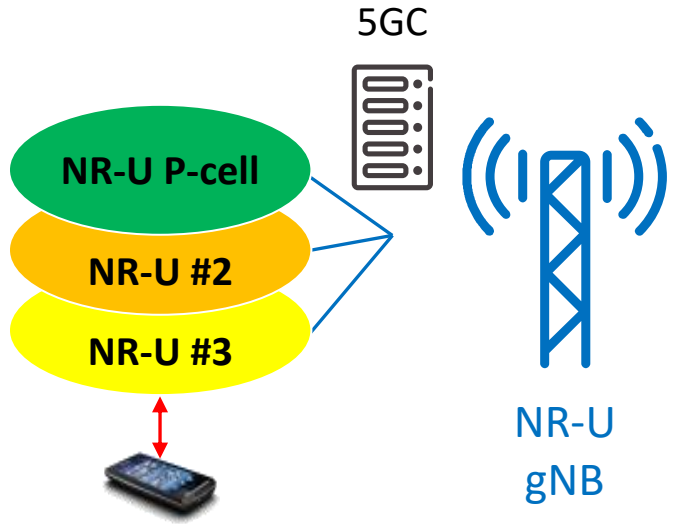
Fixed Wireless Broadband

NR-U Deployment Scenarios

1. **Carrier aggregation between licensed band P-cell and multiple unlicensed NR-U S-cells like LAA**
   - Outdoor and indoors
   - Standard Power yields up to 8x range increase!



2. **Fully standalone NR-U operation unlike LAA**
   - Flexible UL / DL balance for UL-heavy applications

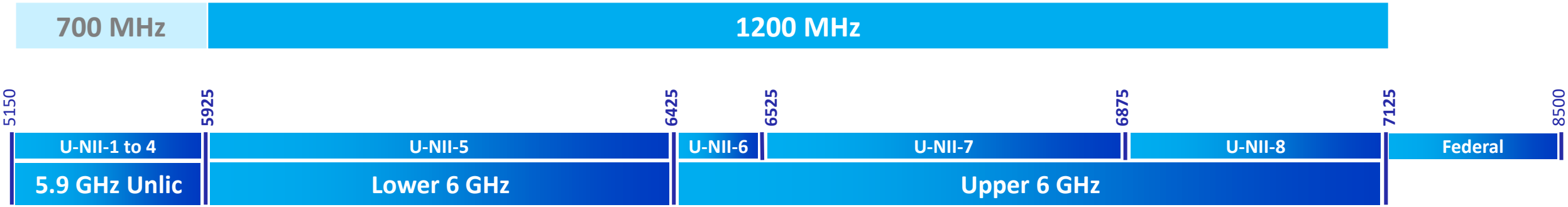


Source: Ericsson

Introduction to 6 GHz Unlicensed

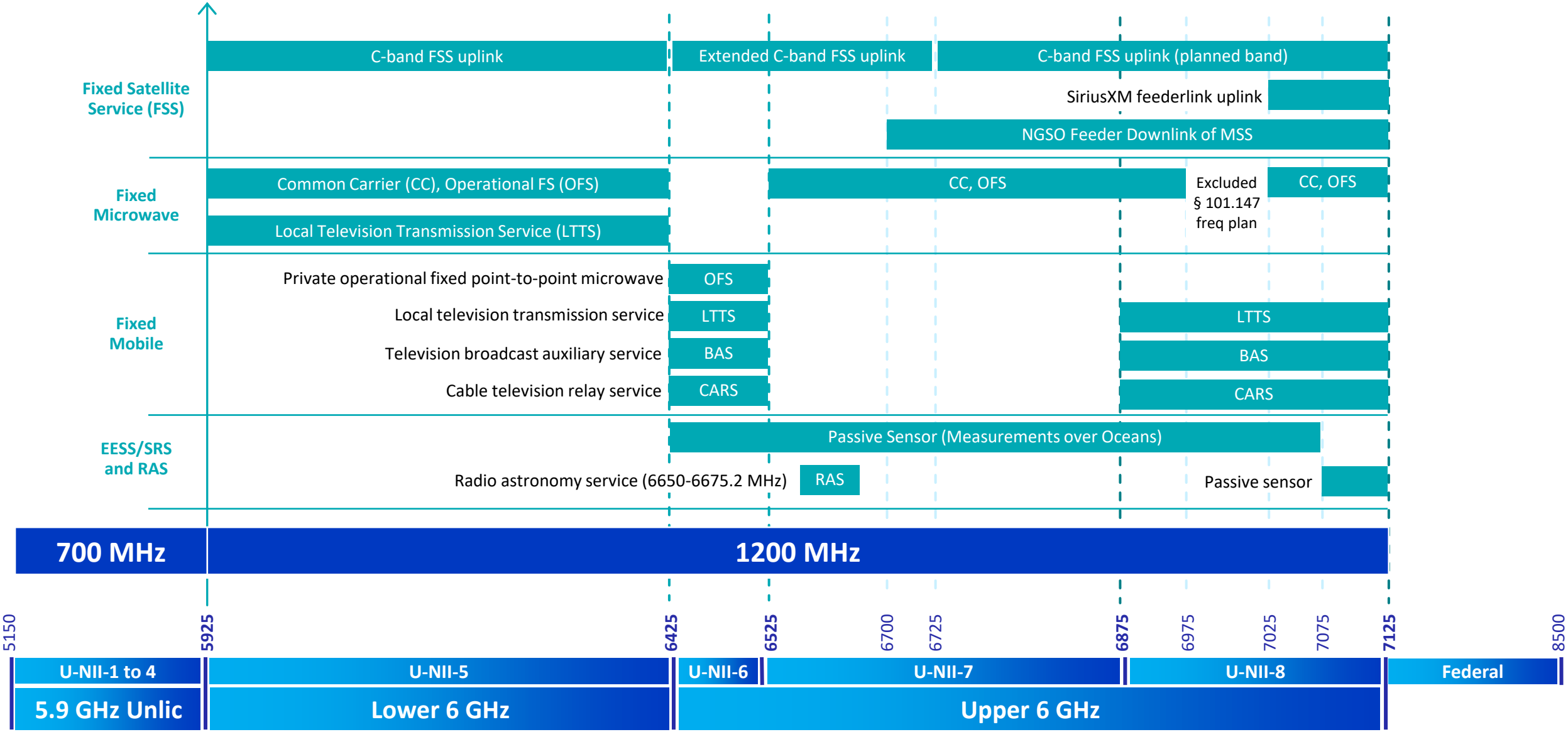
The 6 GHz Unlicensed Allocation is the Largest Ever

Adds 1200 MHz to the U-NII* bands…



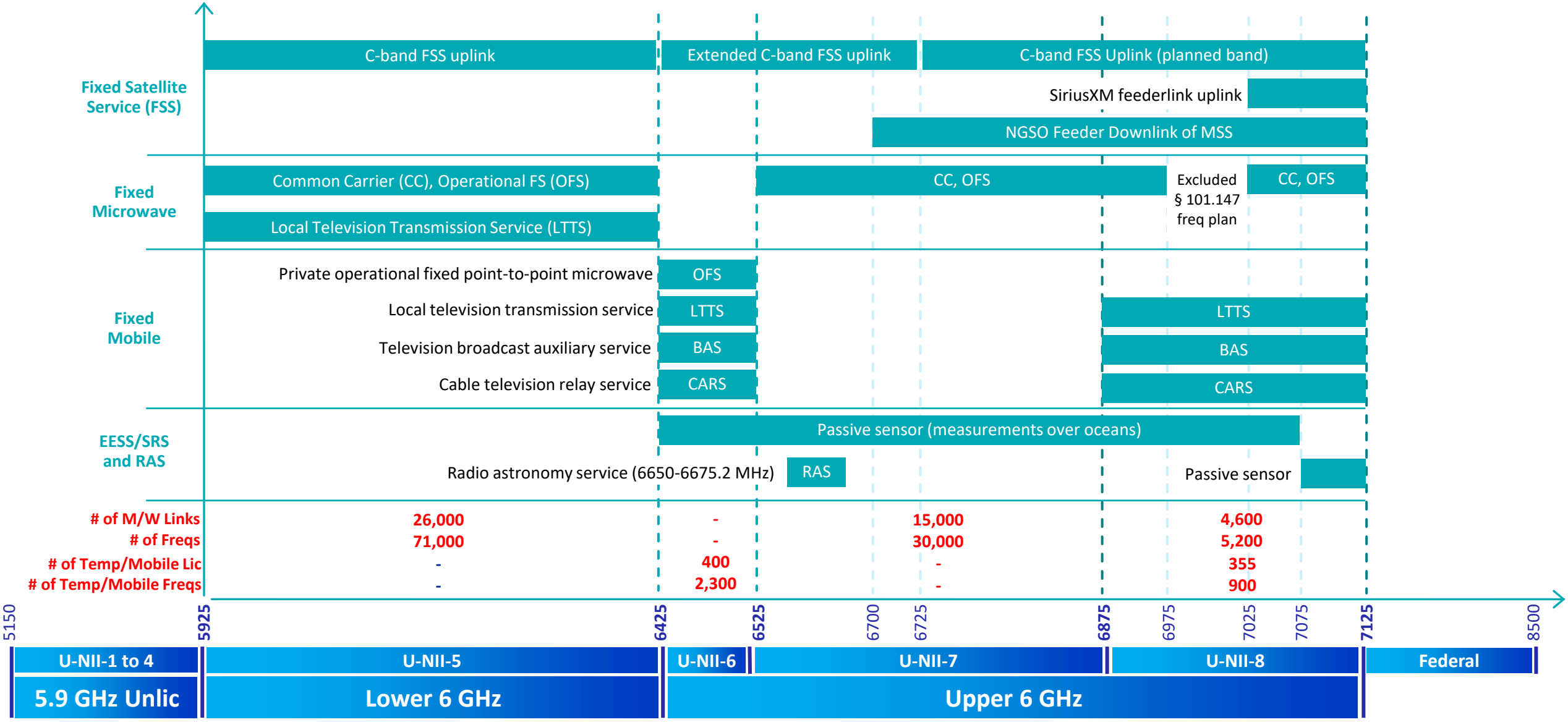
*U-NII = Unlicensed National Information Infrastructure

