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The 3.5 GHz Citizens Broadband Radio Service (CBRS)

An Enhanced Wireless Opportunity For The Cable Industry

A Technical Paper prepared for SCTE/ISBE by

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Introduction to Coordinated Shared Spectrum

Due to the increasing demand for additional mobile broadband capacity, policymakers and regulators face a daunting task in identifying and allocating the foundational spectrum resources. The traditional methods – assigning unused bands (which are non-existent in the desirable sub-6GHz range) or clearing previously assigned bands and then reallocating for either licensed or unlicensed use – are not sufficient to meet all of the demands going forward. Because of these realities, and enabled by relatively recent technological advances, new management regimes are emerging that allow dynamic sharing of spectrum with centralized coordination via geo-location databases with propagation information.

Unlike traditional licensed approaches, which dedicated spectrum to a single licensee for a given area, or unlicensed approaches, which offered no differentiation among users, the central coordination of these new approaches allows for:

- The expansion of previously allocated bands to include additional shared use where and when the incumbents are not using the spectrum, while providing necessary protections to those incumbents.

- The ability to prioritize the shared access to the band, typically giving the incumbents first claim while new shared-access users are able to utilize the spectrum on an 'as available' basis. [Note that there can also be prioritization within the shared-access portion of the band, as indeed is the case with the system described in this paper].

Two leading examples of these Coordinated Shared Spectrum (CSS) approaches are *Licensed Shared Access (LSA)* in Europe and the *Citizens Broadband Radio Service (CBRS)* in the United States. This paper will examine CBRS in more detail, and address the opportunities it presents to the cable industry.

Overview of CBRS

1. Background and FCC Actions

In July 2012, the President's Council of Advisors on Science and Technology (PCAST) submitted a report to President Obama recommending that coordinated spectrum sharing should become a primary regime for Federal policymakers and regulators. Some of the main points of the PCAST report included:

- Limitations of existing spectrum allocation techniques, including the extended time required to clear previously assigned bands for new commercial use.
- Challenges of meeting the continued demands for additional spectrum within the historical framework.
- The 'lightly used' nature (either in terms of location, frequency range, or time) of many spectrum bands that had previously been assigned for government uses.
- Recent technological advances that have made centralized coordination of shared spectrum access possible.

In June 2013, President Obama issued a Memorandum ("Expanding America's Leadership in Wireless Innovation") which strongly supported the spectrum sharing position PCAST had taken and directed the Secretary of Commerce and the National Telecommunications and Information Administration (NTIA) to work with the Federal Communications Commission (FCC) to identify bands occupied by Federal incumbents that could be opened to dynamic shared use by commercial entities. Since this time, the FCC - working in conjunction with NTIA, the Department of Defense (DoD), and other Federal agencies – has identified a few bands where spectrum sharing may be possible.

On April 17, 2015 the FCC issued a Report and Order (R&O) detailing a new Citizens Broadband Radio Service (CBRS) in the 3550-3700 MHz band. The R&O provided a framework within which incumbent users (including the DoD, Satellite Ground Stations, and Fixed Wireless Internet Service Providers) would continue to operate, but would share the band with new commercial entrants who could utilize the band on a shared-access basis. Shared-access would be available in 2 forms:

- Priority Access Licenses (PALs) will provide priority shared access to a certain amount of bandwidth at the geographic level of a census tract. PALs will be granted for terms of 3 years. They will only be granted in the 3550-3650 MHz range, the maximum amount of the 3550-3650 MHz range that may be allocated for PAL operation is 70 MHz in any one census tract, and there are limits on how much spectrum a single licensee can hold via PAL (40 MHz), as well as requirements for competitive bids to ensure a single entity doesn't monopolize the spectrum via the PAL. PAL operation is subject to preemption and frequency reassignment in the event that an incumbent begins operating on a frequency that has been assigned to a PAL user. This is why the PAL license is for a certain amount of bandwidth, but doesn't stipulate a static frequency range since that may change from time to time.
- General Authorized Access (GAA) is somewhat analogous to traditional unlicensed spectrum in that anyone may request use of CBRS spectrum at a given location on an opportunistic basis. The

entire 3550-3700 range may be granted for GAA operation. GAA operation is subject to preemption and/or frequency reassignment from both incumbents as well as PAL users. Additionally, the R&O does not provide protections between multiple GAA users who may be operating in the same location.

