



**CITIZEN'S
BROADBAND
RADIO SERVICE
(CBRS) WHITE
PAPER**

30 September 2018

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1 Document Information

1.1 Contributors

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1.2 Audience

This white paper is intended for IT professionals with responsibility for network infrastructure supporting data communication solutions in the hospitality industry. Hospitality Brand executives who own Telecommunication and Wireless infrastructure strategy and solutions will find the information in this document useful for developing long term infrastructure strategy and standards. Hotel managers and operators will benefit from understanding how CBRS can be leveraged to improve operations and guest experience.

2 Introduction

Hospitality properties need a comprehensive wireless network solution that supports the demands of guests, staff, work flow, applications, the Internet of Things (IoT) and Mobile Network Operators (MNOs). To ensure these requirements are met, this network must be directly under the control of the hotelier or a trusted third party. HTNG's previous Scalable Cellular Workgroup made significant gains toward defining and providing a path toward this goal, yet significant control is still held by the MNOs and the command of their operating frequency bands. This control is an effort by the MNOs to protect the quality of service which at times can be stifling to the hotelier's efforts to deliver the network.

Advances in Wi-Fi networks are required for hospitality properties to deliver wireless access for Internet and work flow, yet have limitations to support secure mobility, interference avoidance and integration with the MNOs. The Citizen's Broadband Radio Service (CBRS) band has the potential to provide a secure private network with mobility interfaces to the MNOs, while remaining under control of the hotelier.

2.1 Overview

Citizen's Broadband Radio Service (CBRS) is a new set of frequency bands that can be shared or lightly licensed for private communication and is currently in the process of regulatory approval in the United States (other regions already utilize this spectrum for commercial communications). CBRS provides 150 MHz of new spectrum that is desperately needed for industries that have congested wireless networks or the desire for more control of their networks.

The hospitality industry, with its diverse and overlapping use of premise wireless connectivity for business processes, is a leading candidate to take advantage of this shared spectrum. Since this shared spectrum technology is a new wireless network option, hoteliers might not have enough information to evaluate its business value and application.

2.2 Purpose

This white paper was developed by HTNG's Citizen's Broadband Radio Service (CBRS) for Hospitality Workgroup to help educate hoteliers' IT personnel on the underlying technology, application of the technology and the major use cases (including, but not limited to voice, data, low power applications, private vs. shared use). In addition, this white paper will document the value of deploying CBRS in hotels. The next workgroup deliverable will address the business models that support deployment of CBRS in hotels.

2.3 Business Models

In addition to this white paper as a primer, HTNG's CBRS for Hospitality Workgroup will develop several business models as use cases for the hospitality industry. These business models will rely on applications that have a positive return on investment to ensure business viability for the use cases. For example, CBRS provides a private network with walkie-talkie functionality of "push-to-talk." This enables staff workflow and safety by allowing a more customized communication network independent of the MNO's. The enablement and improvements will be modeled to show a positive ROI to support the network investment and operation.