… but there are many incumbents



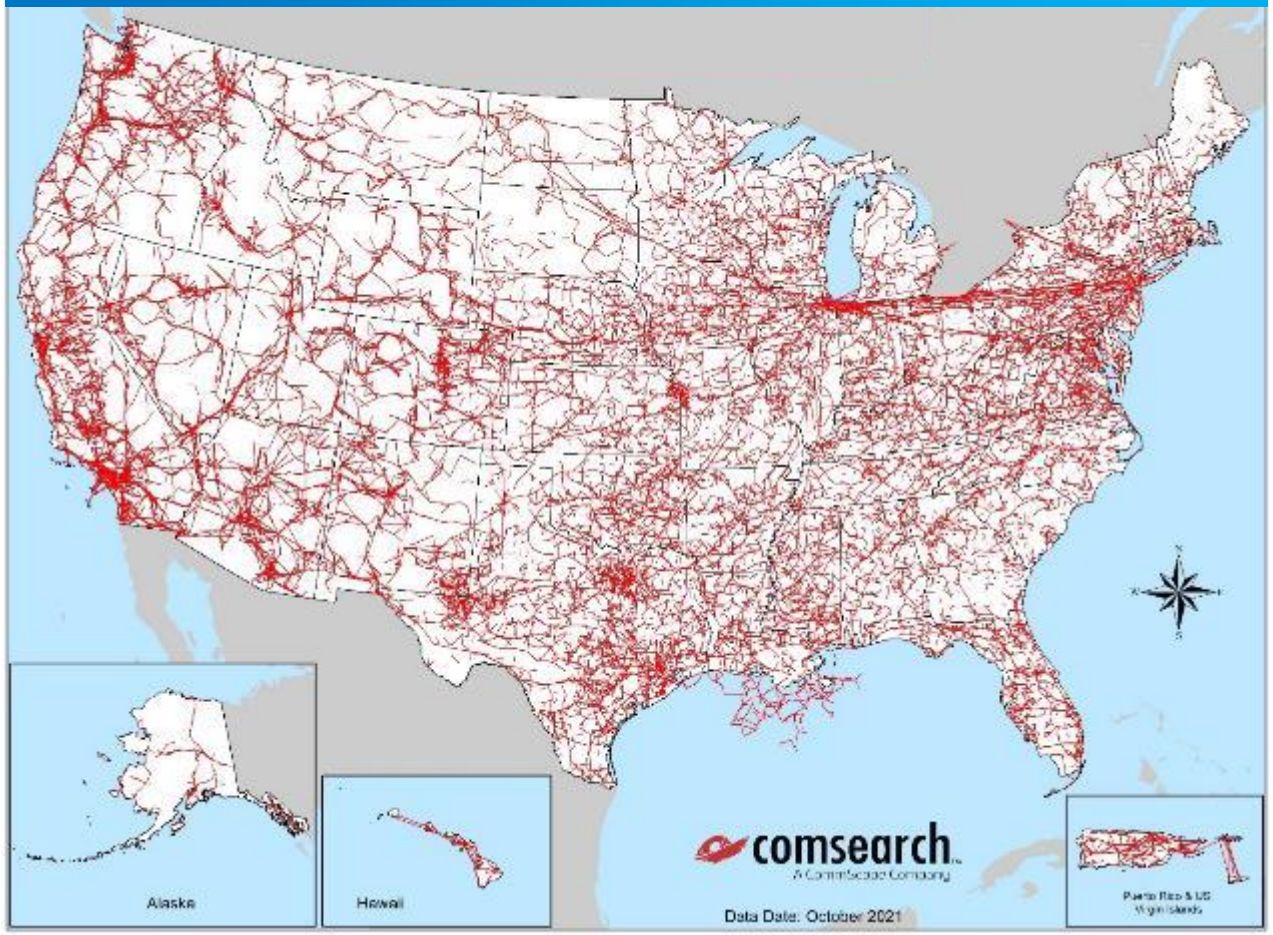
Description of Current 6 GHz Operations

There are many incumbents

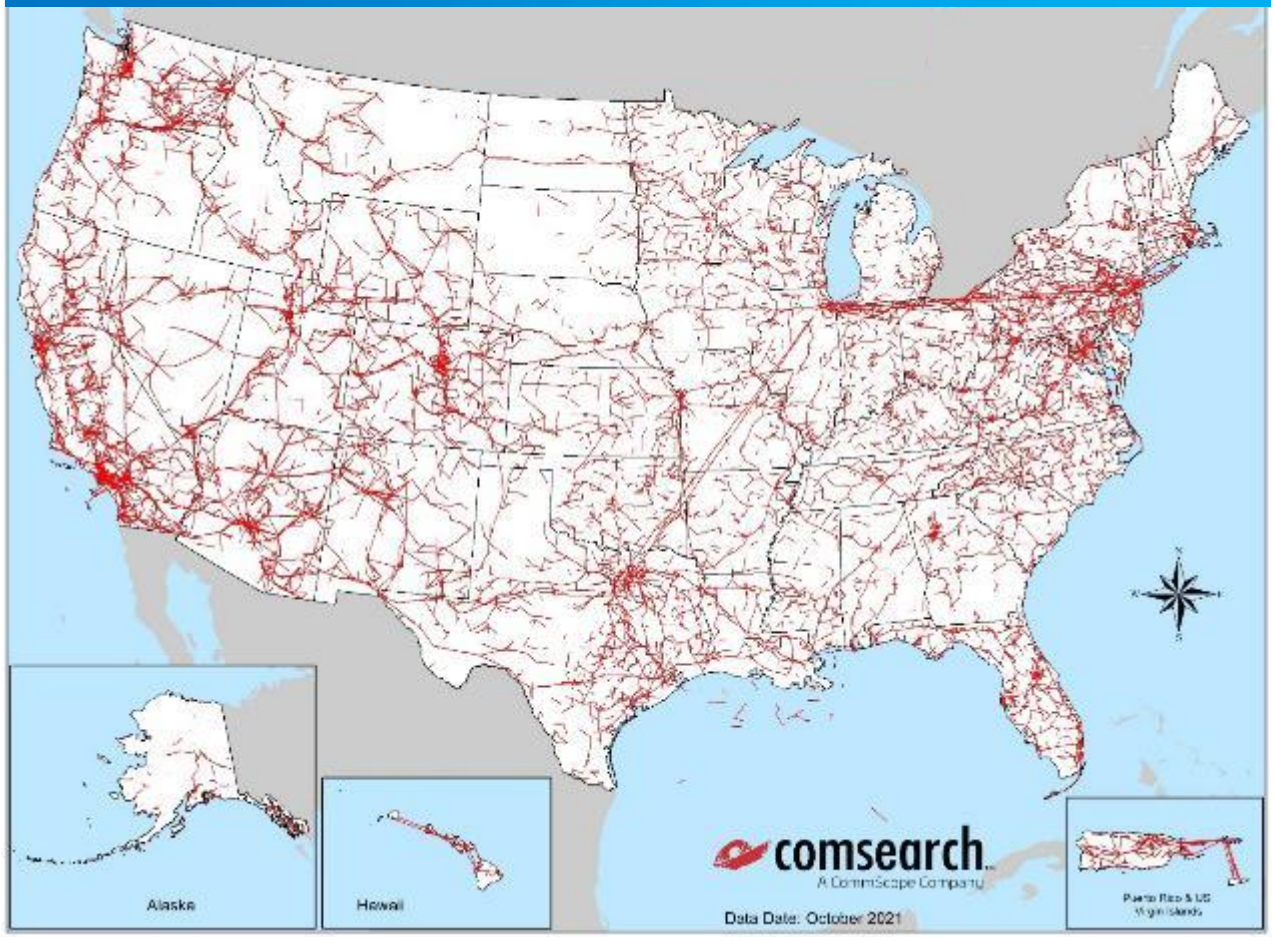


6 GHz Microwave Operations Nationwide

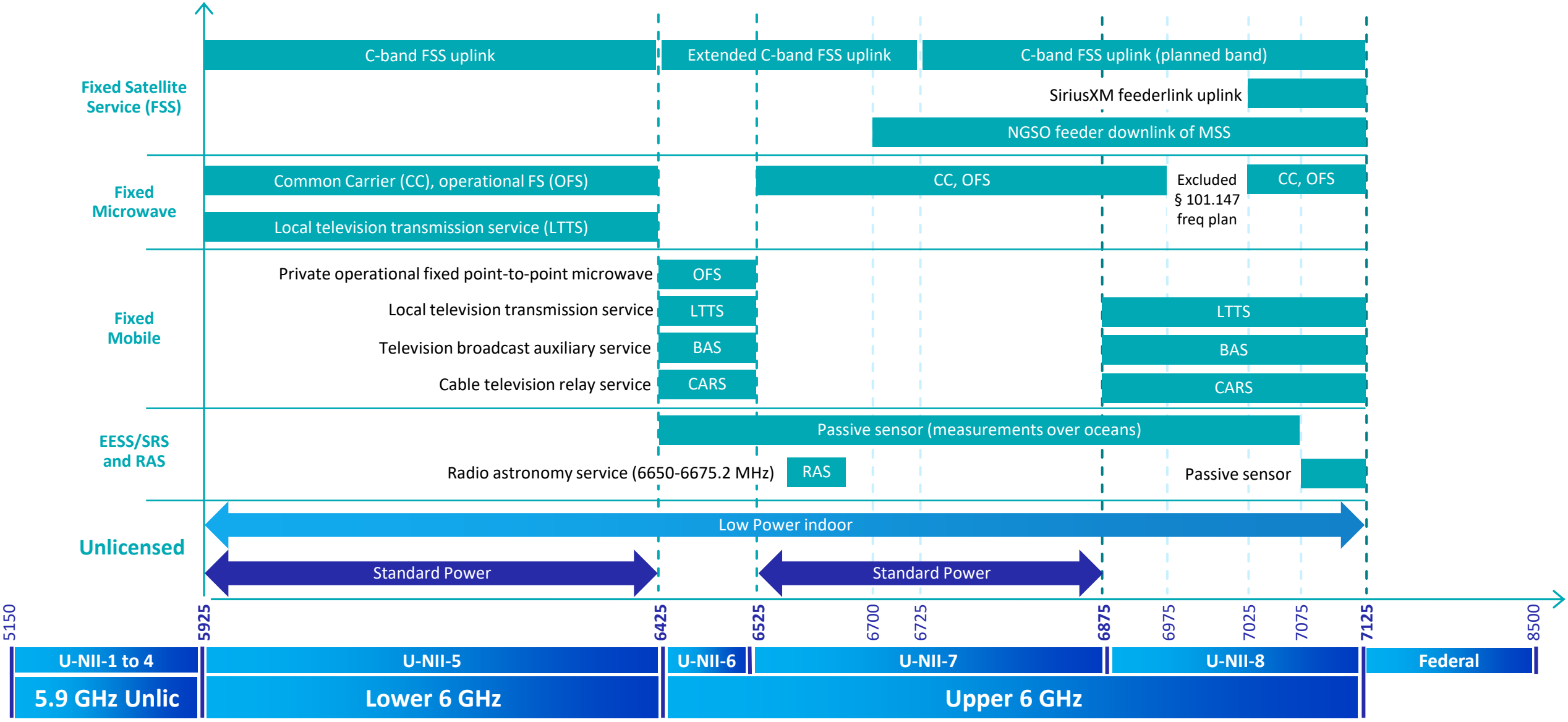
Lower 6 GHz microwave paths
licensed, applied and proposed

