Recommendations to the Federal Communications Commission Based on Lessons Learned from CBRS

FCC Technological Advisory Council

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Introduction

For the purpose of this document, centralized spectrum management means a system in which access to spectrum resources by a particular device is managed by a centralized automated entity. The U.S. has deployed, or is in the process of deploying, three centralized shared spectrum systems:

1. TV Whitespace (TVWS) Database
2. Citizens Broadband Radio Service (CBRS) Spectrum Access System (SAS)
3. 6 GHz Automated Frequency Coordination (AFC) System

For various regulatory and commercial reasons, TVWS deployments have not been extensive. This is widely attributed to the time and uncertainty related to the amount of available spectrum for TVWS services subsequent to the television band incentive auction, which resulted in the lack of committed business interests that could guarantee the availability of commercial products that could be deployed at scale. Meanwhile, 6 GHz AFC is still under development as of this writing. The most extensive experience with centralized shared spectrum (perhaps worldwide) is therefore through the U.S. experience with CBRS, and our recommendations in this document are borne mostly through the CBRS experience.

An introduction to CBRS is beyond the scope of this document. The Wireless Innovation Forum and the OnGo Alliance have numerous resources that provide CBRS information, and the reader is referred to those resources.[1],[2] As of this writing, there are approximately 270,000 CBRS base stations[3] (called Citizens Broadband radio Service Devices, or CBSDs) under

[1] https://cbrs.wirelessinnovation.org/standards

[2] OnGo Alliance, "CBRS and OnGo for Dummies," available at https://ongoalliance.org/resource/cbrs-ongo-for-dummies/

[3] C.f. https://ongoalliance.org/mwc-las-vegas-2022-looking-back-looking-forward/

management by a total of six FCC-approved SASs. Most of those devices operate in areas that are shared with incumbent operations (notably military radars, plus a few non-government fixed-satellite service receive-only earth stations). Those 270,000 devices are operating under Priority Access License (PAL) and/or General Authorized Access (GAA) authorizations. Therefore, industry has accumulated extensive experience with sharing spectrum under the centralized CBRS framework, including protection of incumbents as well as coexistence within and between PAL and GAA tiers.

On the basis of the CBRS experience, the TAC Advanced Spectrum Sharing Working Group has hosted discussions on the topic of lessons learned about centralized spectrum sharing. The consensus is that centralized spectrum sharing in CBRS has been effectively demonstrated, but enhancements to the CBRS framework would improve the utility of spectrum in future shared bands. The purpose of the working group's discussion was to identify possible technical recommendations to be made to the FCC regarding the design and implementation of future such frameworks. This document summarizes those recommendations so identified. The recommendations are in no particular order.

2. Recommendations Background

1. Centralized spectrum management systems should be able to be certified quickly and efficiently and be able to evolve to take advantage of the latest technological advances.

    a. Despite nearly three years of commercial operation, there has been no reported interference from CBRS into protected incumbents in the band. A large number of conservative assumptions are built into the CBRS protection framework (such as propagation parameters, interference protection criteria, etc.), to the extent that optimal shared spectrum efficiency may not have yet been achieved. Propagation models used in spectrum sharing, notably the Irregular Terrain Model (ITM), do not take into account attenuation due to clutter such as buildings and foliage, hence the propagation loss is often underestimated,[4] and predicted interference levels are overestimated. The government (for example, NTIA and

[4] C.f. Clegg, Andrew, "Propagation in the 3.5 GHz CBRS Band," WInnComm 2019, available at https://winnf.memberclicks.net/assets/Proceedings/2019/TS1.3%20Clegg%20updated.pdf

ITS) and other researchers are embarking upon developing new and improved models.[5]

b. Centralized spectrum management systems should be able to evolve. A complicating factor is that, in the case of CBRS, the certification process for testing SASs prior to approval for commercial service was onerous and time-consuming, taking over one year to complete the tests. The processes for recertification of changes does not promise to be any different. Such a burden should not be required in the future when spectrum sharing systems wish to incorporate changes, e.g., improved propagation models.

c. It is recommended that the FCC utilize an effective and time-efficient method for certifying and then re-certifying centralized spectrum management systems as they incorporate system enhancements, including better propagation models and other technical improvements, to improve sharing efficiency.

