

BUILDING A WORLD OF DIFFERENCE

WiFi 6E (IEEE 802.11ax) The Unlicensed 6 GHz

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Background

- Since the ever-increasing demand for wireless broadband continues to grow at a phenomenal pace, FCC has adopted rules to make 1200 MHz of spectrum available for unlicensed use in the 6 GHz Band (5.925-7.125 GHz).
 - According to Ericsson, the average data usage per month in smartphones will increase from 7GB in 2018 to 39GB by 2024¹.
 - According to Cisco, 59% of mobile data traffic will be offloaded to WiFi by 2022².
- This will allow unlicensed devices to share the spectrum with the incumbent services in the 6 GHz!



Current 6 GHz Spectrum

Sub-band	Frequency Range (GHz)	Primary Allocation	Predominant Licensed Services
U-NII-5	5.925-6.425	Fixed FSS	<u>Fixed Microwave FSS (uplinks)</u>
U-NII-6	6.425-6.525	Mobile FSS	Broadcast Auxiliary Service Cable Television Relay Service FSS (uplinks)
U-NII-7	6.525-6.875	Fixed FSS	<u>Fixed Microwave FSS (uplinks/downlinks)</u>
U-NII-8	6.875-7.125	Fixed Mobile FSS	Broadcast Auxiliary Service Fixed Microwave Broadcast Auxiliary Service

FSS: Fixed Satellite Service

Potential issues in UNII-5 and UNII-7 due to existing incumbent MW users



Timeline

2017

Aug 2017

FCC Notice of Inquiry (17-183)

- Asked questions about possible new uses of 6 GHz band
- Ask specifically about unlicensed use
- Break band into two segments:
 - 5925-6425 MHz
 - 6425-7125 MHz
- 88 comments and 6 replies

2018

Jan 2018

RLAN Proponents File RKF Study on Docket

- Study to determine whether RLAN devices can coexist with incumbent microwave
- Provides 2025 estimate of RLAN deployment
- Concludes that LPI devices will not interfere with microwave systems
- Study has been substantially disputed on the docket

2019

Oct 2018

FCC NPRM on Unlicensed use of 6 GHz Band (18-295)

- Proposes new rules for unlicensed sharing with 6 GHz incumbents
- Proposes Automatic Frequency Coordination (AFC) idea
- Asks several technical questions on issues such as:
 - Propagation models
 - Interference protection criteria
 - Building & clutter loss
- 108 comments and 63 replies filed

2020

Apr 2019

Post-comment Period

- Flurry of *ex-parte* filings & meetings
- Additional analyses performed and offered on the record

Apr 2020

R&O/FNPRM

- Rules for Standard Power, Low Power and client devices
- Rules for AFC
- FNPRM for VLP and LPI

RKF Study Report prepared for Google, Apple, Intel, Cisco, Facebook and others.

<https://s3.amazonaws.com/rkfengineering-web/6USC+Report+Release+-+24Jan2018.pdf>



RKF Engineering Study Conclusion

- 10 Continental US (CONUS-wide) simulations were performed corresponding to 910,000 different Low Power Indoor to Fixed Service (LPI-to-FS) interference morphologies and time instances.
 - 99.8% of the FS stations had aggregate interference levels below the target $I/N = -6$ dB³.
 - Only 0.2% of the FS stations had aggregate interference levels above -6 dB.
 - Investigation on the availability impact, assuming availability of %99.999 (315s of down time/year) incurred additional 8 seconds of additional down time.
 - Investigation on the availability impact, assuming availability of %99.9999 (31.6s of down time/year) incurred additional 0.8 seconds of additional down time.
 - Thus, it was deemed LPI devices do not pose any substantial aggregate interference and can be used safely in the 6 GHz band.