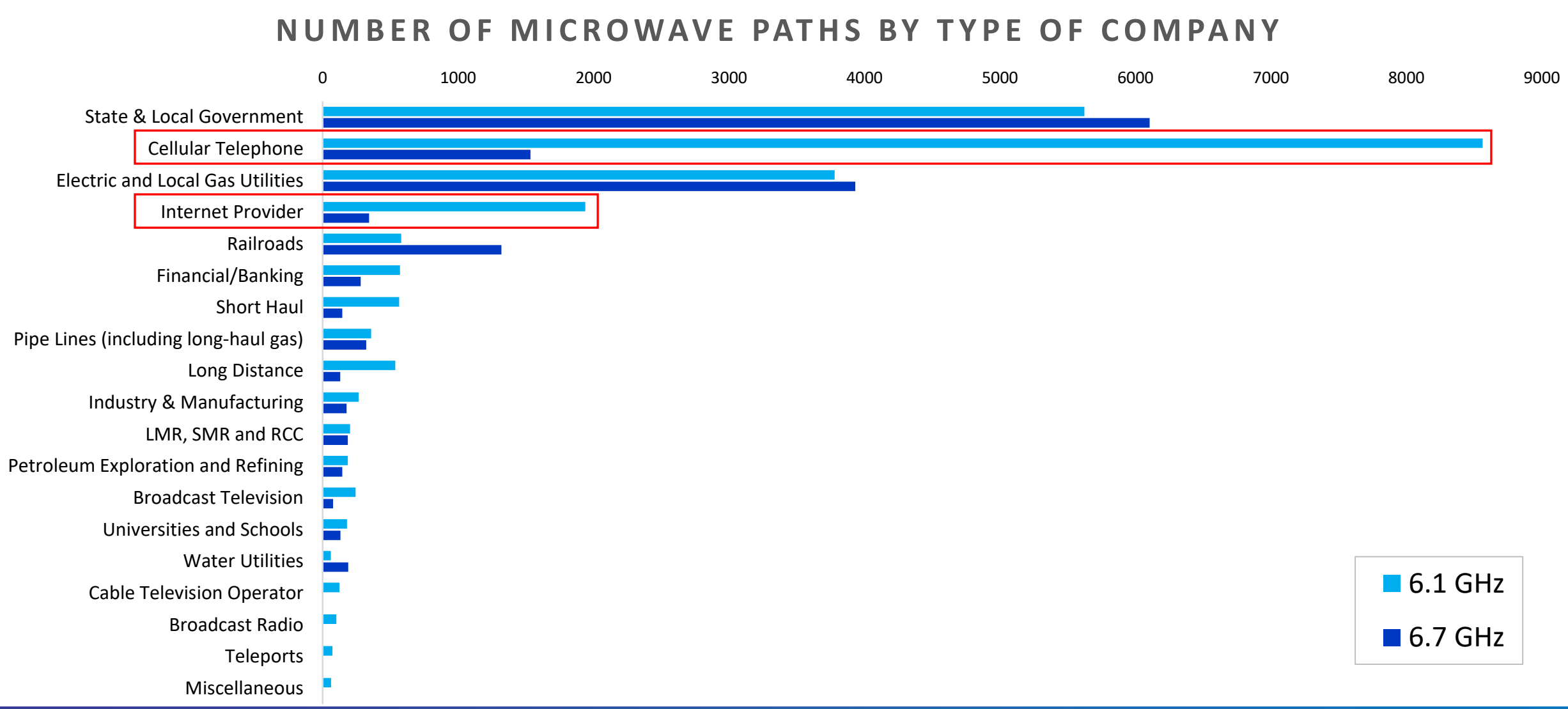


Upper 6 GHz microwave paths
licensed, applied and proposed



All 6 GHz Users

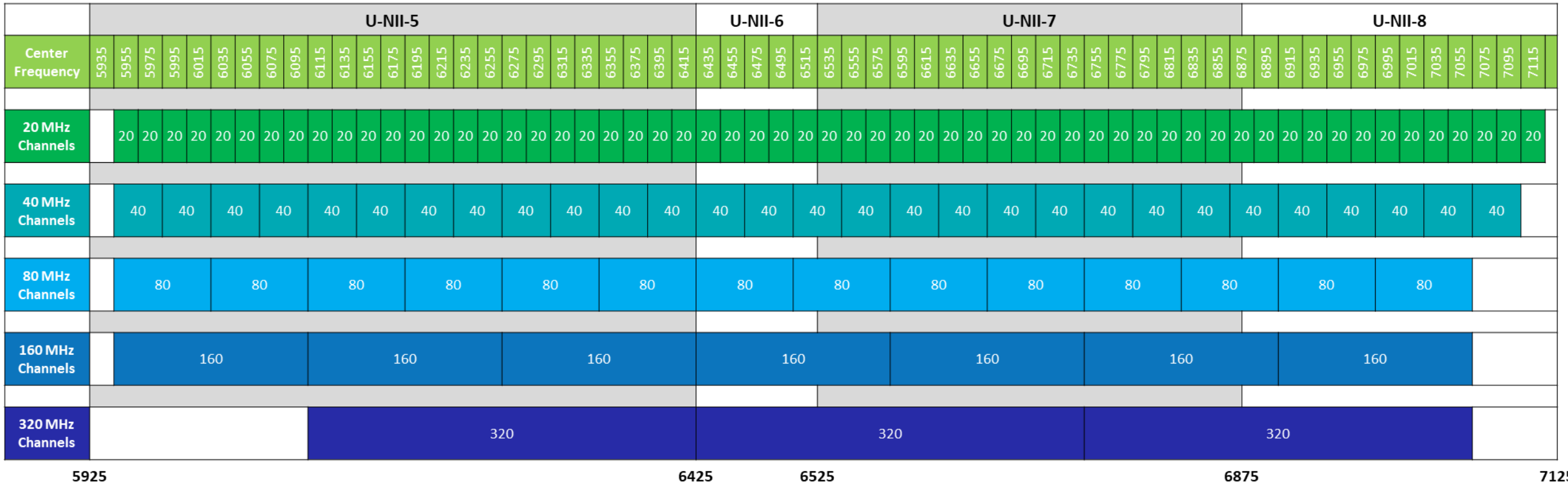




Who uses the 6 GHz Band

Description of Unlicensed 6 GHz Operations

Wi-Fi Channel Plan

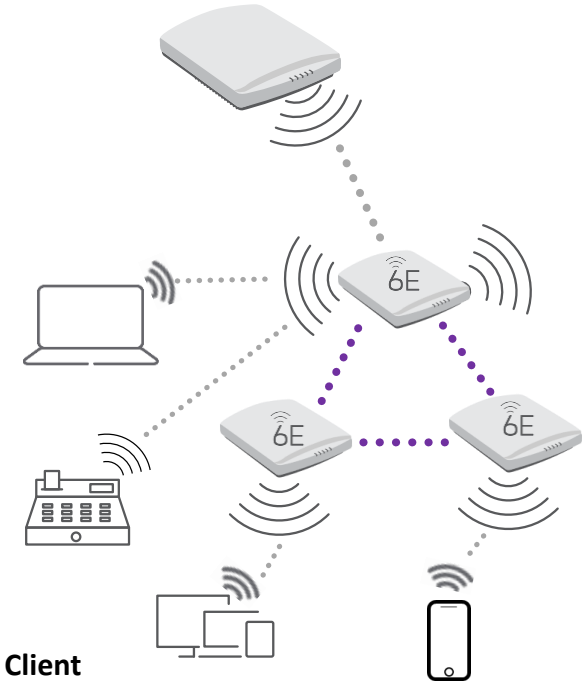


59 x 20 MHz Channels
29 x 40 MHz Channels
14 x 80 MHz Channels
7 x 160 MHz Channels
3 x 320 MHz Channels

Examples of 6 GHz Devices

Low Power Indoor (LPI) AP

- Indoor only
- 1W (30 dBm) max EIRP
- 3 mW/MHz (5 dBm/MHz) max PSD



Client

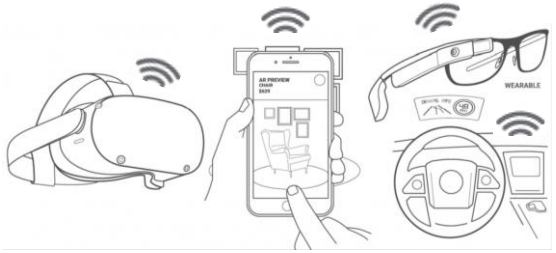
- Indoor
- Under control of Indoor AP
- 250 mW (24 dBm) max EIRP
- 0.8 mW/MHz (-1 dBm/MHz) max PSD

Subordinate

- Indoor
- Under control of Indoor AP
- 1W (30 dBm) max EIRP
- 3 mW/MHz (5 dBm/MHz) max PSD

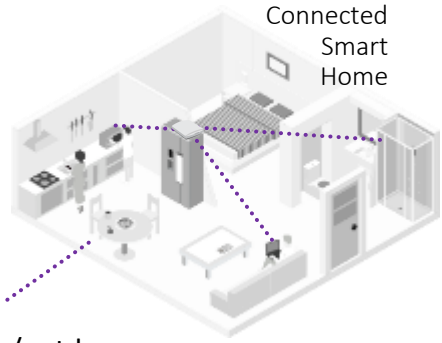
Very Low Power (VLP)

- Indoor/outdoor
- 25 mW (14 dBm) max EIRP
- 0.3 mW/MHz (-5 dBm/MHz) max PSD



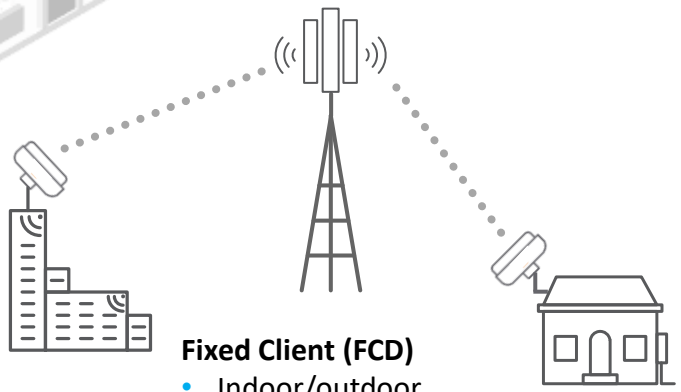
Standard Power AP (SPAP)

- Fixed indoor/outdoor
- 4W (36 dBm) max EIRP
- 200 mW/MHz (23 dBm/MHz) PSD
- Must use AFC
- Automated geolocation (x,y)



Client

- Indoor/outdoor
- 4X less power than connected AP
- 1W (30 dBm) max EIRP
- 50 mW/MHz (17 dBm/MHz) max PSD



Fixed Client (FCD)

- Indoor/outdoor
- 1W (30 dBm) max EIRP
- 50 mW/MHz (17 dBm/MHz) max PSD
- Must use AFC
- Automated geolocation (x,y)

Examples of Low Power Indoor Devices

Device Type	Max EIRP	Max PSD	Geolocation Required?	AFC Required?	Limitations	Bands
Indoor AP 	1W (30 dBm)	3 mW/MHz (5 dBm/MHz)	No	No	• Indoor only • Integrated antenna (not external) • No weatherized enclosure • Wired power (no battery) • Must be labeled: "**FCC regulations restrict operation of this device to indoor use only**"	U-NII-5 to U-NII-8 5925-7125 MHz
Subordinate 	1W (30 dBm)	3 mW/MHz (5 dBm/MHz)	No	No	• Indoor only • Under control of Indoor AP • Integrated antenna (not external) • No weatherized enclosure • Wired power (no battery) • Can't be used to connect devices between separate buildings or structures • Must be labeled: "**FCC regulations restrict operation of this device to indoor use only**" • Must be certified separately	U-NII-5 to U-NII-8 5925-7125 MHz
Client 	250 mW (24 dBm)	0.8 mW/MHz (-1 dBm/MHz)	No	No	• Indoor only • Under control of Indoor AP • Integrated antenna (not external) • No weatherized enclosure • Wired power (no battery) • Operating power must be 6 dB below associated SP AP transmit power	U-NII-5 to U-NII-8 5925-7125 MHz

Examples of Standard Power Devices

Device Type	Max EIRP	Max PSD	Geolocation Required?	AFC Required?	Limitations	Bands
Standard Power AP 	4W (36 dBm)	200 mW/MHz (23 dBm/MHz)	Yes	Yes	• Antenna elevation angle requirements	U-NII-5 & U-NII-7 5924-6425 MHz & 6525-6875 MHz
Fixed Client 	4W (36 dBm)	200 mW/MHz (23 dBm/MHz)	Yes	Yes	• Can only connect to a SP AP • Client device intended as CPE • Permanently attached to a structure • Antenna elevation angle/power limitation requirements	U-NII-5 & U-NII-7 5924-6425 MHz & 6525-6875 MHz
Client 	1W (30 dBm)	50 mW/MHz (17 dBm/MHz)	No	No	• Operating power must be 6 dB below associated SP AP transmit power	U-NII-5 & U-NII-7 5924-6425 MHz & 6525-6875 MHz

