MOBILE EXPERTS

CBRS White Paper:

CBRS: New Shared Spectrum Enables Flexible Indoor and Outdoor Mobile Solutions and New Business Models

March 2017

Kyung Mun

What is CBRS?

In April 2015, the Federal Communications Commission (FCC) formally established *Citizen Broadband Radio Service* (CBRS) for shared commercial use of the 3.5 GHz (3550-3700 MHz) band with the incumbent military radars and fixed satellite stations.[1] For the first time, dynamic spectrum sharing rules have been defined to make additional spectrum available for flexible wireless broadband use while ensuring interference protection and uninterrupted use by the incumbent users. Under the plan, a novel three-tier sharing paradigm coordinates spectrum access among the incumbent military radars and satellite ground stations and new commercial users. The three tiers are: *Incumbent*, *Priority Access License* (PAL), and *General Authorized Access* (GAA) users.

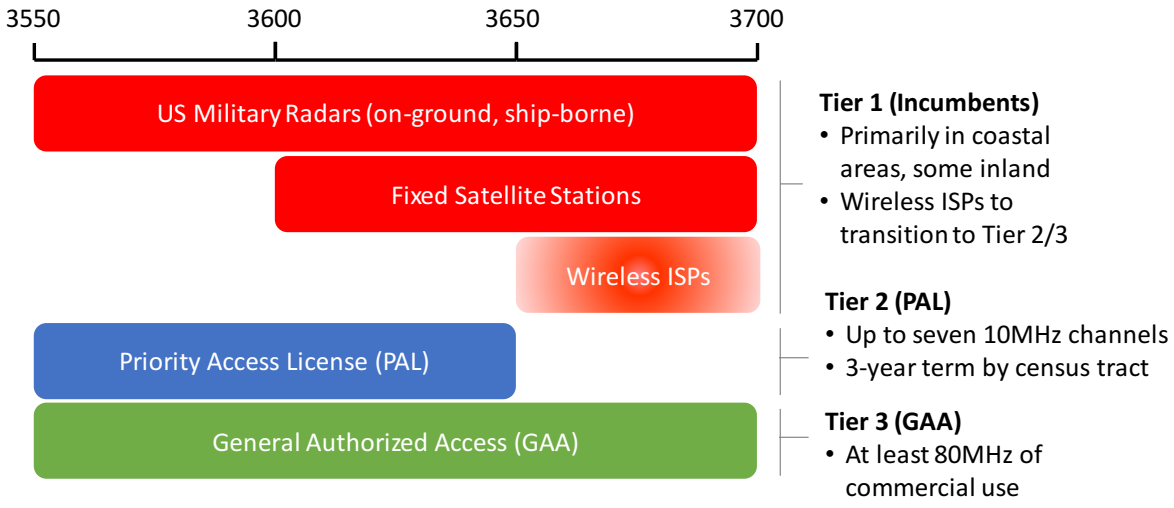

Figure 1. CBRS 3-Tier Shared Spectrum Licensing Structure

In the highest tier, Incumbent military radar systems, satellite ground stations, and wireless ISPs (temporarily) are protected from possible interference from the lower tier PAL and GAA users at all times.

Tier 2 PAL users have the next highest priority access and are protected from GAA users. PAL licenses within the 3550-3650 MHz portion of the band are assigned based on spectrum auctions. Each PAL license covers a 10 MHz channel for a single census tract for a three-year term. For any given census tract, up to seven total PALs may be assigned. With over 70,000 census tracts in the U.S., each PAL spectrum license is expected to cost much less and encourage participation from variety of stakeholders. It should be noted that a PAL frequency range may change over time, based on incumbent activity.

[1] FCC Report and Order and Second Further NPRM formally established CBRS in April 2015.

Finally, the lowest tier GAA users are permitted to use any portion of the 3.5 GHz band not assigned to higher tier users. With an open access rule, GAA provides free access to the spectrum, similar to unlicensed spectrum. Since PAL licenses are limited to a maximum of 70 MHz in any given census tract; at a minimum, 80 MHz are available for GAA use when not in use by Tier 1 incumbents. While GAA operation does not require a costly license, GAA operators must coordinate their use of the spectrum through the dynamic spectrum sharing system.