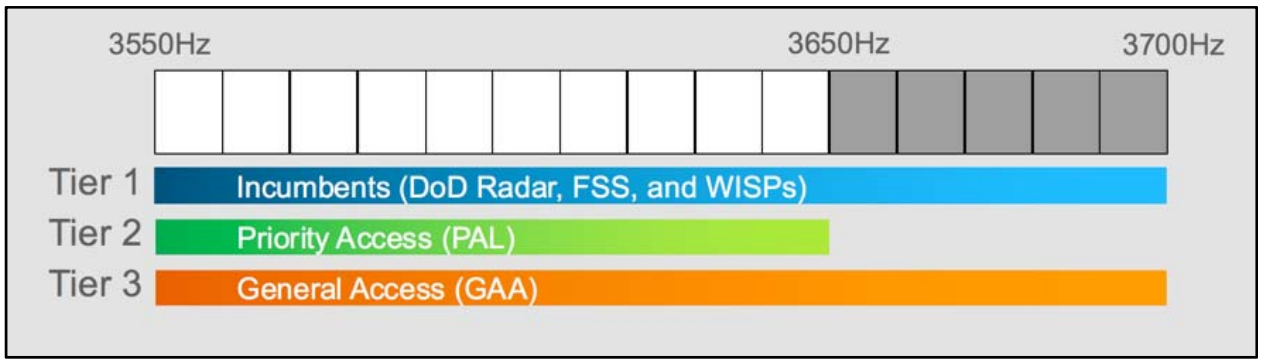

Figure 1 – The CBRS 3-Tiered Spectrum Sharing Framework

On April 28, 2016 the FCC issued a Reconsideration and 2nd R&O for CBRS. This reflected follow-up items that were not decided in the first Order, and the Commission's decisions on questions and issues that various industry participants had raised after the initial R&O was issued. The issuance of the 2nd R&O signifies the bulk of the formal guidance that is expected.

[Note that as with other FCC guidance regarding operation in licensed and unlicensed bands, the CBRS R&O does not specify any air interface technology(ies) that may be implemented in the band, but simply lays out the requirements around shared-access and protections for both the incumbent and PAL users].

2. CBRS Functional Components

Because it introduces dynamic coordination and allocation of spectrum, and also due to the preemption requirements, CBRS introduces a number of new functional components beyond the Radio Access Network (RAN) and Core levels.

2.1. Spectrum Access Systems

A Spectrum Access System (SAS) provides the centralized coordination that enables the CBRS 3-Tier sharing framework. A SAS models the CBRS spectrum for a given area in near real-time using the geo-location information and operating parameters (e.g. frequency and power level) of radio nodes as inputs to propagation models that can accurately assess potential interference to other users. Before a radio node can begin transmitting in the CBRS band, it must first perform the following (simplified) functions:

- Register with a SAS (indicating its location, among other parameters)
- Request a spectrum grant from the SAS (indicating desired frequency range, requesting either PAL {if licensed for PAL} or GAA operation, and desired power level)
- Receive a spectrum grant from the SAS (indicating the frequency range and operating power limit)

If the RF environment for an area changes after radio nodes have been authorized for operation, especially in the event of detection of incumbent activity, the SAS can inform the radio node that it needs to either modify its operation (e.g. switch to an alternate frequency) or cease transmitting.

The FCC expects that multiple entities will provide SAS services to the CBRS ecosystem. Therefore these various SASs will also need to communicate amongst themselves in order to ensure that they each have an accurate understanding of the overall environment.