Examples of Very Low Power Devices

Device Type	Max EIRP	Max PSD	Geolocation Required?	AFC Required?	Limitations	Bands
	25 mW (14 dBm)	0.3 mW/MHz (-5 dBm/MHz)	No	No	• Integrated antenna (not external) • Cannot operate as part of fixed outdoor infrastructure such as poles or buildings • Must prioritize spectrum above 6105 MHz	U-NII-5 to U-NII-8 5925-7125 MHz

SOME VLP APPLICATIONS*

Displays for AR/VR

- Imaging headsets, headphones, game controllers, keyboards, hearing aids

Automotive applications

- Vehicle infotainment, maintenance, tracking, security and other applications

Screen mirroring & wireless casting

- Smartphones, tablets, TVs, projectors, and many other devices
- Wireless streaming of cloud-based content directly to end-user devices

Healthcare

- Real time patient monitoring
- Vital signs monitoring
- IV drug delivery control
- AR for surgery and other treatment workflows

Wearable and on-body uses

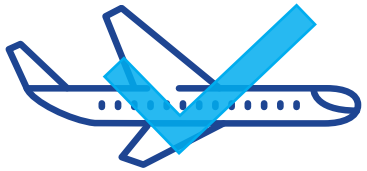
Short-range hotspots

Accurate Wi-Fi indoor location and navigation

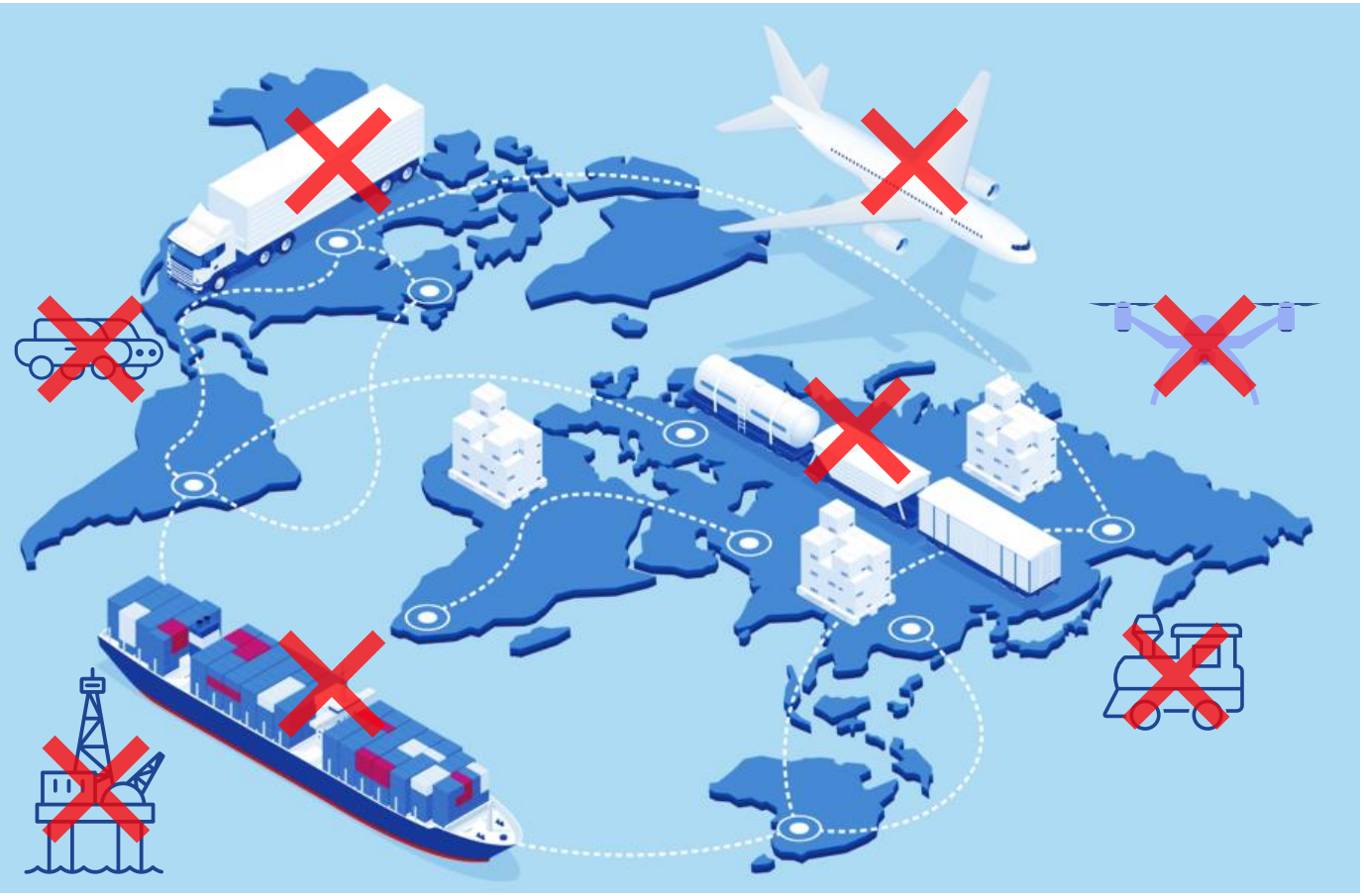
Automation

*Apple, Broadcom, Cisco, Facebook, Google, HPE & WFA

Prohibitions & Limitations: LPI & Standard Power

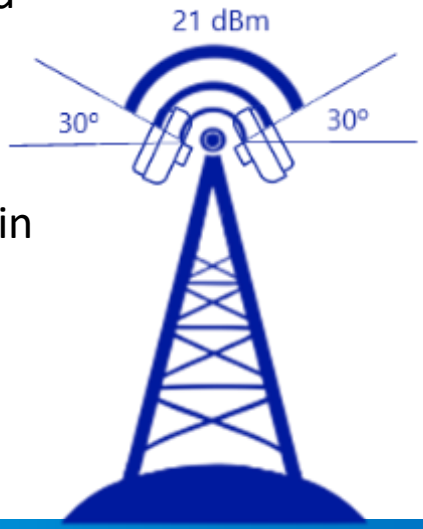


10,000 ft. +



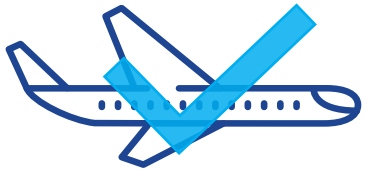
For now, prohibited on oil platforms, cars, trains, boats, and aircraft below 10,000 ft.

However, APs can operate in the 5925-6425 MHz bands (U-NII-5) in large aircraft while flying above 10,000 feet.



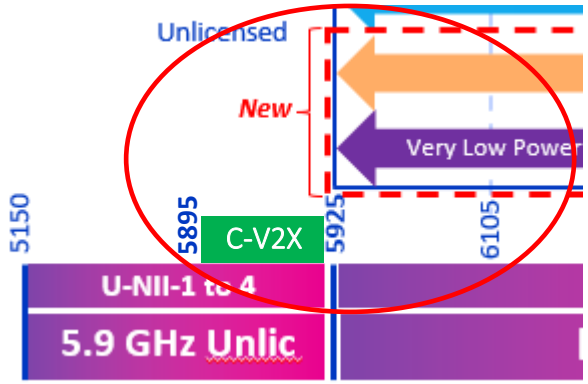
EIRP for outdoor Standard Power device must be **below 125 mW** (21 dBm) for antenna elevation **greater than 30°** above horizon.

Prohibitions & Limitations: VLP



10,000 ft. +

For now, prohibited on oil platforms and aircraft below 10,000 ft.



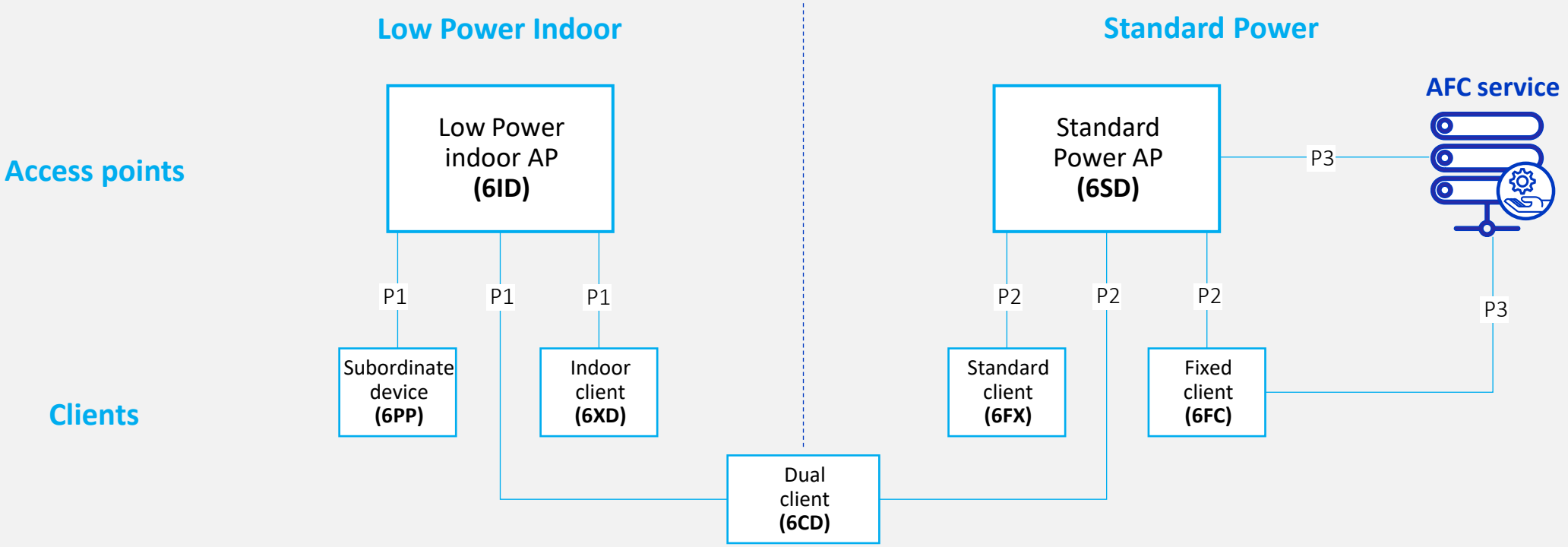
Must prioritize spectrum above 6105 MHz to ensure that C-V2X safety of life services below the U-NII-5 band are protected from harmful interference.

FCC Equipment Classes for Low Power & Standard Power*

	Class ID	Description
Low Power	6ID	Low Power indoor access point.
	6PP	Subordinate indoor device. These devices are under control of a Low Power indoor access point.
	6XD	Low Power Indoor client. These devices are under control of a Low Power indoor access point.
	6CD	Dual client. These devices are under control of either:
		Low Power indoor access point (6ID) or
Standard Power		Standard Power access point (6SD)
	6SD	Standard Power access point. These devices are managed by the Automatic Frequency Coordination (AFC) system.
	6FX	Standard client. These devices are under control of a Standard Power access point.
	6FC	Fixed client. These devices are associated with a Standard Power access point.