3 CBRS Use Cases for Hospitality

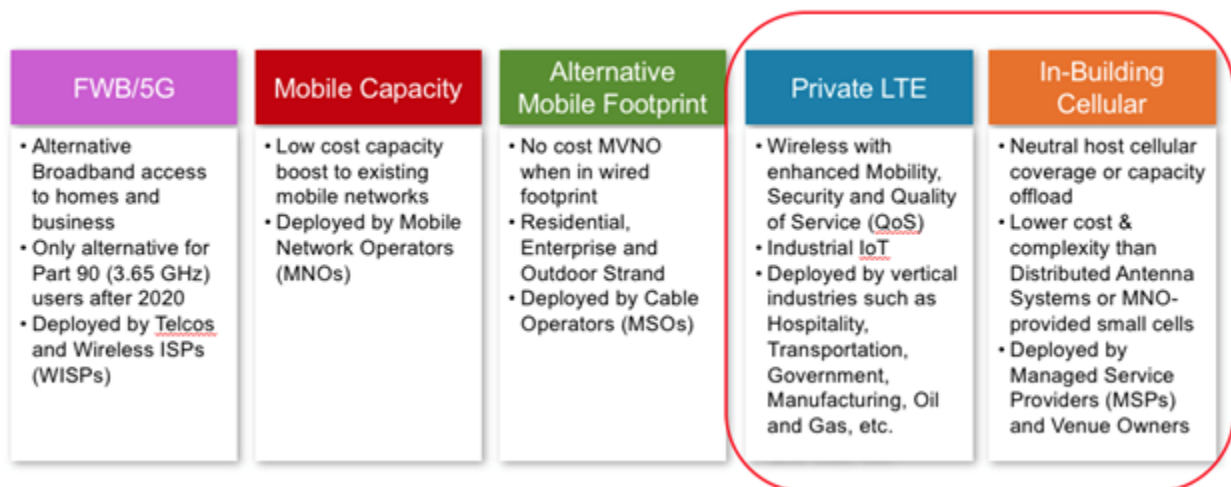
The hospitality industry currently has many applications that will benefit from the features that differentiate CBRS from current wireless standards, including Wi-Fi and cellular. From the ability to control a property's network, to the inherent security and Quality of Service (QoS) levels for mission and business critical applications, CBRS can deliver high value services to the property's network.

The CBRS spectrum, with its unique licensing scheme, enables many use cases for wireless communication. The spectrum is also able to support many protocols including LTE for mobile phones and devices. For the first time in history, enterprises in the hospitality industry are now able to install and operate cellular networks in their facilities the same way they do with Wi-Fi. The challenge is the interoperability of the new devices that are required to operate in coordination with the existing infrastructure.

CBRS is unique in how it supports multiple use cases within the same frequency band. The CBRS network allows the simultaneous use of everything from cellular LTE services, broadband "Wi-Fi like" data transmission to narrowband IoT. These are not mutually exclusive and give hospitality organizations the ability to use CBRS infrastructure in many roles over time. Additionally, CBRS bandwidth can work in coordination with other bands and applications. For example, cellular carriers are planning to use CBRS to expand data throughput to mobile devices anchored on their licensed spectrum, thus offloading Wi-Fi networks and the cellular network to reduce congestion and improve service levels.

Figure 1 below summarizes various use cases for CBRS. Since the first three use cases focus on service providers, such as MNOs, this document will focus on the last two use cases: Private LTE and In-Building Cellular for hospitality.