CBRS Technology Overview (How does it work?)

A key element of the CBRS spectrum sharing architecture is the *Spectrum Access System* (SAS). A SAS maintains a database of all CBRS base stations, formally referred to as *Citizens Broadband Radio Service Devices* (CBSDs), including their tier status, geographical location, and other pertinent information to coordinate channel assignments and manage potential interferences. To mitigate possible interference to tier 1 military radar systems, environmental sensors known as the *Environmental Sensing Capability* (ESC) will be deployed in strategic locations near naval stations, mostly along coastal regions, to detect incumbent activities. When incumbent use is detected, the ESC alerts the SAS, which then directs CBSDs utilizing impacted CBRS channels in that area to move over to other channels. The cloud-based SAS enforces the three-tier spectrum sharing mechanism based on FCC rules via centralized, dynamic coordination of spectrum channel assignments across all CBRS base stations in a region.

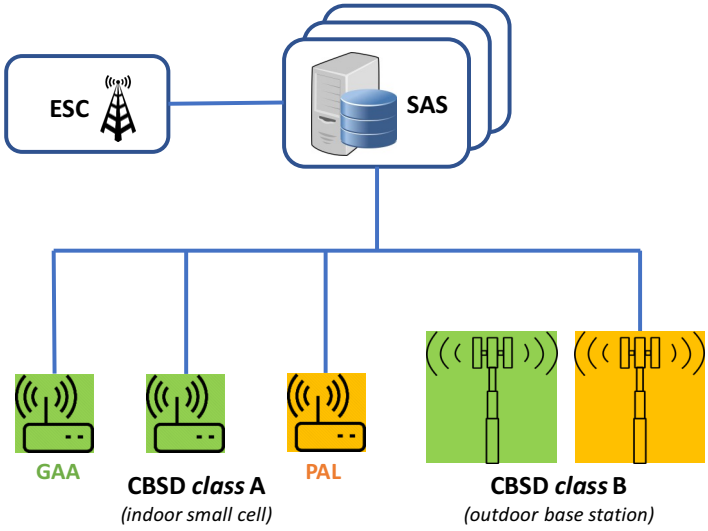

Figure 2. CBRS Functional Overview

The CBRS rulemaking defines two classes of base stations: *class A* and *class B*. A *class A* base station can be thought of as indoor or low power outdoor small cells with a maximum conducted power of 24 dBm (per 10 MHz) and maximum EIRP of 30 dBm (1 watt). This type of small cell is similar to "enterprise-class" small cells in the marketplace with 250mW transmit power with a typical 2 dBi omni antenna or up to 6 dBi directional antenna. Meanwhile, a *class B* base station is meant for outdoor use with a maximum EIRP of 47 dBm (50 watts). With a very high-gain antenna, outdoor CBRS base station can potentially be used for fixed wireless purposes. While indoor and outdoor base stations can be assigned to either GAA or PAL, we expect to see more indoor GAA deployments until ESC certification and PAL auctions get finalized.

Use Cases and Business Models

Considering that a tier 1 US mobile operator holds, on average, about 130 MHz of licensed spectrum, 150 MHz of favorable mid-band spectrum in the CBRS band is a significant resource for further mobile capacity expansion. In addition, the flexible three-tier licensing framework lowers the barrier to spectrum and promotes success-based investment for new entrants. CBRS offers cost-effective LTE solutions for both indoor and outdoor applications; opens up new use cases; and, encourages business innovations from old and new players alike.