*From FCC KDB 987594, 8/7/23, subject to change

FCC Equipment Classes for Low Power & Standard Power*



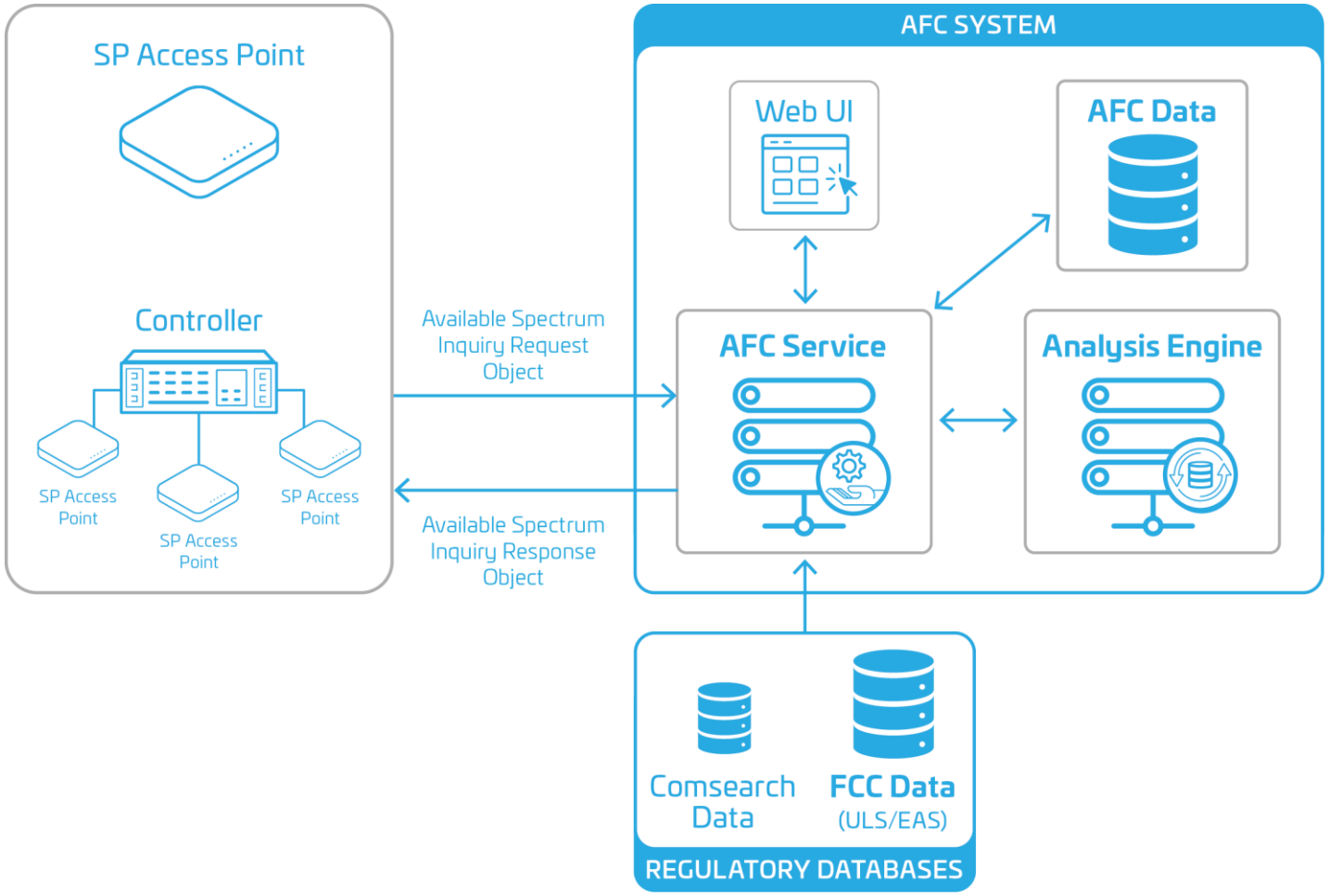
P1: Client and subordinate devices under control of Low Power indoor access point.
P2: Client devices under control of standard access point.
P3: Standard Power Access Point and fixed client devices managed by the AFC.

*From FCC KDB 987594, 8/7/23, subject to change

Automated Frequency Coordination (AFC) System

AFC Operation

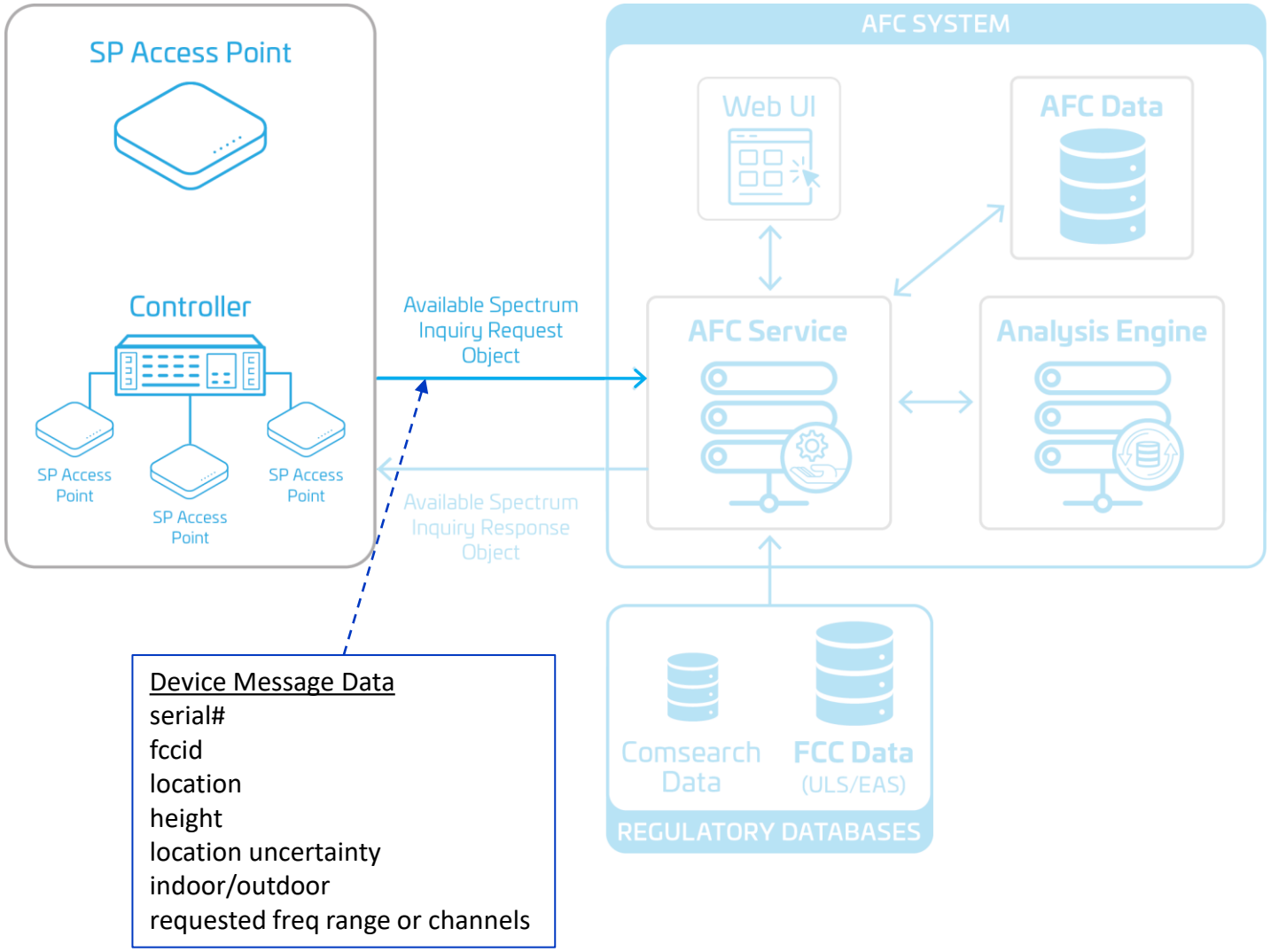
AFC FUNCTIONAL ARCHITECTURE



AFC Operation: SPAP & FCD Requirements

- Standard Power APs (SPAPs) and Fixed Client devices (FCDs) must:
  - Use an AFC to operate in the 6 GHz bands
  - Automatically geolocate
  - Register with AFCs by sending basic information to AFC (including location)
  - Provide updated information to AFC
  - Check in with the AFC every 24 hours
    - If check in fails, device has until 11:59pm of following day to establish contact or it must shut down
  - Use security methods to prevent accessing non-approved AFC systems and unauthorized modification of device
- Device controllers can act as device proxies when interacting with the AFC