Figure 1: Use Cases for CBRS



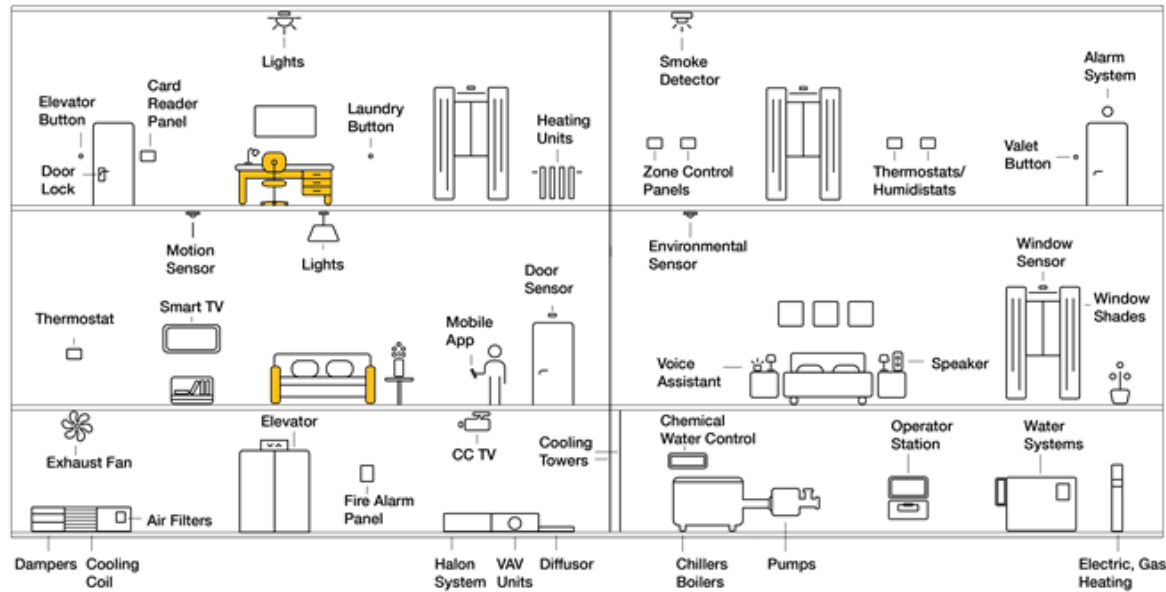
3.1 Private LTE

Hoteliers now have the opportunity to own and operate their own secure, quality controlled wireless network without relying on a cellular carrier or the inherent compromises of Wi-Fi and other unlicensed operating bands like inconsistent service levels due to interference and congestion.

The following is a non-exhaustive list of potential Private LTE applications for the hospitality industry:

- **Employee communications:** Secure push-to talk staff communications within individual and between managed properties
- **Telephony functionality:** similar to a Premise-based system (i.e. PBX) Guest and staff can use voice communications with PBX functionality
- **Guest on premise communication:** guest voice and data communications where guest's devices auto authenticate on arrival, independent of MNO services
- **POS with mobile support:** Secure wireless data support for mobile and nomadic POS terminal
- **Operational Automation:** Task orders, cleaning cart location and optimization, confirmation of room availability, robotic-based cleaning and delivery, etc.
- **Mobile eCommerce:** Secure point-of-sale terminals through the facility for ticket sales, food and beverage, the spa and more
- **Security/Safety:** CCTV surveillance cameras in parking areas or other places where wires don't reach, mobile video monitoring, etc.
- **Building Management:** Monitoring and controlling thermostats, lighting, elevators, power systems, and more shown in Figure 2 below:

Figure 2: In-Building Management Devices



Source: HTNG IoT Workgroup publication "How Hospitality can win with IoT"

Private LTE is a term used when non-service providers deploy a cellular network for their own use, such as improving operations or reducing the cost of doing business, rather than for public access. Private LTE over CBRS can provide tangible benefits over alternative wireless technologies, especially for use cases or applications that require:

- **High Reliability** - CBRS uses a central coordination service, called a Spectrum Access System (SAS), for assigning unique radio channels based on the exact location of the radio transmitters. This means that CBRS radio waves will be free from interference that is common to unlicensed alternatives in the ISM and UNII bands (Wi-Fi bands). For those with even more stringent reliability requirements, or who want to serve a broader area outside their own facilities, CBRS has provisions for an even more exclusive PAL tier that will be available for purchase through an FCC auction. Finally, since a Private LTE network is not shared with (or enforces priority over) public access users, it does not get overwhelmed during special events or emergencies.
- **Quality of Service** - CBRS uses LTE, the same cellular technology used in today's most advanced mobile networks. LTE has a proven track record of delivering quality voice and two-way video even under heavy user loads, due to its more controlled and scheduled user access and end-to-end packet tagging and prioritization.
- **Performance, Coverage and Cost** - Private LTE networks that are over CBRS provide a unique blend of performance, coverage and cost. CBRS delivers much higher data rates relative to IoT technologies such as Bluetooth LE and Zigbee, but with much longer range and battery life than Wi-Fi. Further, LTE over CBRS can support cellular low power device IoT protocols such as CAT-M1 and NB-IoT. And unlike public cellular networks, there is no monthly data fee to use LTE over CBRS.
- **Mobility, Security and Convenience** - LTE technology was built from the ground up for mobility, including handovers and inter-cell session continuity which are particularly critical for voice communications. CBRS users are free to move throughout the facility and are even handed over to or from outdoor mobile operator networks when user move outside of CBRS coverage. In addition, LTE uses SIM-based security and authentication, the gold standard for cellular networks since 1991. The result is that users are automatically and securely on-boarded and handed over to other access points without having to ask for a password, requiring the user to manually go through multiple tiny phone screens and type in that password.