2. An alternative to the use of interference based on aggregate interference should be explored.

   a. In a sharing environment in which multiple centralized spectrum management systems are available, and each manages spectrum access for a subset of devices in the band, the methodology to predict interference on the aggregate of signals from all devices requires that all competing spectrum management systems share all interference-related information with each other. Besides the competitive disadvantage of having to share proprietary information with one another, exchanging data substantially slows the process of assigning spectrum. For example, CBRS SASs exchange hundreds of megabytes of data each evening. After receiving this data, each SAS goes through a complicated process of computing aggregate interference, with each calculation involving large numbers of devices propagating to large numbers of reference points, representing millions of path loss calculations. Aggregate interference calculations can therefore take substantial compute resources and time to complete. A device that requests spectrum during the day in many cases cannot

[5] NTIA ITS will be providing a session at an upcoming Wireless Innovation Forum conference covering their latest work on propagation measurement and prediction for spectrum sharing (see https://conference.wirelessinnovation.org/winncomm-2022-virtual-program)

be offered a final determination of spectrum availability until this process (data exchange and computation) has played out, which can take 24 hours or more.

b. It is recommended to explore simplifying the manner in which aggregate interference is taken into account for interference protection. For example, can multiple exposure factors based on average deployment density be used instead?

3. Detecting incumbent activity solely by the use of dedicated sensors should be avoided.

    a. In CBRS, most incumbent military radar activity is detected and notified to a SAS by the use of a network of dedicated coastal sensors, called an Environmental Sensing Capability (ESC). Based on over two years' of operation of ESC networks, the CBRS community has determined that while ESCs are capable of detecting incumbent activity, they have the substantial downside of negatively impacting CBRS use in areas within up to 80 km from the sensors. This is due to meeting NTIA's imposed interference limits on the sensors so that they can "hear" radar out to potentially several hundred kilometers. This constraint limits where CBRS can be deployed and has been shown to impact as many as 15,000,000 potential CBRS customers, despite network optimizations. And new ESC networks are being deployed, which increases the total impact. The basic issue is that in-band sensing creates in-band interference constraints, limiting the use of the very band that the sensors are designed to enable.

    b. Therefore, it is recommended that dedicated sensing networks similar to ESC to protect incumbents as the sole enabler of shared spectrum be avoided.

    c. Other options should be explored including Informing Incumbent Capability (IIC), a limited version of which has been deployed by DoD in the CBRS band, as the TARDyS3 project.[6] To address potential security concerns, the working group notes that in IIC-type of systems the federal user and NTIA could agree on intentional random errors that are added to locations of users whose security must be protected so that reverse engineering of approved spectrum use does not compromise locations. ESC systems and IIC might operate in a

[6] https://sam.gov/opp/2f00353d714a4e63bdf17a2ff799c7dc/view

complementary manner initially, to ensure that incumbent usage claims can be validated and proper application of IIC can be confirmed.

4. The Commission's license databases are often not suitable for many shared spectrum applications.

   a. The ULS and other Commission licensing databases serve as regulatory databases, keeping track of which licensee holds which licenses. Although the databases contain technical data for many licenses, experience has shown that the quality of the data that are provided by the licensee is sometimes poor, or completely missing, and cannot always be relied upon for interference calculations. In some cases, data elements that are needed to compute interference are not collected. Further, the data are often not kept up-to-date by the licensees. For example, despite the requirement that FSS earth stations must register once per year to receive protection from CBRS,[7] most do not. The experience of centralized spectrum management system operators has been that requesting changes to Commission databases results in the realization that such changes, if possible, will take a very long time to implement, potentially one or more years.

   b. It is recommended that the FCC undertake a study of modernizing its licensing databases, and making them more agile so as to more quickly respond to changing needs.