Model #1: Mobile Operator Capacity Augmentation

Competing on unlimited service plans, mobile operators are desperately seeking cost-effective capacity expansion solutions. Despite their efforts to quickly refarm and deploy new licensed spectrum, it seems the demand is quickly taking up any slack in network capacity. Meanwhile, the capacity expansion plans through small cell densification have been slow to scale as projects have been mired in municipal approval processes. Moreover, commercial LTE-U/LAA launch to opportunistically harness the unlicensed 5 GHz spectrum has also been slow to ramp with market pushback from Wi-Fi constituents. In the midst of these challenges, CBRS offers 150 MHz of sparsely used spectrum for LTE capacity expansion -- without the complexity of sharing the band with Wi-Fi. Furthermore, higher regulatory power limits and better RF propagation characteristic of the lower 3.5 GHz band yields a longer range than the 5 GHz band. For outdoor deployments, the maximum power limit of up to 47dBm EIRP for outdoor CBRS base stations provides a significant boost for outdoor scenarios. Simply put, CBRS offers more flexible approaches to indoor and outdoor mobile solution than other unlicensed spectrum choices like LTE-U/LAA.

Mobile operators can augment capacity in two ways with CBRS. First, the 3.5 GHz GAA spectrum bands can be used as supplemental data links as defined in the LTE-U/LAA/eLAA construct while a licensed band is used as an "anchor" carrier for control signaling and a primary data path. Second, TD-LTE on the CBRS bands can transport both control signaling and data traffic over the 3.5 GHz shared spectrum. In both cases, CBRS offers a higher level of network quality control afforded with LTE-based solutions as compared to Wi-Fi offload.

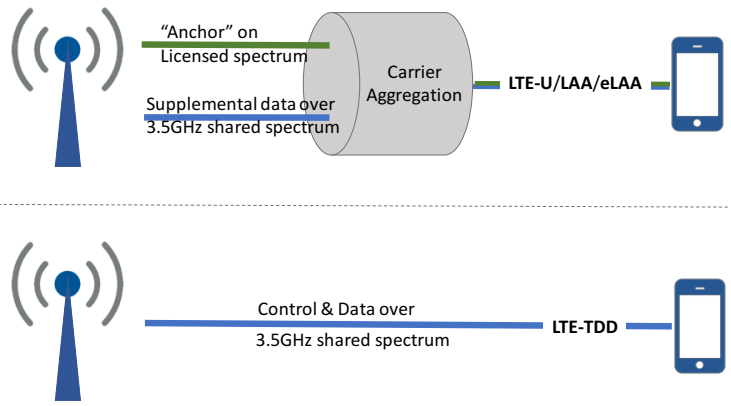

Figure 3. Mobile Operator Capacity Expansion using CBRS

10-MHz channels allow mobile operators to apply carrier aggregation to boost peak speeds, in addition to boosting capacity.

While securing PAL licenses for indoor deployments may not yield much benefit, PAL licenses for outdoor deployments can be useful in guaranteeing a certain amount of spectrum in traffic hotspots. With PAL licensing, an operator can effectively secure up to 40 MHz of CBRS bands in strategic geographical locations. Dependent upon how much CBRS networks are built out and levels of incumbent activities in a given area, the operator can utilize additional CBRS bands on GAA basis and opportunistically take advantage of extra spectrum resources.

Model #2: New Entrant/Cable Operator MVNO

CBRS is a great option for new entrants like cable operators to build out an LTE network, and is a compelling traffic offload option for the cable operators looking to enter the mobile wireless industry with a Mobile Virtual Network Operator (MVNO) strategy. LTE service across both host macro network and owned CBRS small cell network may simplify network integration efforts and will likely result in more predictable user experience than offloading to Wi-Fi. Since cable operators do not yet own much licensed spectrum, this is a big upgrade from Wi-Fi. The cable operators can capture additional subscriber mobile traffic on the 3.5 GHz band with LTE and 2.4/5 GHz bands with Wi-Fi to reduce the amount of charged traffic going over to the host mobile operator network.

The profitability of a MVNO business case is heavily dependent on lowering the amount of traffic going over to the host mobile operator network. Since an MVNO pays a mobile operator for traffic going over the host operator's network, higher subscriber usage directly translates to higher network cost. Hence, for the cable operators, this means offloading subscriber traffic over to owned networks as much as possible.