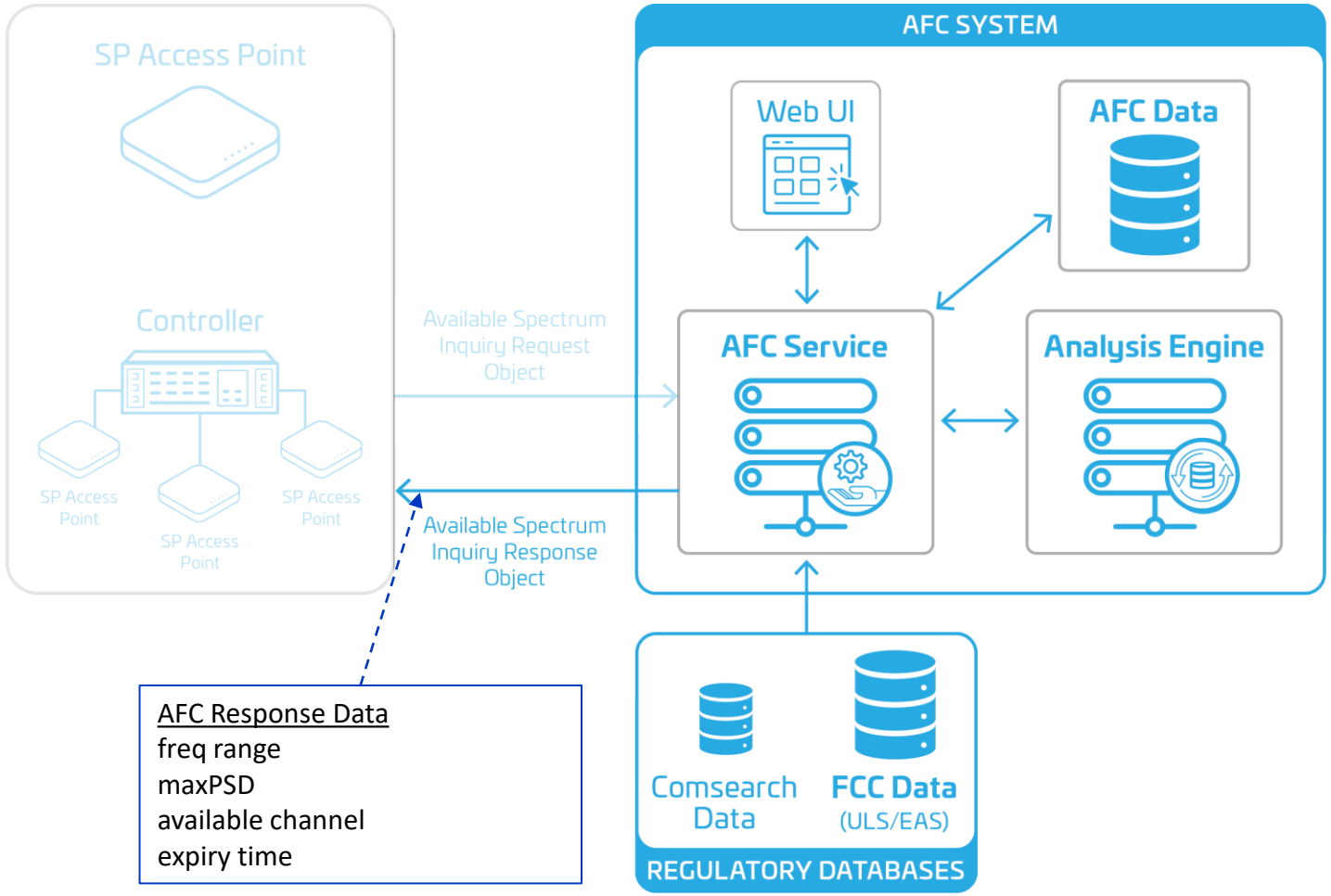
AFC FUNCTIONAL ARCHITECTURE



AFC Operation: AFC Requirements

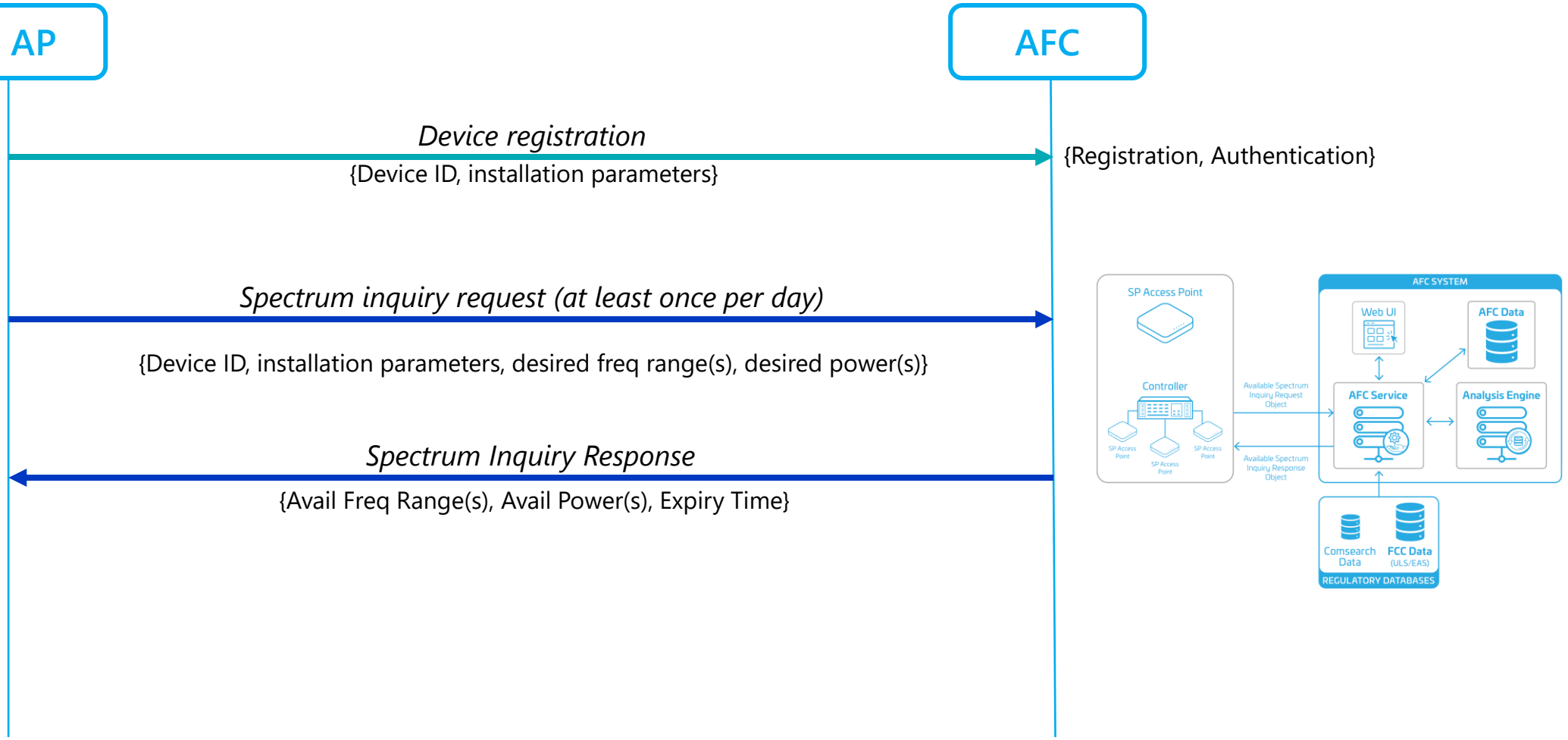
- AFCs must:
  - Use FCC databases (ULS & EAS) for information on protected/licensed incumbent systems
  - Verify validity of device FCC ID
  - Determine available frequencies and max permissible transmit EIRP using device registration query data
  - Return lists of available spectrum/channels and max powers
    - In 3 dB steps between 21 dBm and 36 dBm
  - Store registered information in a secure database until an SPAP or FCD ceases operation at a location
  - Deregister device if no contact with AFC within 3 months