3.2 In-Building Cellular

In-Building Cellular is the use case that provides reliable cellular MNO services to employees, visitors and guests throughout an entire facility. Many hoteliers thought deploying these networks was the exclusive domain of mobile network operators and, until CBRS, they were right.

Before the advent of CBRS, the facilities with low "foot traffic" were viewed with reluctance by mobile operators to invest in and improve their own networks or participate in a neutral-host DAS network. In-Building Cellular over CBRS enables the facilities owner to support the MNOs

by deploying a cost-effective “mini” cellular network using the CBRS band, similar to the way they deploy Wi-Fi today. It is also possible to extend CBRS frequencies into existing DAS systems or combine them with other multi-band, multi-operator distributed radio systems.

The clear advantage of CBRS is that it is inherently neutral-hosted (e.g. one in building network can support subscribers from multiple mobile operators). Since the band is separate from licensed bands, complex frequency coordination and approvals from the MNOs are not required and the network can be deployed faster at a significantly lower cost than DAS. MNO subscribers simply roam in and out of the areas with weak mobile operator coverage, much like they do when traveling overseas.

Having a standalone LTE cellular network that is fully interoperable with the MNOs will require access to each MNO's core network. That MNO core access enables the seamless roaming envisioned and referred to in this section. The MNO's core networks are carefully protected and only certain entities are allowed access; mostly to facilitate certain key functions of the MNO that include roaming with other operators.

Verizon has announced “it expects to have 3.5 GHz Citizens Broadband Radio Services (CBRS) capable devices, including smartphones, entering its lineup by the end of this year [2018].” This is a very important step toward widespread adoption of CBRS, especially in smartphone devices, where CBRS will be used to augment the capacity of mobile broadband service on the Verizon mobile network. Once deployed, these devices could be configured in the future to connect to private LTE, multi-operator and neutral host networks.

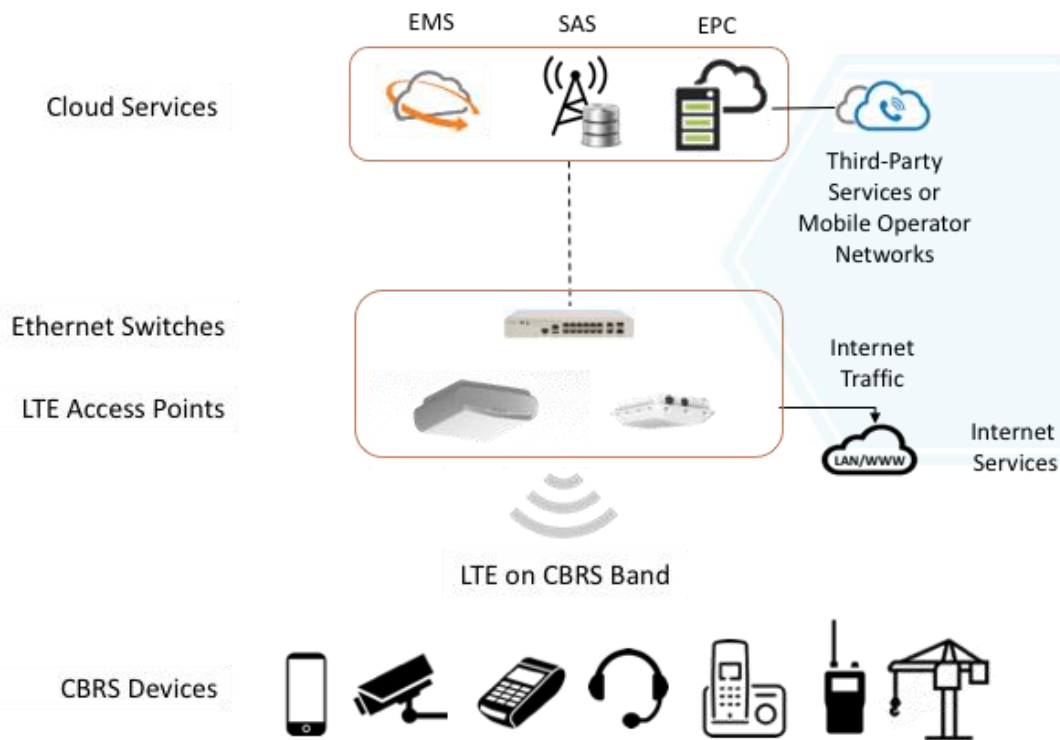
The CBRS Alliance is an industry trade association formed to facilitate the use of the CBRS band for wireless access that is not controlled or limited by the MNOs. The CBRS Alliance views Verizon's announcement as a positive direction for the industry by establishing user devices with CBRS interfaces and overall showing the usefulness of the band. The CBRS Alliance believes a compelling business case with positive ROI will be required to loosen the MNOs protection of their core network and enable full interoperability.