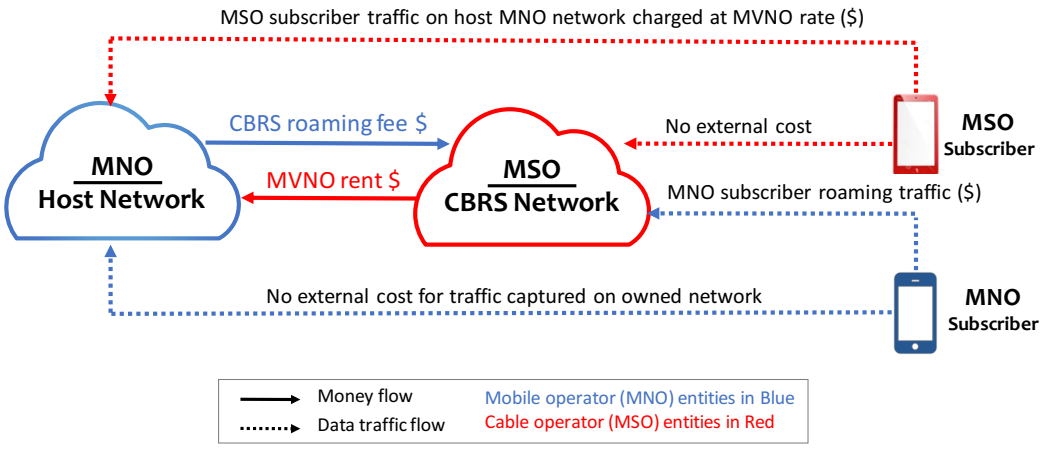

Figure 4. New Entrant MVNO Capacity Improvement Business Model

One possible new business model involves a "swap" arrangement with the host mobile operator to allow MNO subscribers to roam onto the CBRS network in exchange for a lower MVNO terms.

Having owned LTE-based network in strategic places where most of subscriber traffic is generated or consumed, affords additional optionality for the cable operators. Besides reducing MVNO expenses through traffic offloading, the cable operators can negotiate for better MVNO terms involving a potential "swap" deal.

Model #3: Neutral Host RAN

There is a growing need for neutral host providers to bridge the gap between very large projects with direct mobile operator involvements and large numbers of smaller projects that are too small for mobile operators to consider, but too complex for enterprises to handle on their own. There is an opportunity for new entrants with CBRS deployments that involve SAS coordination and managing core network integration with mobile operators. Beyond the obvious large public venues such as stadiums and airports, hi-rise buildings, large hospitals, and university campuses are well suited for neutral host providers to address a growing, pent-up demand for in-building wireless coverage and capacity expansion. For enterprises with limited IT/telecom resources, a neutral host provider can take over the technical work and coordination with the operators. About 30 billion square feet of US commercial floor space has poor mobile coverage.[2] With broad support from all four major operators and leading device platform vendors, neutral host providers can create a major new category of mobile coverage, funded by the enterprise or property owner.