5. The Commission should set clear expectations regarding coexistence among peer users

   a. In the CBRS framework, no defined coexistence rules exist among the lowest (GAA) tier. While industry has attempted to create GAA coexistence guidelines, it has largely been unsuccessful due to the diversity of use cases that are deployed in CBRS. SASs have no authority to apportion spectrum between GAA users so that interference between networks can be controlled; such authority would constitute implicit ownership of an exclusive license. Indeed, the determination of interference to a network cannot be determined objectively short of a

[7] 47 CFR 96.17(d)

recognition of one network degrading the other's ability to communicate effectively, nominally defined as harmful interference.

b. It is recommended that the FCC should set expectations clearly for all parties when it comes to shared spectrum, especially as it relates to secondary coexistence.

6. Potential new users of shared bands should be aware of the constraints imposed by sharing

   a. The CBRS PAL auction netted over $4.5 billion in revenue among more than 200 winning bidders. Even so, SAS Administrators were surprised to discover that some winning bidders seemed to have a poor understanding of the nature of shared use, such as the geographic and time extent of disruptions to operations caused by the need to protect incumbents. While the industry provided extensive information on CBRS encumbrances,[8] the Commission itself did not reference such information in their releases and did not itself issue any comprehensive releases dedicated to encumbrances.

   b. It is recommended that in future shared spectrum bands, the Commission proactively publish or reference dedicated information with respect to band encumbrances and the possible impact to shared users of the band, prior to auction.

7. Virtualized/disaggregated radio technology should be accommodated.

   a. In CBRS, base stations and user devices must have a valid FCC ID to be authorized for spectrum access. In the standard model of certification in which a hardware model consists of a specific piece of equipment run by specific firmware/software, such certification is unambiguous. But as technology moves to greater use of virtualization, in which an instance of a base station or user device could be an amalgamation of various hardware and software components (with some software even being cloud-based instead of native to the hardware)

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[8] Wireless Innovation Forum, *CBRS Incumbent Protections and Encumbrances Overview*, https://winnf.memberclicks.net/assets/CBRS/WINNF-TR-5003.pdf

which can be combined in a multitude of different combinations, the concept of "one device model, one FCC ID" breaks down.

b. Because innovation in both virtualized hardware and cloud-based spectrum sharing are desired, it is recommended that the FCC consider how system virtualization impacts future shared spectrum frameworks, and whether modifications to the standard hardware certification process are needed.

8. Better foresight of adjacent band situations is needed.

   a. When CBRS was first introduced, DoD used the immediately adjacent band below it for the same type of radar operations as within the CBRS band itself, and the band immediately above CBRS was used by receive-only fixed-satellite earth stations. Within a short period of time, both adjacent bands were authorized for use by high-power flexible use deployments at power levels nearly 1000 times greater than CBRS, creating concerns over coexistence among neighboring services at the band edges. The impact to the ESC networks at the lower boundary is particularly concerning. Although in proceedings for both the lower and upper adjacent services the CBRS community brought out concerns, there were no substantive rules or action taken by the Commission to help ensure coexistence. Such potentially adverse developments are concerning for the long-term stability of a band (and not just for CBRS or for shared spectrum bands generally). There are limited methods that industry can use to mitigate adjacent band co-existence issues. For example, if the adjacent band systems are time division duplex (TDD) and based on the same air interface technology, they can use TDD synchronization to reduce interference in some cases. However, there are limits to such solutions if the use cases across the band edges use different uplink/downlink weighting.

   b. It is recommended that the FCC consider more concrete steps to facilitate coexistence at band edges when rule changes are made that can negatively impact one or more existing services.

9. Regulatory certainty is important to the success of shared spectrum.

   a. In TVWS, the TV spectrum environment was changing rapidly due to the digital TV transition and the incentive auction. The amount of TV spectrum (or more specifically, white space within that spectrum) that would ultimately be available was far from certain. Development of the TVWS device ecosystem was stunted as a result. This was one of the reasons for the lack of significant uptake of TVWS technology.

b. Regulatory spectrum certainty is important to all stakeholders in the industry. A formal long-term spectrum plan for both the FCC and NTIA would greatly benefit providers, vendors, and incumbents. While any plan would continually evolve over time it would provide the industry an opportunity to innovate in support, encourage technology upgrades and provide planning for providers to support additional services.
c. It is recommended that the FCC consider the extent to which regulatory certainty can be provided for the future status of a potentially shared spectrum band (for example, by creating a long-term spectrum plan coordinated with NTIA) before the sharing framework is proposed and implemented.