4 In-Building Deployment Characteristics & Scenarios

4.1 CBRS Network Hierarchy

CBRS equipment for indoor applications is very similar in form and function to Wi-Fi network equipment. There are Citizen's Broadband Service Devices (CBSD), either stand-alone LTE Access Points or integrated into Wi-Fi APs, with AP controllers on site or in the cloud. LTE Access Points connect to the Internet for traffic and SAS access with Intranet accessibility for private access.

Figure 3: Wi-Fi Like Network Hierarchy on an Ethernet Network



- EMS: Element Management System
 - Helps the network owner monitor and manage the CBSDs
 - Typically includes configuration, fault management, asset management and performance management functions
 - Can be on-premise, on a private data center or on a public cloud
- SAS: Spectrum Allocation Server
 - Provides the channel(s) for the network to operate on
 - Required per FCC rules
 - Offered as a cloud service

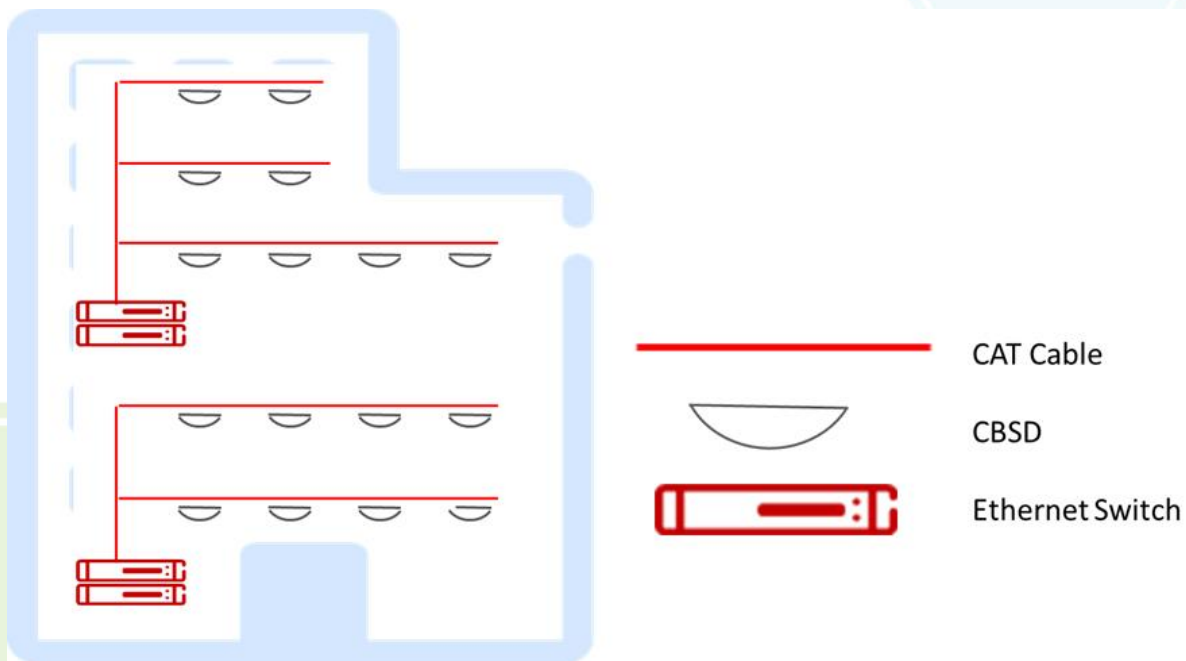
- EPC: Evolved Packet Core
 - Contains the user database (e.g. who is allowed on the network)
 - Enforces policies on the users (e.g., throughput limits or monthly data caps)
 - Acts as a gateway to external networks such as the public Internet or MNOs
 - Handles mobility and other aspects of the network
 - Can be on-premise, on a private data center or on a public cloud
- Ethernet Switch and/or Radio Controller
 - Provides IP connectivity and power to LTE Access Points over Cat5/6 cables or fiber
- CBSD or LTE Access Point
 - Provides the radio interface for CBRS access devices such as smartphones
- CBRS Devices
 - Provide the radio connection to LTE Access Points
 - Must support "LTE Band 48"
 - Other functions depending on the application