2.2. Environmental Sensing Capability

The DoD incumbent usage in 3550-3650 MHz is by shipborne radar systems. In order to ensure that the operation of these radars is protected from interference by other users, an Environmental Sensing Capability (ESC) is being developed and deployed along the coasts. ESC sensors will detect when incumbent operation occurs in their area and inform the SASs so that any potentially interfering PAL or GAA users can be reassigned to other frequencies.

Due to the operational security requirements around DoD operations and movement, the specific data on incumbents is generalized or obfuscated.

2.3. Radio Base Stations

In CBRS, the radio nodes are referred to as Citizens Broadband Radio Service Devices (CBSDs). As noted previously, CBSDs must communicate with a SAS prior to commencing operation in the CBRS band. Additionally, they must maintain connectivity with the SAS via a heartbeat mechanism in order to continue operation. If a CBSD loses connectivity with its registered SAS, it must cease operation. This reflects a “fail off” or “fail safe” philosophy that ensures incumbent protection in all circumstances.

While individual CBSDs may operate independently and communicate directly to a SAS, CBSDs are likely to be deployed in large managed networks in the same way that Long Term Evolution (LTE) eNodeBs or Wi-Fi Access Points are deployed in carrier networks. In these larger scale networks, the communications between the CBSDs and the SAS may be aggregated via a function that is called the Domain Proxy. This Domain Proxy capability can be implemented as part of a Network Management System / Element Management System (NMS / EMS) or as a separate instantiation.

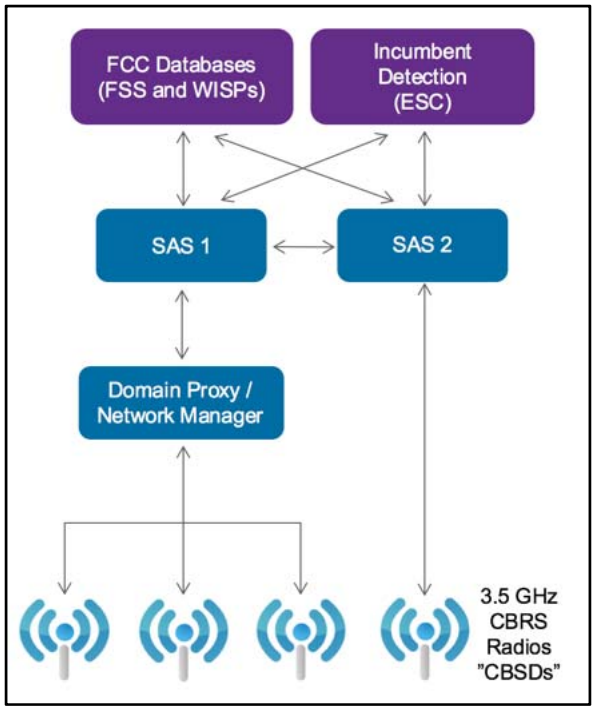

Figure 2 – CBRS Functional Components

3. The Role of The Wireless Innovation Forum

The Wireless Innovation Forum (WInnForum) is a multi-stakeholder organization involved in various advanced wireless and spectrum initiatives. The Spectrum Sharing Committee of WInnForum has undertaken the work of developing the architecture, requirements, protocols, and test methodology necessary to deploy CBRS solutions based on the framework as laid out by the FCC. The work has largely been divided into the following areas:

- Operational and Functional Requirements (Working Group 1)
- Security Requirements (Working Group 2)
- Protocol Interface Specifications (Working Group 3)
- Testing and Certification (Working Group 4)

4. The Role of the CBRS Alliance

The CBRS Alliance was announced in July 2016 and is focused on enabling LTE-based solutions for the CBRS band. Unlike the WInnForum, the CBRS Alliance is not primarily a specification development body but is instead looking to integrate and extend the work being done in various other organizations (including WInnForum) so that all of the specific requirements for LTE operation in CBRS are addressed. The CBRS Alliance also has a marketing function to promote solutions and technologies to the broader market and an effort to ensure interoperability around WInnForum specifications.