Basics of the FCC Rulemaking

• Report & Order (R&O)

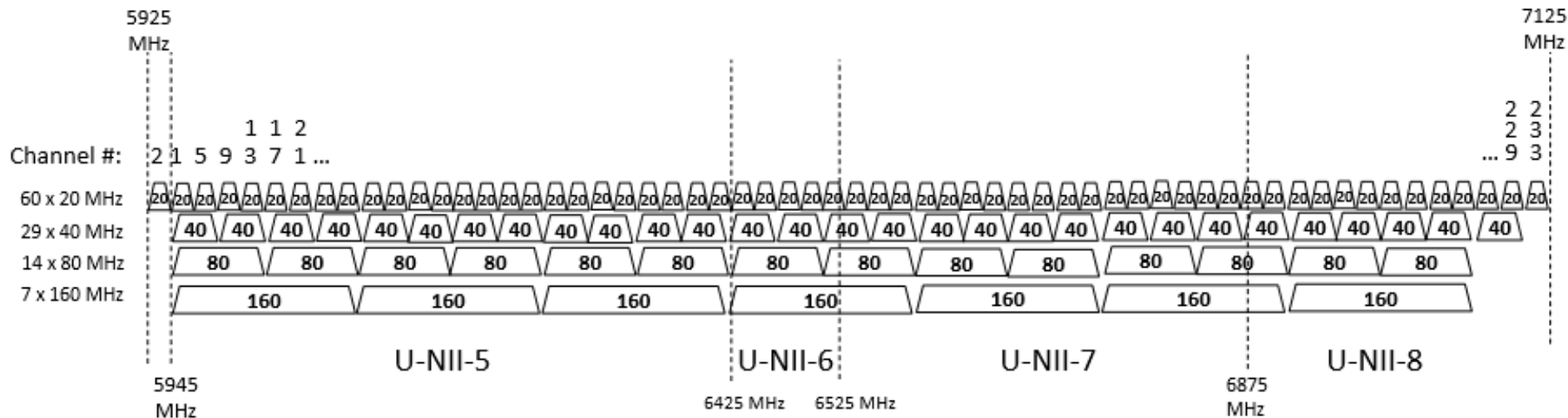
- Allocates 1200 MHz for unlicensed devices.
- FCC authorized 2 types of unlicensed operations in the 6 GHz band:
 - **Low Power Indoor (LPI)** APs can operate in the unlicensed 6 GHz without the AFC at a max EIRP of 30 dBm /320 MHz (or 5dBm/MHz).
 - **Standard Power** APs can operate both indoors and outdoors BUT must use AFC.
- Automated Frequency Coordination (AFC) is a geolocation database of available frequencies/powers based on incumbent usage. It is directly connected to the Universal Licensing System (ULS).
- **No mobility** permitted for Standard Power or LPI*
- Suggests a new Multi-Stakeholder Group (MSG) to study issues and support development of AFC requirements.
 - **BV is an active member in the MSG.**