3. Summary of Recommendations

The TAC recommends that the FCC:

1. Utilize an effective and time-efficient method for certifying and then re-certifying centralized spectrum management systems as they incorporate system enhancements, including better propagation models and other technical improvements, to improve sharing efficiency.

2. Explore simplifying the manner in which aggregate interference is taken into account for interference protection.

3. Avoid the required use of dedicated sensing networks similar to ESC as the sole enabler of shared spectrum. Consider other options such as IIC.

4. Undertake a study of modernizing the Commission’s licensing databases, and making them more agile so as to more quickly respond to changing needs.

5. Set expectations clearly for all parties when it comes to shared spectrum, especially as it relates to secondary coexistence.

6. Proactively publish or reference dedicated information with respect to band encumbrances (both in-band and adjacent bands) and the possible impact to shared users of the band, prior to auction.

7. Consider how system virtualization impacts future shared spectrum frameworks, and whether modifications to the standard hardware certification process are needed.

8. Consider more concrete steps to facilitate coexistence at band edges when rule changes are made that can negatively impact one or more existing services.

9. Consider the extent to which regulatory certainty can be provided for the future status of a potentially shared spectrum band (for example, by establishing a long-term spectrum plan coordinated with NTIA) before the sharing framework is proposed and implemented.

4. Thoughts on Improvements to Future Spectrum Management Systems Based on Lessons Learned from CBRS (for Future Study)

1. **Improving Dynamic Operation.** Dynamic operation of the Spectrum Management System can serve to increase the efficiency of spectrum usage by optimizing the frequency assignments as conditions change. As discussed below, changing propagation and the needs and locations of the users can be accommodated quickly to prevent the situations that may lead to interference while maximizing spectral efficiency. Additionally, if interference feedback is provided, a fast-acting Spectrum Management System will be able to quickly alleviate the problem.

2. **The Application of Actual Propagation Data to Improve the Assignments.** Maximum allowed emitted power levels are currently set to ensure that interference with incumbents does not occur under the longest propagation distances that are expected, even if this worst case is short lived and a rare occurrence. Varying maximum emitted power levels with actual propagation can serve two purposes. It would allow each user to compensate for varying propagation by modifying transmit power and could increase the efficient use of spectrum while still avoiding interference. Propagation could be

dynamically estimated with various tools, including monitoring fixed beacon transmitters and AI/ML tools that are based on the conditions affecting propagation in order to estimate transmission distances.

3. **Consideration of the User's Transmitter and Receiver Locations and Characteristics of their Receivers (such as Adjacent Channel Rejection Envelopes).** In lieu of receiver susceptibility standards, the Spectrum Management System may be capable of avoiding adjacent channel interference by maintaining and using a database of each user's receiver characteristics and the locations of all transmitters and receivers that the users operate. Although a dynamic complex analysis will be required, the Spectrum Management System would be capable of assigning frequencies such that transmitters on one channel are never physically close enough to receivers on the adjacent channels to cause interference based on the particular receiver's adjacent channel rejection envelope.

   Each user's information must be kept confidential, known only to the Spectrum Manager and used only to improve interference avoidance. If a user refuses to provide detailed information about either equipment locations or performance specifications because of competitive considerations, that user can still be assigned frequency channels but must be forewarned that they would not be afforded the same interference protections as they could have if that information was made available.

4. **The Use of Interference Feedback from Incumbents and Already-Assigned Users.** In a dynamic Spectrum Management System, accepting interference reports from already assigned users would provide valuable feedback to determine if the frequency and power level assignment techniques discussed above are adequate. The timing is important, since an interference report that occurs soon after the start of operation of another user could indicate a miscalculation in the choice of frequency and power level assigned to the latest user. It could also indicate an erroneous estimation of propagation distances. The feedback is invaluable in improving the frequency management model. Additionally, in the short term, the reception of interference reports allows the Spectrum

Management System to recalculate potential interference scenarios and reassign the channel of the suspected interferer to quickly alleviate the problem.