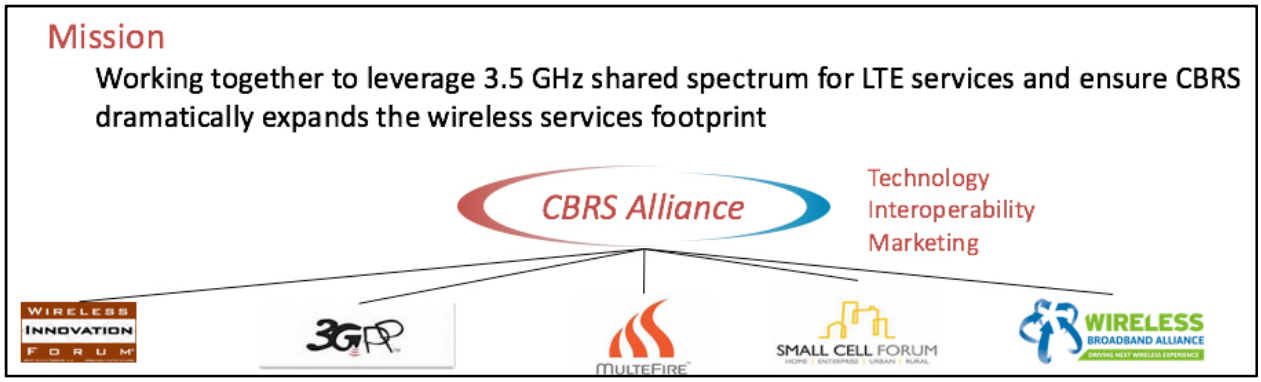

Figure 3 – The CBRS Alliance

5. CBRS as an Optimum Small Cell Band

Due to the propagation characteristics of wavelengths in the mid 3GHz range and the relatively low maximum transmit powers that the FCC has mandated for CBRS (30 dBm EIRP Indoors and 47 dBm EIRP Outdoors, both measured over 10 MHz), the band is considered optimal for small cell deployments.

6. Challenges with In-Building Cellular Coverage

There are no good options available today to provide in-building cellular coverage to the vast majority of commercial properties and public venues.

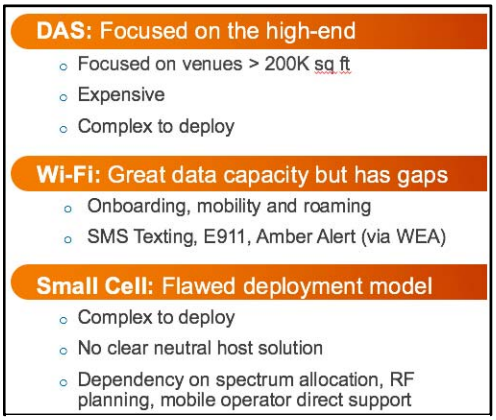

Figure 4 – Challenges with In-Building Cellular Coverage

Distributed Antenna Solutions (DAS) are extremely expensive and time consuming to deploy and involve coordination with each tenant mobile operator in order to deploy their licensed spectrum on the DAS. For these reasons, DASs are typically only deployed in facilities over 200,000 sq ft which have very high public traffic (airports, stadiums, shopping malls, etc…).

Traditional, licensed-band, small cells only support a single mobile operator, thus requiring an Enterprise or public property owner to deploy multiple parallel systems in order to provide service to all of their employees or guests. And again, they require coordination with the RAN/RF planning team of the mobile operator whose spectrum is being utilized in order to ensure that the in-building small cell deployment doesn't adversely affect the outdoor macro network. For these reasons, despite the obvious needs for densification and in-building coverage, actual deployments of licensed small cells have not been anywhere close to the numbers that had been forecast.