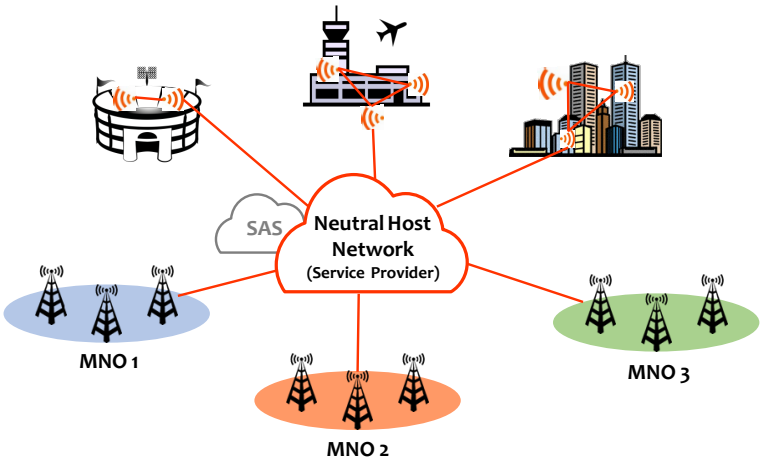

Figure 5. Neutral Host Network Provider using CBRS

Model #4: Enterprise Private LTE

Large enterprises have traditionally deployed Wi-Fi networks to satisfy the growing wireless data demand. However, it has been a poor substitute for seamless mobile voice services indoors. While Distributed Antenna Systems (DAS) provide the multi-operator support, they are considered too expensive for many enterprises, and too complicated in dealing with mobile operators to secure signal sources. CBRS radios, like Wi-Fi access points, that support a multi-operator capability and run seamless LTE services are a powerful improvement.

[2] Mobile Experts, "*Unlicensed Business Models, Players, and Opportunities*", Dec. 2016.

An opportunity to create a private LTE network, in similar manner as Wi-Fi, to run enterprise- or venue-specific applications on mobile devices of consumers or workers enables tremendous flexibility -- and allows enterprises to tap into broader device and app store ecosystems that already exist. For instance, a large corporation can run secure enterprise CRM and communication tools on workers' mobile devices through a private LTE network at enterprise campuses. In another example, a heavy industry company can set up a private LTE network at a remote mining site and run industrial IoT applications on LTE devices. A recent demo from Nokia, Qualcomm and Alphabet showcasing a live 360-degree VR streaming from a race car is yet another example of new user experiences that can be enabled on high-capacity private LTE networks leveraging the CBRS bands.

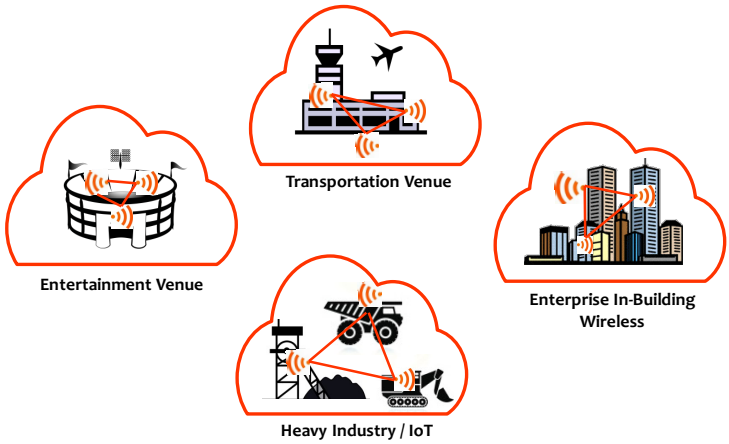

Figure 6. Enterprise Private LTE Networks

Comparative Economics of CBRS

CBRS offers attractive unit economics for mobile coverage and capacity. Up to 150 MHz of favorable mid-band spectrum at expected low spectrum acquisition cost opens new business opportunities that have been prohibitive in the past. With the support of all four major mobile operators in the U.S., and the existing use of 3.5 GHz as an LTE band in other parts of the world, the device ecosystem support for the 3.5 GHz CBRS band/technology is more likely than ever, and the broadening ecosystem is likely to bring scale advantages and consequently low-cost solutions. Comparative unit economics in terms of monthly cost to deliver a gigabyte of data shows that a CBRS base station can potentially deliver a 40% reduction relative to a traditional LTE small cell leveraging licensed spectrum.[3] The primary advantage of CBRS comes from the capability to aggregate up to 40 MHz of cheap spectrum even though extra costs for SAS and mobile operator gateway handling are incurred for CBRS.

[3] Our cost model includes major CAPEX and OPEX elements including radio equipment, spectrum, hosted core, site lease, backhaul and power. We estimate monthly costs for the radio and spectrum costs using a straight-line depreciation of 8 years for macro, 4 years for small cells, and 20 years for licensed spectrum.