AFC FUNCTIONAL ARCHITECTURE



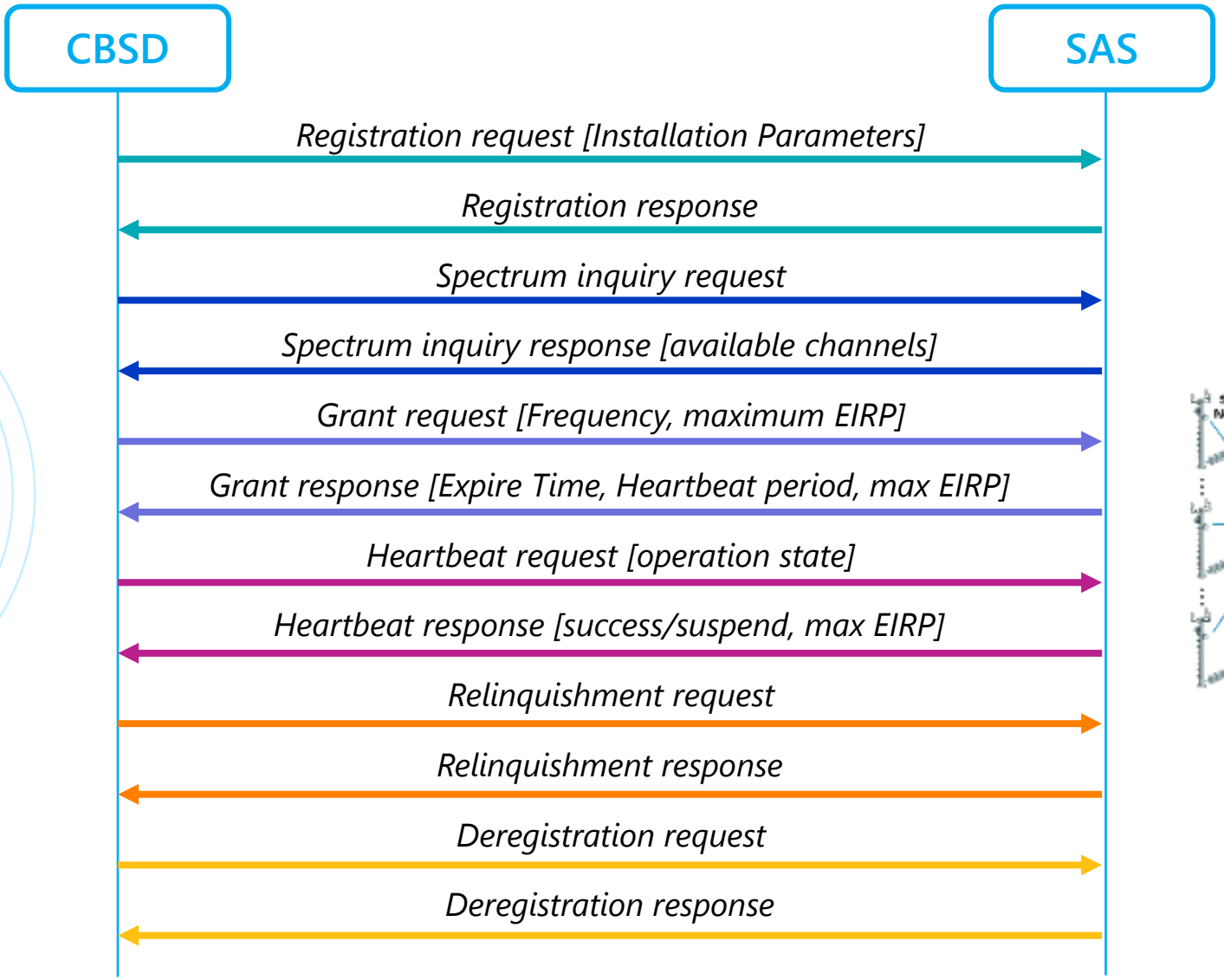
AFC-SP AP Message Protocol

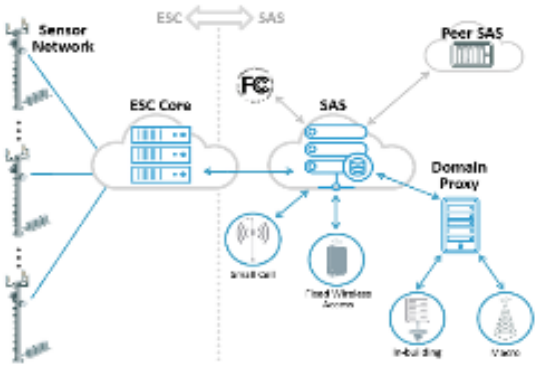
AFC is much simpler than…



SAS-CBSD Message Protocol

…the CBRS SAS

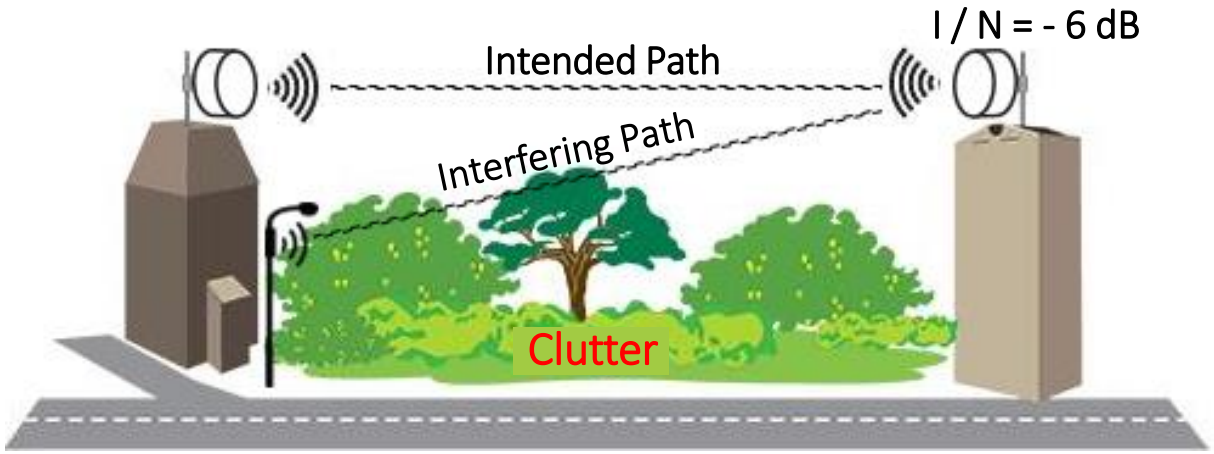




AFC Operation: Calculations

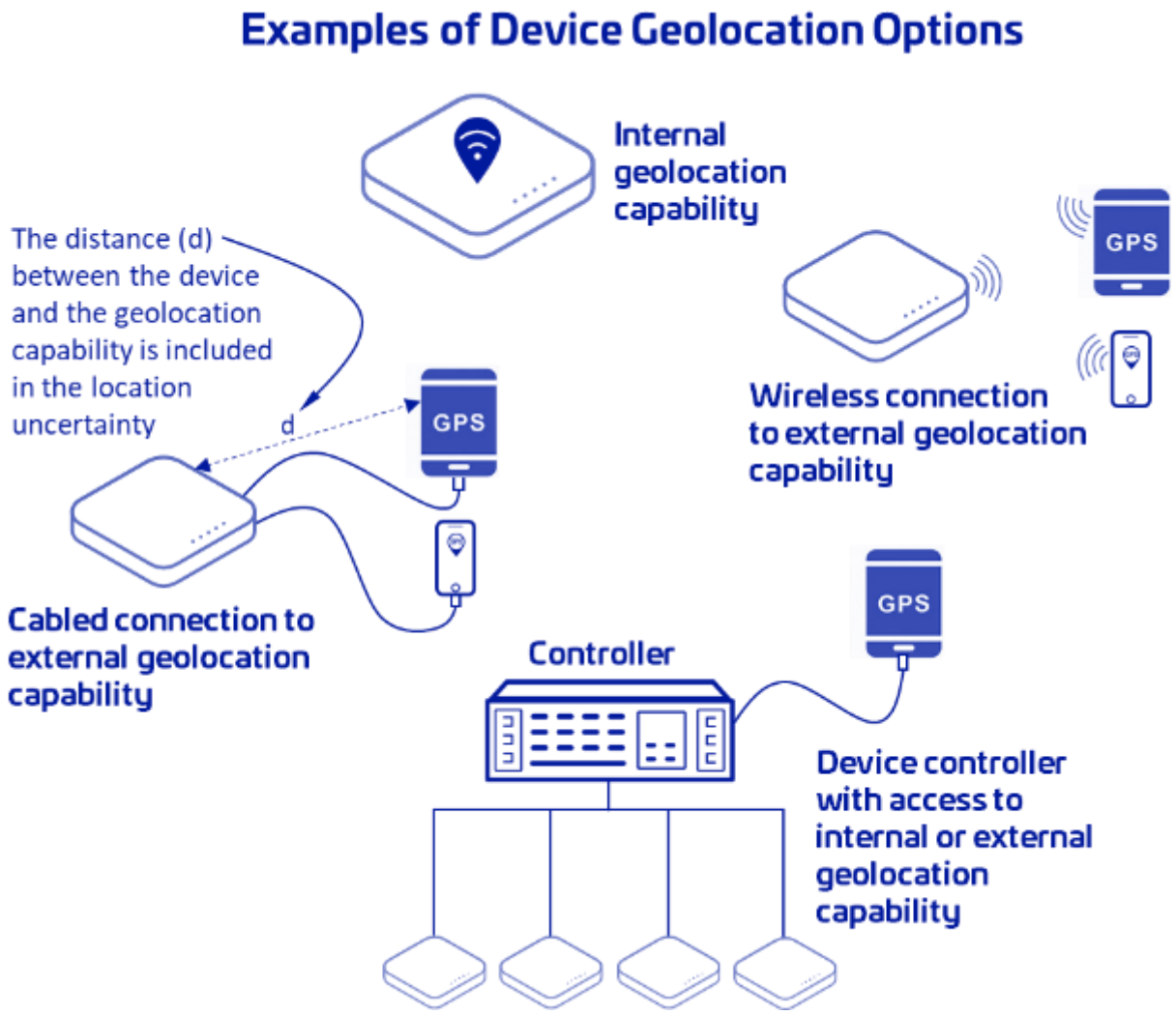
- **Propagation models** (multi-model approach)
  - FSPL for short distances (>30m)
  - WINNERII for intermediate (30m – 1km)
  - ITM for longer (beyond 1 km)
  - Will require site-specific information as available (buildings, terrain)
    for determining LOS conditions
  - BEL for indoor-only devices: 20.5 dB
- **Clutter**
  - ITU-R P.2108 for urban/suburban
  - ITU-R P.452 for rural

- **IPC: I/N = -6dB**
- **No power aggregation of RLANs**
- **Need to protect radio astronomy in 6650.0-6675.2 MHz** at certain locations using exclusion zones based on Radio LoS from RLAN to RA site:
  - *Arecibo, PR*
  - *Green Bank, WV*
  - *Very Large Array, NM*
  - *Very Long Baseline Array (10 sites)*
  - *Owens Valley Array, CA*
  - *Allen Telescope Array, CA*



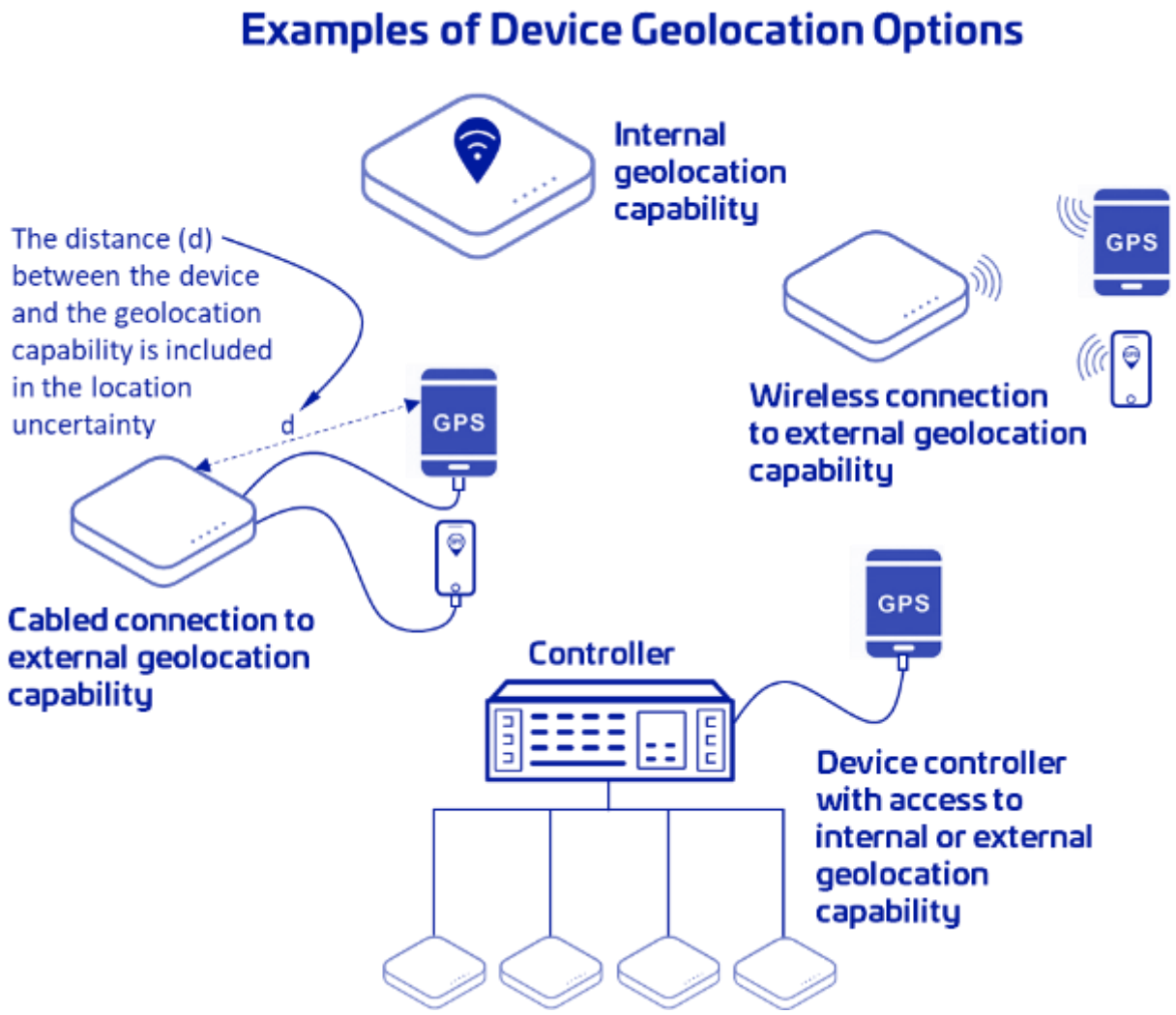
Device Geolocation: Requirements

- Device must be able to automatically determine its geographic coordinates (lat, lon) and location uncertainty (in meters) with a 95% confidence by using either:
  - ✓ an internal geolocation capability or
  - ✓ an integrated capability to securely connect to an external geolocation device or service
- Device height can be provided automatically or by the installer.
- External geolocation source may be connected through either a secure wired or a secure wireless connection that ensures that only an external geolocation source approved for use with a device provides geographic coordinates to that device.
- An extender cable may be used to connect a remote receive antenna to a geolocation receiver within a device.
- For devices that don't use an internal geolocation capability, the uncertainty must account for the accuracy of the geolocation source and the separation distance between such source and the device.
- A single geolocation source may provide location information to multiple Standard Power access points or fixed client devices.
- The device must report these coordinates and location uncertainty to an AFC system at the time of activation from a power-off condition.
- Applicants for certification of a device must demonstrate the accuracy of the geolocation method used and the location uncertainty.



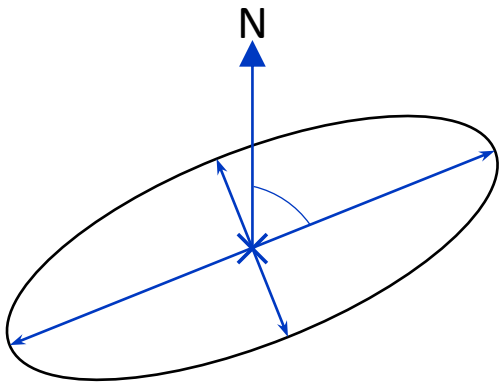
Device Geolocation: FCC Certification

- Must include Persistent Inquiry Approval (PIA) with device certification filing that includes three documents:
  1. General description of geolocation methods
  2. Details that justify the 95% confidence level claim and demonstration of the testing method and calculations used to verify
  3. Description of the method used to determine that the device has not been moved after a power cycle



Device Geolocation: AFC Treatment of Location Uncertainty

Ellipse

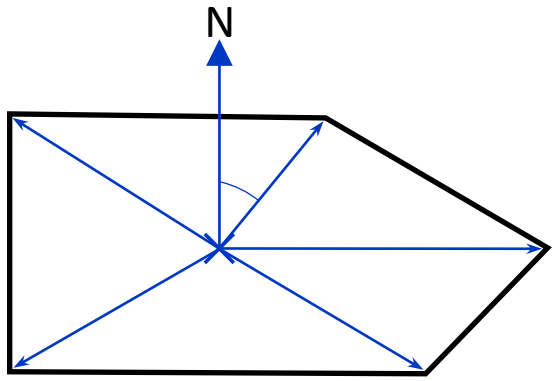


- Center point (latitude, longitude)
- Uncertainty reflected in major & minor axis (meters)
- Orientation relative to True North

Linear Polygon

- Each point (latitude, longitude)