Wi-Fi continues to carry the bulk on in-building wireless data, and will do so for the foreseeable future. However its use as a cellular augmentation service is limited by issues with onboarding, transparent access using cellular credentials, and the fact that it is often challenging to provide quality-of-service guarantees in high density Wi-Fi deployments (both Public and Private). 'Carrier Wi-Fi Calling' is a significant advance in mobile service delivery over Wi-Fi and will meet the in-building voice coverage needs of some

properties, however properties with high voice quality requirements (e.g. hotels and office buildings) are unlikely to find Wi-Fi Calling a viable solution due to the uncoordinated nature of unlicensed spectrum.

7. Advantages of Neutral Spectrum Solutions

As noted above, the in-building opportunity for DAS and licensed small cells has been significantly constrained by their reliance on licensed spectrum, which requires close coordination with the mobile operator who owns the license for that area. Neutral spectrum (e.g. unlicensed spectrum or CBRS in GAA operation) is easily deployable by a property owner or any type of wireless systems operator. There are also significant economies of scale with regards to device support, as single radio chipsets are able to address the entire market (the economics and scale of Wi-Fi in the 2.4 GHz and 5 GHz bands are analogous).

Finally, and critically, neutral spectrum allows for multi-operator service delivery using a single access point / small cell with a single radio interface. Wi-Fi has inherent support for multi-operator services (either via discreet SSIDs or via advances such as Hotspot 2.0 / Passpoint). With recent efforts to deliver LTE services in neutral spectrum (e.g. TD-LTE in CBRS as well as MulteFire in 5 GHz), work is ongoing to extend LTE to support multi-operator modes of operation.

The benefits of neutral spectrum are summarized in analysis from Wireless 20/20 which concluded that *"Using neutral spectrum that all operators can support can save 40-60% of TCO vs. multi-operator DAS or small cells."*

8. Cable Industry Wireless Initiatives

Multiple System Operators (MSOs) have aggressively deployed wireless services throughout their coverage areas, leveraging their broadband access presence in the residential and small/medium business markets by complementing it with MSO-managed Wi-Fi, while also deploying MSO-owned Wi-Fi assets to cover high-traffic public spaces and fill gaps in coverage. Further, they are now linking these separate footprints into a common platform which can provide transparent access to their subscribers, either via a common SSID (the Community Wi-Fi Model) or Hotspot 2.0 mechanisms. And they are forming roaming relationships with other MSOs and fixed wireless operators to expand subscriber coverage beyond their service areas. Examples would include the Cable Wi-Fi consortium, the bi-directional roaming announcement between TWC (now part of Charter) and Boingo, as well as the international roaming announcement between Comcast and Liberty Global.

To complement this expanding web of interconnected Wi-Fi coverage, MSOs are interested in offering mobile LTE services to their subscribers. This is reflected in the frequent press/analyst musings about cable companies bidding on licensed spectrum, exercising of MVNO rights, and the like. However, the cost to acquire licensed spectrum and deploy a national LTE network are daunting (especially at a time when cellular ARPU is falling). And the MVNO path fails to fully leverage the MSO's strengths with in-building presence and its HFC network for connectivity and backhaul. Acquisitions or mergers between the cable and mobile industries would also address the need, but cost and regulatory approval have hindered any such developments. The following slide from New Street Research captures these alternatives well, and also lists the issues with each.