*mobility is allowed in aircrafts over 10,000 ft

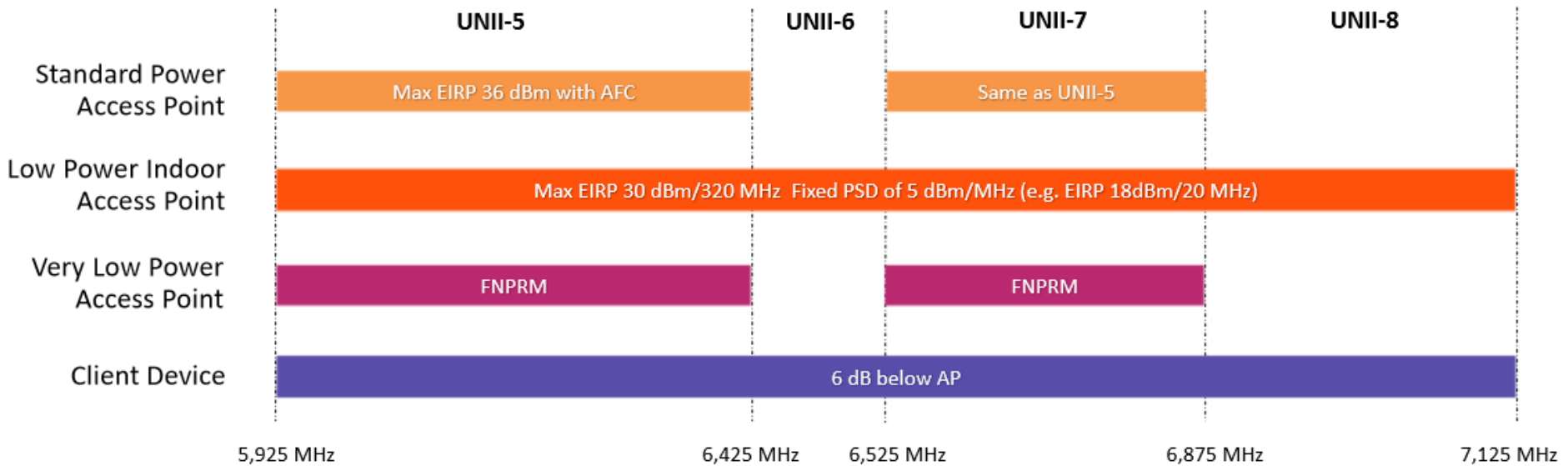


6 GHz WiFi Channel Plan

- Number of channels per BW
 - 60 x 20 MHz
 - 29 x 40 MHz
 - 14 x 80 MHz
 - 7 x 160 MHz



Unlicensed Power Limits in the in the 6 GHz



Device Class	Operating Bands	Maximum EIRP	Maximum EIRP Power Spectral Density
Standard-Power Access Point (AFC Controlled)	U-NII-5 (5.925-6.425 GHz)	36 dBm	23 dBm/MHz
Client Connected to Standard-Power Access Point	U-NII-7 (6.525-6.875 GHz)	30 dBm	17 dBm/MHz
Low-Power Access Point (indoor only)	U-NII-5 (5.925-6.425 GHz) U-NII-6 (6.425-6.525 GHz)	30 dBm	5 dBm/MHz
Client Connected to Low-Power Access Point	U-NII-7 (6.525-6.875 GHz) U-NII-8 (6.875-7.125 GHz)	24 dBm	-1 dBm/MHz

Same power level permitted in the 5 GHz

Automated Frequency Coordination (AFC) from R&O

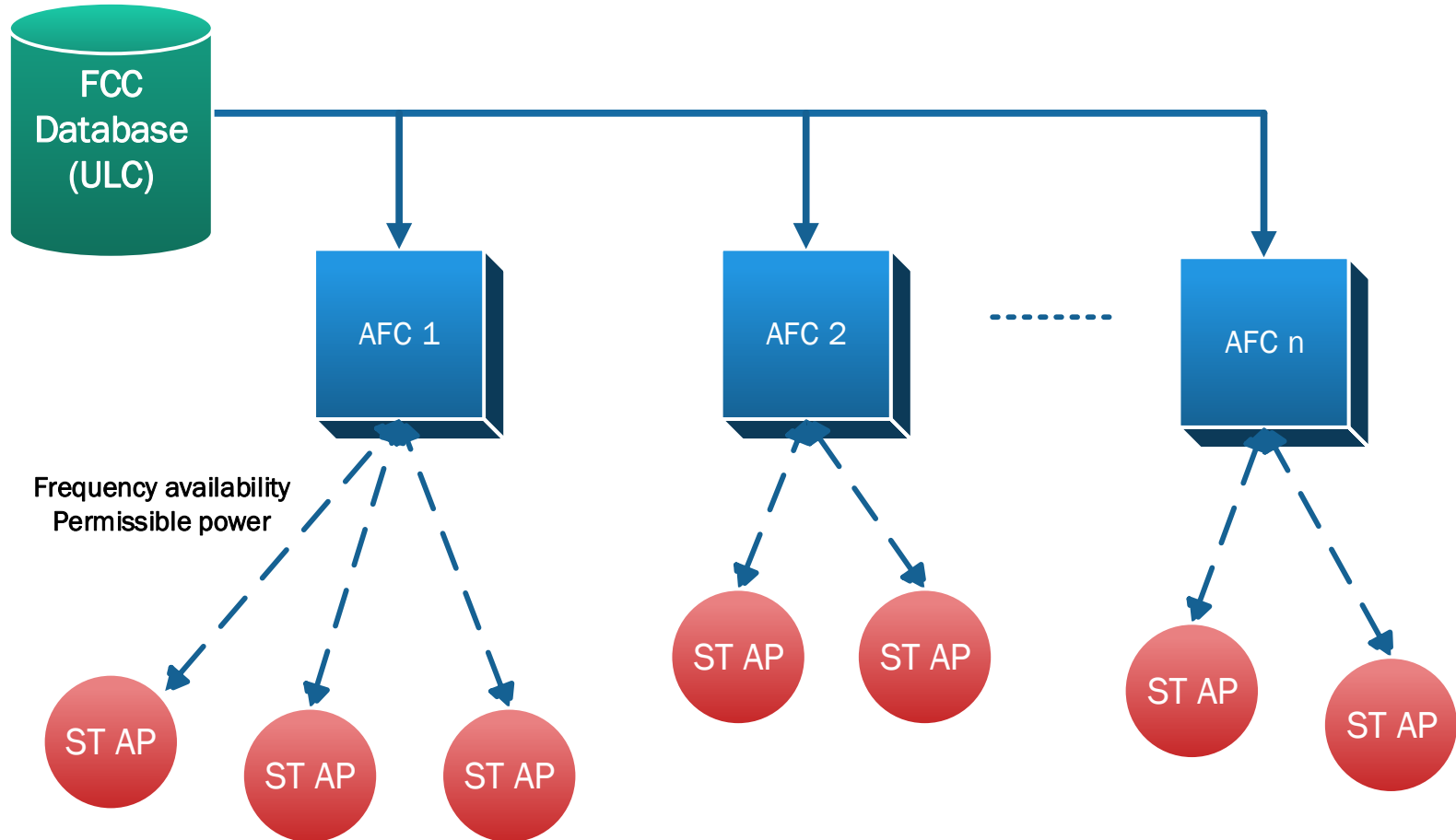
- The main objective of AFC system is to protect fixed service MW links and prevent any potential harmful interference in UNII-5 and UNII-7.
- The use of an automated system to control access to spectrum is not new. FCC has used similar approaches previously to:
 - Protect TV reception from unlicensed white space devices in the TV bands.
 - Protect satellite earth stations and government radars from devices of the CBRS (3550-3700 MHz)
- Commenters acknowledge that a properly designed AFC system in the UNII-5 and UNII-7 bands will protect incumbent operations⁴.
- The AFC will consist of several components:
 - The framework design and AFC operations
 - The operational requirements regarding Standard Power Aps (e.g. geolocation capabilities, Antenna-related restrictions)
 - The interference protection parameters that protect the incumbent fixed service operations