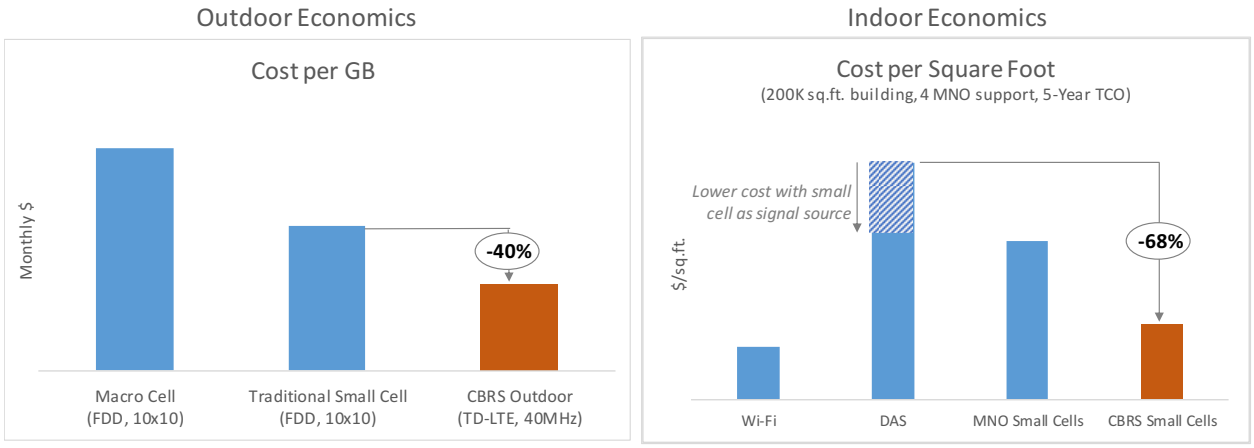

Figure 7. Comparative Unit Economics of Outdoor and Indoor Deployments[4]

For indoor coverage, our study shows a much lower "cost per square foot" in terms of unit economics for CBRS relative to DAS and traditional small cell deployments. A key factor: a single CBRS radio can support all four major operators in the 3.5 GHz band by default. In comparison, multiple, parallel operator-specific small cells are required in a traditional licensed small cell deployment case. Although DAS cost can be brought down with less expensive small cell as a signal source for smaller venues, CBRS still offers a much lower-cost alternative for mobile LTE coverage. (While Wi-Fi offers a lower cost solution for in-building wireless coverage, seamless mobile voice service is not possible with Wi-Fi.) Additionally, CBRS can be used to provide a quality LTE layer for wireless data services in enterprise venues where the 2.4 GHz and 5 spectrum bands are heavily utilized by Wi-Fi.

Concluding Remarks

CBRS is blazing a new trail in spectrum policy and is opening new opportunities along the way. The novel approach to spectrum sharing is opening up 150 MHz of favorable 3.5 GHz band whose ecosystem already has traction worldwide. Chipset and equipment ecosystem for the 3.5 GHz band has been gathering momentum through global TD-LTE developments around 3GPP band 42 (3400-3600 MHz) and band 43 (3600-3800 MHz). The FCC petition to update the rules for the 3.7-4.2 GHz band could potentially open additional shared spectrum for a total of 650 MHz, which would be more than the combined total licensed spectrum holdings of all four major operators![5] CBRS offers tremendous opportunities for traditional operators and new entrants alike to enable both in-building wireless and outdoor mobile coverage and capacity expansion at lower cost.

[4] Based on Mobile Experts research on *Small Cells*, *DAS*, *and Carrier Wi-Fi/LTE-U*

[5] Fixed Wireless Communications Coalition (FWCC) filed a petition to update the rules for the 3.7-4.2 GHz band allocated for the satellite industry.

A large swath of spectrum, a flexible spectrum licensing regime, and a growing CBRS ecosystem supported by all major operators bodes well for technology and business innovations in the CBRS band. There is a growing optimism around new business opportunities that can be enabled by LTE-based solutions in the CBRS band. With 3GPP band 48 (3550-3700 MHz) designation, the 3.5 GHz CBRS ecosystem is gaining global scale beyond the U.S. This optimism will ignite the virtuous cycle of expanding market opportunities for CBRS and all its ecosystem partners.