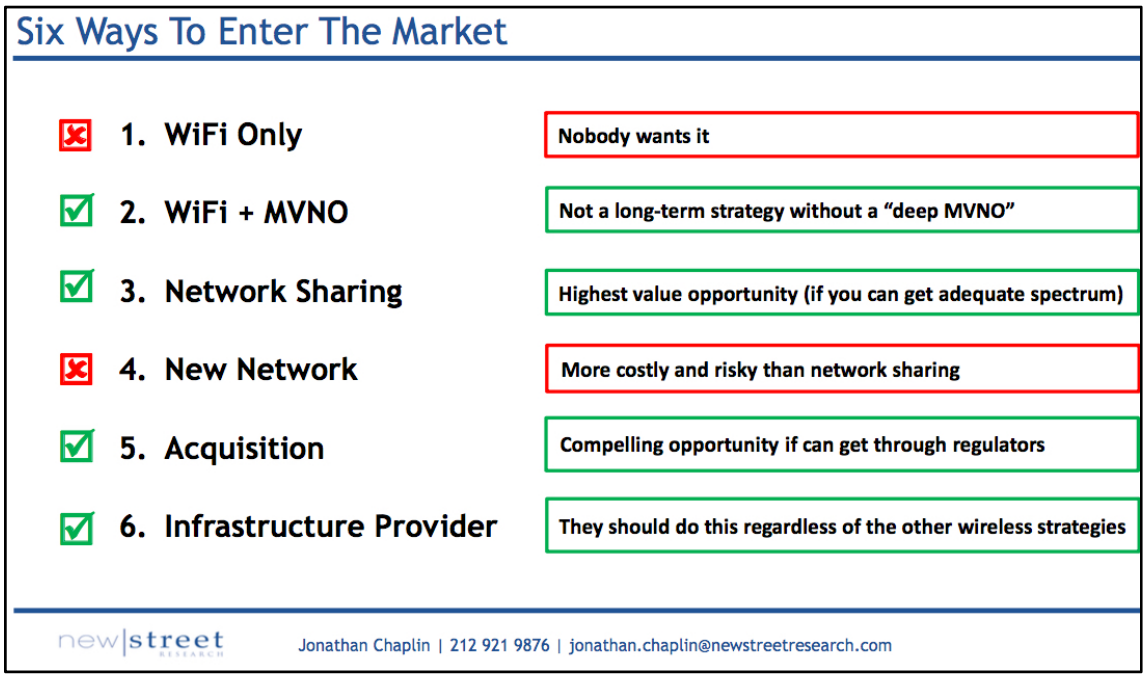

Figure 5 – MSO Wireless Options for LTE Services

9. The Opportunity with CBRS

The introduction of CBRS will allow MSOs to deploy their own LTE services using low cost spectrum at either the PAL or GAA tiers. It is a natural complement and extension of their existing in-building Wi-Fi coverage for the small/medium business market, and also will give them a strong value proposition to satisfy the cellular coverage requirements in larger Enterprise buildings, hotels, conference centers, and the like. Because CBRS-based LTE will offer a cost profile more similar to Wi-Fi than traditional LTE (especially in regards to spectrum expense), it creates a natural path for MSOs to overlay LTE on their existing Public Wi-Fi footprint.

Additionally, this MSO-controlled, in-building and urban outdoor LTE footprint will be very attractive to mobile operators, who have been both seeking in-building coverage options for their subscribers and also struggling to acquire sufficient / appropriate sites to provide denser urban coverage. In this way MSOs and MNOs could enter into negotiations on bi-directional roaming agreements with both parties bringing significant assets to the 'table', the MSO providing in-building coverage and urban capacity with a native LTE service and the MNO providing a national network footprint. Each side would possess something the other would desire in order to complete their coverage.