AFC System Framework and Database

- FCC sought comments on two approaches:
 - **Centralized:** all data and computations are performed in a central location.
 - Several commenters from the MW community preferred this approach⁵ due to its simplicity, consistency and uniformity.
 - Consisted with CBRS and TVWS approach.
 - **Decentralized:** the Standard APs maintain a local DB and performs the necessary computations.
- AFC system would use data from ULS (official licensing DB for MW links in UNII-5/UNII-7) to determine the location of incumbent users to establish the protective or exclusion zone.
 - Licensees have the responsibility to keep and maintain the accuracy of data in ULC.
 - AFCs will download DBs from ULS daily and is supposed to protect even pending applications (MW link pending license and not operational yet).
- AFC to protect operations in Canada and Mexico by obtaining information about their MW systems.
- AFC to provide frequency availability at max EIRP (36 dBm) as well as available frequencies at lower power levels (down to 21 dBm; in steps of 3 dB).
 - Lower power → smaller distance of separation → more spectrum.
 - Useful where high congestion of fixed MW services.

AFC Possible Functional Architecture



Operational Requirements for Standard Power APs

- AFC requires
 - Standard Power AP's geographic coordinates
 - Incorporated geo-location capability, such as GPS.
 - If no GPS signal, alternatives are left to manufacturers, such as external geo-location source (wireless or wired).
 - Antenna height (AGL).
 - Manually: The device installer to provide the AGL height
 - Automatically: Once this technology is available.
- Standard Power APs to contact an AFC at least once a day to obtain the latest list of available frequencies at its location (same as ULC update interval).
- **Notes:**
 - Multiple AFCs will be designated.
 - Multiple entities can split functions of AFC among themselves, such as data repository, registration, query services, etc. → reduces cost per entity.
 - AFC serves for a 5-year term. Renewed based on performance.
 - AFC will act as an autonomous system. No need for AFC to AFC sync since all data comes from ULS.