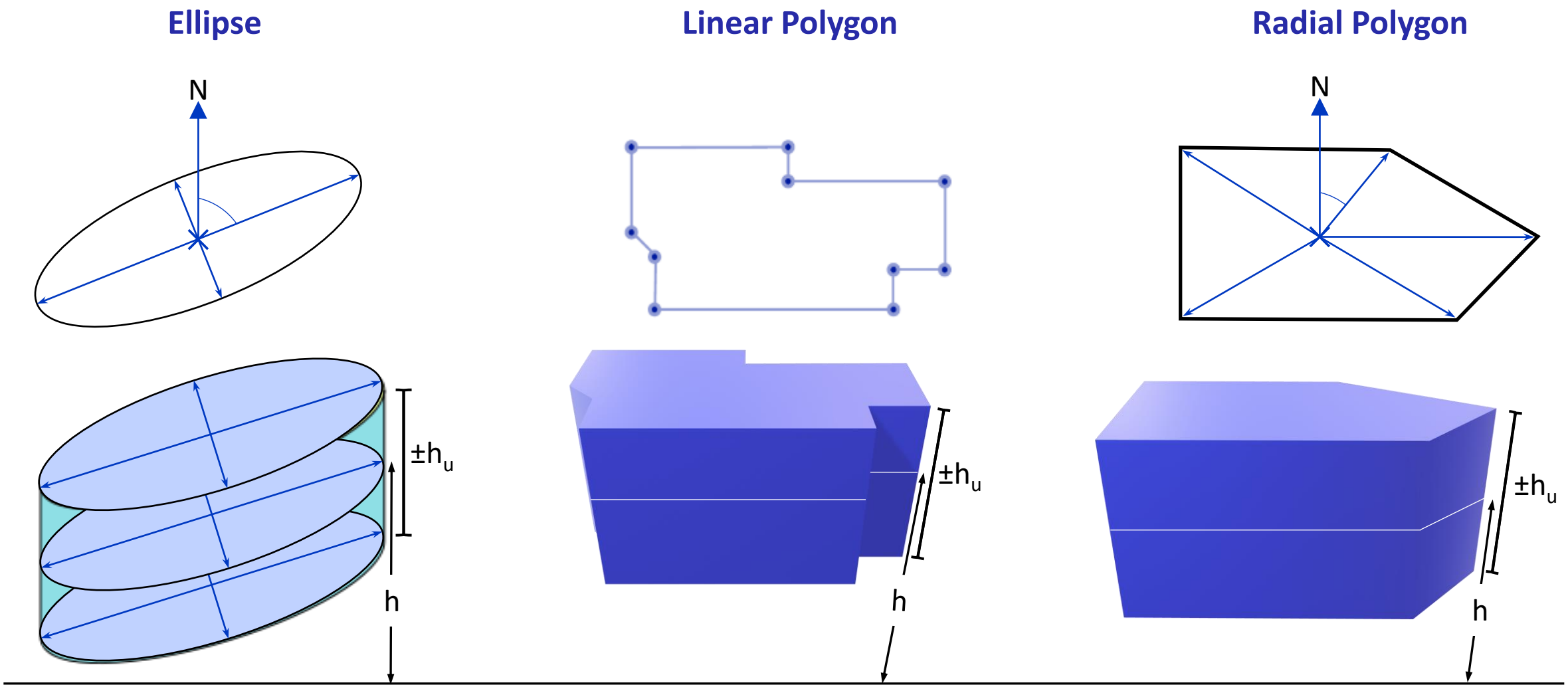
Radial Polygon



- Center point (latitude, longitude)
- Each vector (angle, distance)

- Height of the device antenna in meters (AGL)
- Vertical distance in meters above and below the value of the height field within which the device is located

Device Geolocation: AFC Treatment of Location Uncertainty



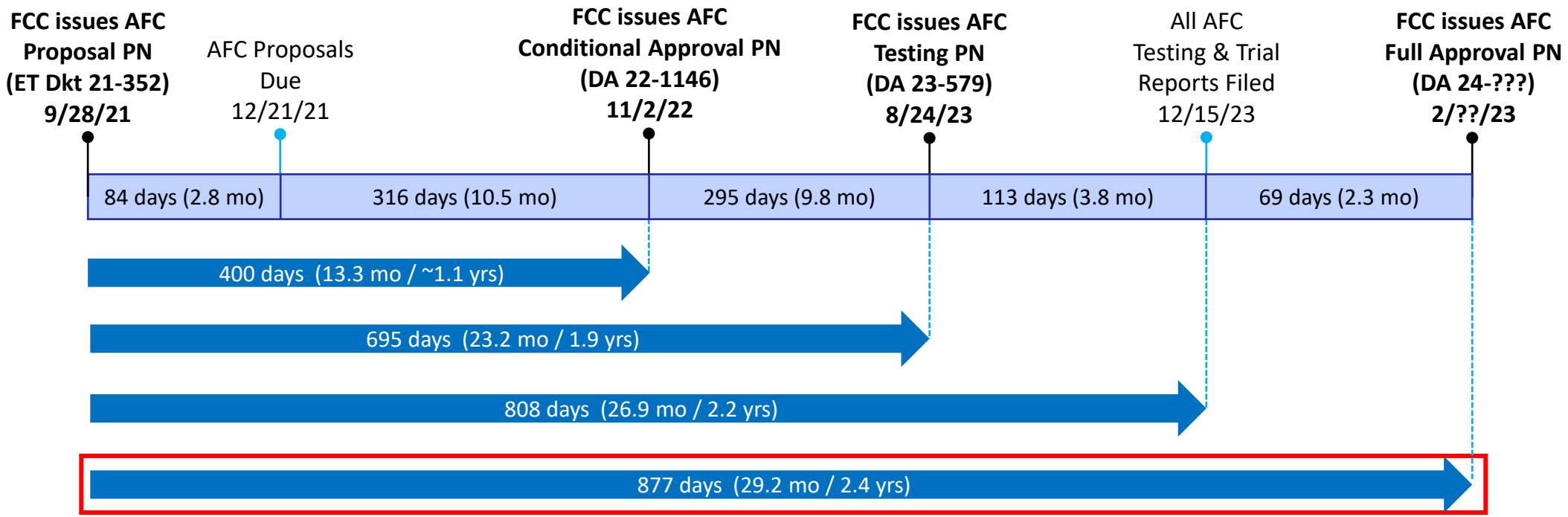
AFC Commercialization and Timeline

Broadcom†*	Plume*
Comsearch†	Qualcomm†
Federated Wireless†	Red Technologies
Google	Sony†
KeyBridge	Wi-Fi Alliance†*
Kyrio*	Wireless Broadband Alliance†*
Nokia	

†Currently in Certification

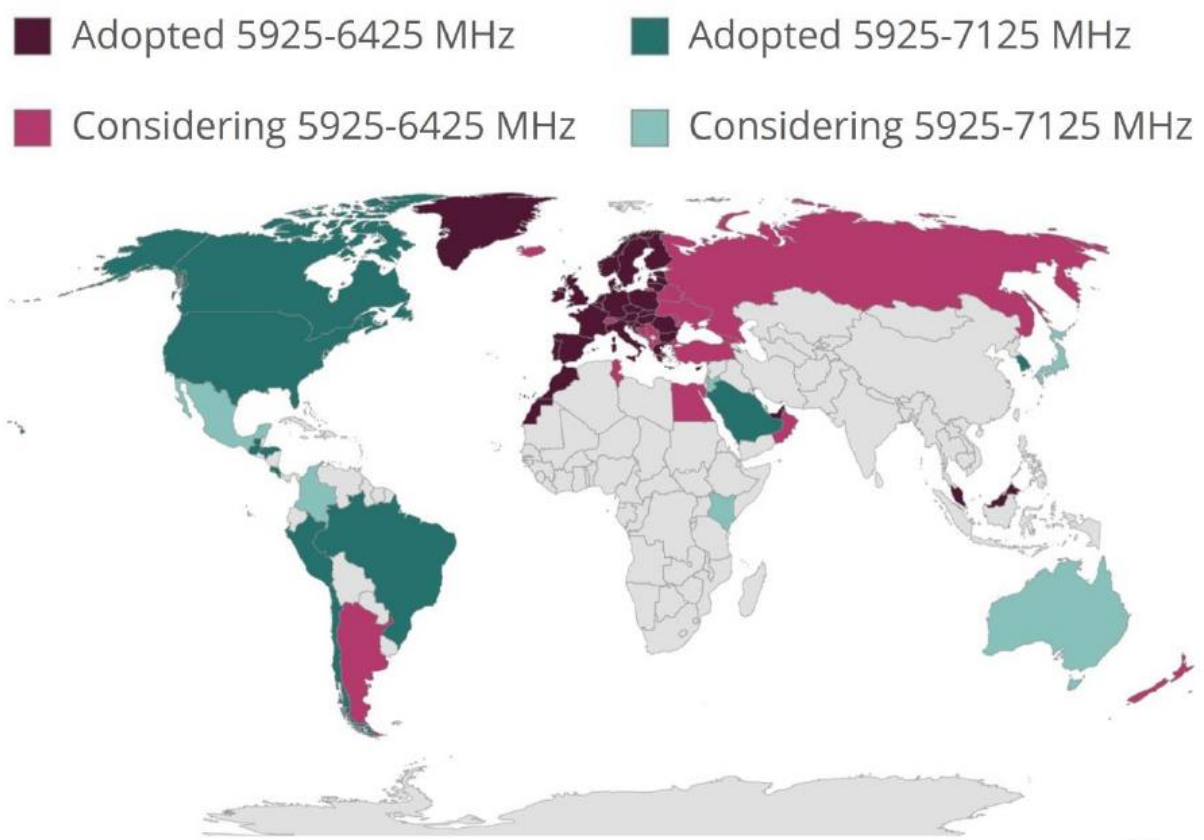
*Using Open AFC

Conditionally Authorized AFC Operators



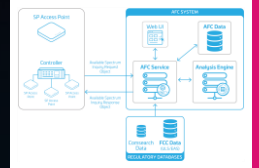
AFC Testing & Certification Timeline

COUNTRY	STATUS	SPECTRUM	AFC
Argentina	Considering	5925-6425 MHz	
Australia	Adopted	5925-6425 MHz	
	Considering	6425-7125 MHz	X
Brazil	Adopted	5925-7125 MHz	
CEPT	Considering	5925-6425 MHz (*only considering 5945-6425)	
Canada	Adopted	5925-7125 MHz	X
Chile	Adopted	5925-7125 MHz	
Colombia	Considering	5925-7125 MHz	
Costa Rica	Adopted	5925-7125 MHz	
Egypt	Considering	5925-6425 MHz	
European Union	Adopted	5925-6425 MHz (*only adopting 5945-6425)	
Guatemala	Adopted	5925-7125 MHz	
Honduras	Adopted	5925-7125 MHz	
Japan	Considering	5925-7125 MHz	
Jordan	Considering	5925-7125 MHz	
Kenya	Considering	5925-7125 MHz	
Korea	Adopted	5925-7125 MHz	X
Malaysia	Adopted	5925-6425 MHz	?
Mexico	Considering	5925-7125 MHz	X
Morocco	Adopted	5925-6425 MHz	
New Zealand	Considering	5925-6425 MHz	
Norway	Adopted	5925-6425 MHz	
Oman	Considering	5925-6425 MHz	
Peru	Adopted	5925-7125 MHz	
Qatar	Considering	5925-7125 MHz	
Saudi Arabia	Adopted	5925-7125 MHz	X
South Korea	Adopted	5925-7125 MHz	
Tunisia	Considering	5925-6425 MHz	?
Turkey	Considering	5925-6425 MHz	
United Arab Emirates	Adopted	5925-6425 MHz	
United Kingdom	Adopted	5925-6425 MHz	
	Considering	6425-7125 MHz	?
United States	Adopted	5925-7125 MHz	X



International use of 6 GHz

Summary



AFC is the 3rd generation of centralized DSM methods

Certification & commercialization of DSM systems is a years-long process

Unlicensed use of the 6 GHz band presents exciting new opportunities

There is substantial incumbent use of the 6 GHz band

Incumbent use is protected by a combination of device limitations & the AFC

AFC concept is simpler than previous DSM efforts

Device geolocation presents challenges

Still more work to be done

Q & A

Mark Gibson

Sr. Director, Spectrum Regulatory & Policy

mark.gibson@commscope.com