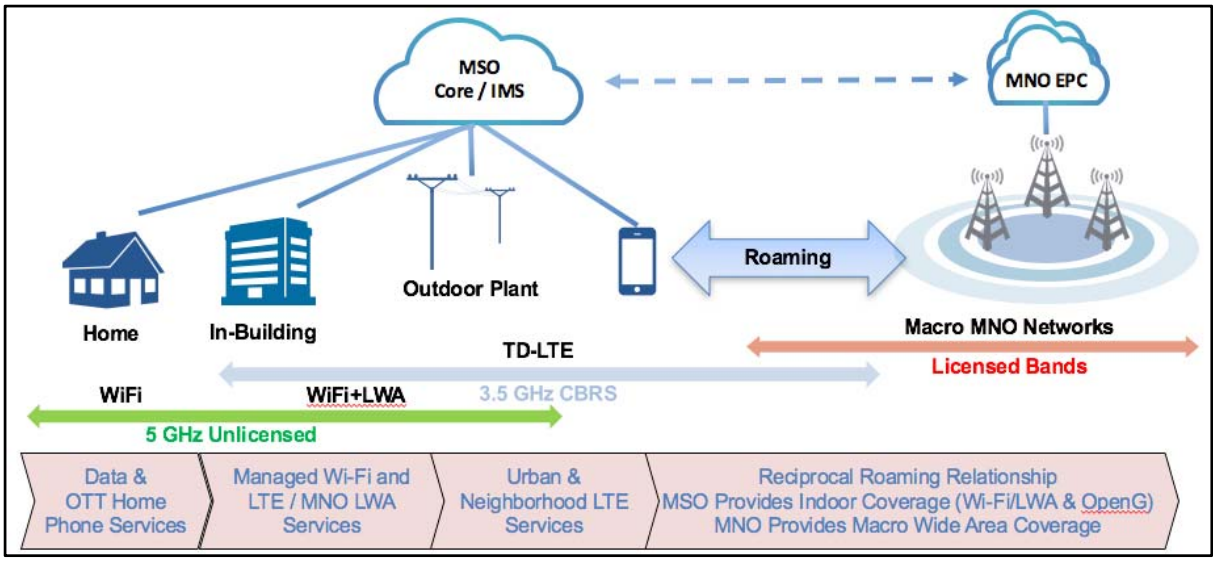

Figure 6 – Expanded MSO Wireless Opportunities with CBRS

10. Timeline for Commercialization of CBRS

The FCC has begun a process to authorize SAS and ESC administrators, and 8 companies filed their intention to provide those services by the May 15, 2016 deadline. The first wave of SAS administrator authorizations are expected in late 2016 or early 2017, dependent upon the FCC review process. It is anticipated that after the SAS and ESC authorizations are completed, the FCC will begin certifying the CBSDs for CBRS operation. Most participants believe that the initial authorization for CBRS service activation will be granted in 2017 for GAA operation, with PAL service taking additional time due to the scale of the PAL auction (up to 7 PAL licenses across ~74,000 census tracts) and the mechanisms necessary to create a secondary trading market for the PALs.

Conclusion

As the first example of 3-Tiered Coordinated Shared Spectrum, CBRS stands to radically change how spectrum is allocated and utilized going forward, breaking down the traditional barriers between fully licensed and unlicensed bands and allowing regulators to repurpose lightly used bands for expanded commercial usage. Because CBRS spectrum is available to anyone and can be used to deploy / deliver LTE services at a much lower cost than fully licensed LTE, MSOs will now have a reasonable path to deploying LTE coverage as an overlay to their existing Public Wi-Fi. This will create new dynamics between the cable and mobile industries and lead to opportunities for partnering around reciprocal footprint sharing.

Abbreviations

CBRS	Citizens Broadband Radio Service
CBSD	Citizens Broadband Radio Service Device
CSS	Coordinated Shared Spectrum
DAS	Distributed Antenna Solutions
ESC	Environmental Sensing Capability
GAA	General Authorized Access
LSA	Licensed Shared Access
LTE	Long Term Evolution
MulteFire	Standalone, unlicensed spectrum solution for LTE
PAL	Priority Access License
SAS	Spectrum Access System
SSID	Service Set IDentifier
TD-LTE	Time Division LTE (multiplexed downlink/uplink)

Bibliography & References

Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, REPORT AND ORDER AND SECOND FURTHER NOTICE OF PROPOSED RULEMAKING, April 15, 2015

Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, ORDER ON RECONSIDERATION AND SECOND REPORT AND ORDER, April 28, 2016

Code of Federal Regulations, Title 47, Part 96