Interference Protection Analysis

- The following are the technical parameters that the AFC will use to calculate the exclusion zones:
 - **Propagation models**
 - Free Space Model for short distances ($d < 30$ meters): Not realistic
 - WINNER II (Wireless World Initiative New Radio phase II) for medium distances ($30\text{m} < d < 100\text{m}$) LOS and NLOS; suited for urban, suburban, and rural environments⁶.
 - Based on popularity in the world⁷, academic literature⁸, and commenters⁹.
 - Irregular Terrain Model (ITM) for longer distances to account for terrain and clutter. ($1\text{ Km} < d < 2000\text{ KM}$), proven reliable in SAS to manage CBRS¹⁰.
 - ITM + ITU-R. P.2108 (clutter model) for urban and suburban environments.
 - ITM + ITU-R. P452-16 (clutter model) for rural environments.
 - Interference Protection Criterion
 - $I/N = -6$ dB metric is used, where I is the interference from unlicensed devices.
 - Supported by various MW incumbents¹¹.
 - AFC will not consider aggregate interference; the closest unlicensed device always dominate.
 - AFC should provide in addition to the co-channel exclusion zone, an adjacent channel exclusion zone.



Co-Channel Probabilities for Different Channel Bandwidths

Channel Bandwidth	# of Channels in 6 GHz	# of Channels in 2.4 GHz, U-NII 1 and U-NII 3	Total # of Available Channels	Pr (Co-channel in 6 GHz band)
160 MHz	7	0	7	14.29%
80 MHz	14	2	16	6.25%
40 MHz	29	5	34	2.94%
20 MHz	59	12	71	2.82%

$Pr = [\text{Co-Channel} / \text{Total \# of Channels}]$; assuming MW BW= 30MHz

$$Pr_{80\text{MHz}} = 1/16 = 6.25\%$$

$$Pr_{20\text{MHz}} = 2/71 = 2.82\%$$



Other AFC Considerations

- **Security:**
 - Protecting stored data in AFC's database
 - Protecting communications between AFC and standard-power Aps, directly or indirectly through a proxy server (wired or wireless outside UNII-5/UNII-7 bands).
 - Safeguarding recommendations by AFC to ensure the standard-power AP will use AFC frequency/power recommendations.
- The Commission does not mandate any particular security protocol. It is left to MSG and AFCs to implement robust security protocols and will be subjected to the Commission's review and approval during the AFC system certification process.
- Some requirements:
 - Unlicensed device must authenticate and register with AFC.
 - FCC ID
 - Serial number



Low Power Indoor Access Points (LPI)

- Not AFC Controlled: studies show no harmful interference imposed on incumbent services.
- Permissible across the whole 6 GHz band
- 3 restrictions are employed by the Commission for LPIs:
 - Limited to Indoor operation ONLY
 - Median signal loss from a traditionally constructed bldg. is 17dB.
 - This loss is sufficient to protect nearby incumbent users from potentially harmful interferences.
 - Required to use a contention-based protocol, like “listen before talk”, such as CSMA/CA.
 - This protocol gives an extra layer of protection since the AP/user can’t transmit if channel/frequency is busy.
 - Low power operations AP: Max EIRP is 30 dBm/320 MHz (5 dBm/MHz).
 - Unlicensed client devices EIRP is limited to 6dB below the LPI device → this make sure that the unlicensed client device remains in close proximity to the AP; 24 dBm/320 MHz (-1 dBm/MHz)



Multi-Stakeholder Group (MSG)

- MSGs have been successful in the past in providing the Commission with valuable insights and information regarding new spectrum uses in shared bands.
- MSG addressing issues concerning both Standard Power APs & LPI in the 6 GHz band could provide valuable insights into complex coexistence issues and provide a forum for the industry to work cooperatively towards efficient technical and operational solutions.
- MSG will be a new group focuses solely on issues relevant to 6 GHz (i.e. not an extension of any other MSG).
- The Commission invites stakeholders from all sectors of the 6 GHz to participate: WSPs, RLANs/APs network equipment manufacturers, potential AFC operators, existing MW 6 GHz incumbent licensees, academic experts, and so on.



Multi-Stakeholder Group (MSG)-Cont'd

- MSG is encouraged to address any issue deemed appropriate, such as interference detection and mitigation in the event that an incumbent licensee experiences harmful interference, whether it is from Standard-power or LPI APs.
 - Procedures: What procedure or process can be followed if an incumbent licensee has an interference complaint?
 - A process should be created which can effectively address and resolve interference claims w/o the involvement of the Commission's Enforcement Bureau (CEB).
 - Goal: Because a widespread availability of 6 GHz unlicensed devices is not expected immediately, the MSG if conducting tests related to developing procedures and processes regarding interference detection and mitigation, is expected to set a goal of implementing any agreed upon device related features before unlicensed 6 GHz devices reach consumers.
 - AFC: AFC system development for Standard-power APs. Tasks could include:
 - How to implement the propagation models?
 - What communication protocols between AFC and Standard-Power APs.
 - AFC system testing and certification procedures
 - Including complete and up-to-date incumbent data.
 - Best practices: MSG to develop best practices and standards concerning standard-power APs and LPIs that will benefit all users of the 6 GHz, both incumbents who are seeking additional protection and the unlicensed users who seek to utilize the 6GHz band.
 - Such as device and communication link security.



Conclusion

- Unlicensed 6 GHz is here to stay.
- ONLY Standard-power APs are to be controlled by the AFC system.
- LPI APs are deemed not to pose any harmful interference on the incumbent licensees.
- The probability of a co-channel for an unlicensed device with an incumbent user is between %3 to %14.
- Similar methodology was followed CBRs/SAs and TVWS with no problems reported so far; Hence, there is high confidence in the system presented.
- MSG was formed in 2019 and BV is a member in the group.
 - Discussions are currently undergoing in regards to interference analysis between the stakeholders.



References

1. Ericsson, *Ericsson Mobility Report* at 17 (June 2019).
2. *Cisco VNI* at 17.
3. To avoid interference to FS receivers in the 6 GHz band, the I/N threshold should not exceed -6 dB. See, e.g., *In the Matter of Higher Ground LLC Application for Blanket Earth Station License*, Order and Authorization, 32 FCC Rcd. 728, ¶ 16 (2017).
4. Fixed Wireless Communications Coalition Comments at 13; APCO Comments at 2; National Spectrum Managers Association Comments at 32 (arguing that all UNII-5 and UNII-7 operation must be under the control of an AFC); AT&T Reply at 15-19.
5. Cambien Networks Comments at 5 (arguing that a centralized location can easily be updated any time a new device is to be included in the protective services list, or if a device is no longer using resources.); MidContinent Comments at 14; Sony Comments at 3 (contending that a centralized model will minimize the cost, complexity, and resource demands of access points and client devices, thereby encouraging market adoption); Northeast Colorado Cellular Comments at 2; NPSTC Comments at 10 (pointing out that, if the AFC is centralized, the algorithms and protocols can be updated as needed rather easily, as compared to updating every deployed access point and associated client device); City of Austin Comments at 2; City of New York Comments at 3; El Paso Electric Comments at 3 (“any registration requirement should include a centralized AFC system operated by a single organization for the sake of consistency and uniformity”); Idaho Power Comments at 6; Ultra-Wideband Alliance Comments at 8.
6. The urban, suburban, and rural WINNER II channel models are referred to as C2, C1, and D1, respectively. WINNER II Channel Models Part 1, at Table 2-1 (propagation scenarios) and Table 4-4 (path loss models). <https://www.cept.org/files/8339/winner2%20-%20final%20report.pdf>



References

7. Patrick Marsch et al., “5G System Design: Architectural and Functional Considerations and Long-Term Research”, 2018, at 57.
8. Martin Döttling et al, “Radio Technologies and Concepts for IMT-Advanced,” 2010, at 75.
9. Broadcom Comments at 16 (proposed model uses the WINNER II model to assess interference levels under real-world conditions); RKF engineering Solutions Reply Comments at 5 (its study used WINNER II propagation model for RLANs in Urban and Suburban environments up to 1 KM away from the FS receiver and that “the WINNER II model is based on a large set of measurements that capture the variability of the different morphologies, and in doing so, takes into account location and structure variability for Urban and Suburban areas”).
10. *Requirements for Commercial Operation in the U.S. 3550-3700 MHz Citizens Broadband Radio Service Band*, Wireless Innovation Forum, Document WINNF-TS-0112, at 11 (June 25, 2019), <https://winnf.memberclicks.net/assets/CBRS/WINNF-TS-0122.pdf>
11. Fixed Wireless Communications Coalition Comments at 17, 22; Utilities Technology Council et al. Comments at 15.