4.2 Architecture Options

4.2.1 Wi-Fi Like

CBSDs contain radio and baseband components in an integrated unit that connects via CAT cable and Ethernet switches.

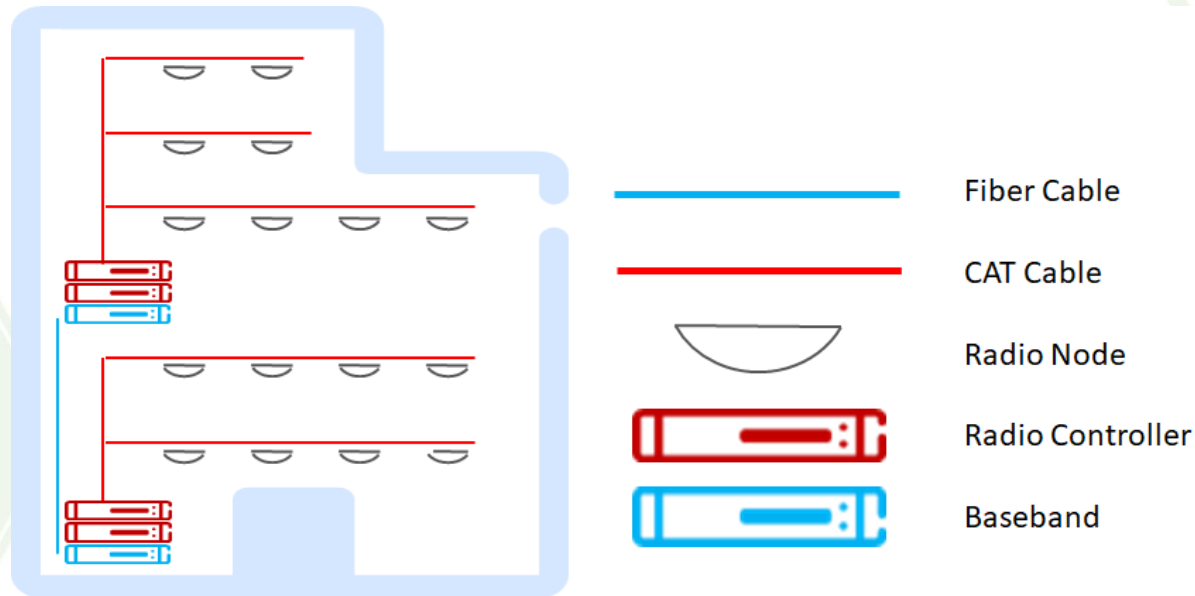
Figure 4: Wi-Fi like CBRS Equipment Components Example



4.2.2 Distributed

A number of different architectures exist to implement the standalone CBRS network. One example uses CAT-6 cabling to interconnect radios to a controller baseband.

Figure 5: Distributed CBRS Equipment Components

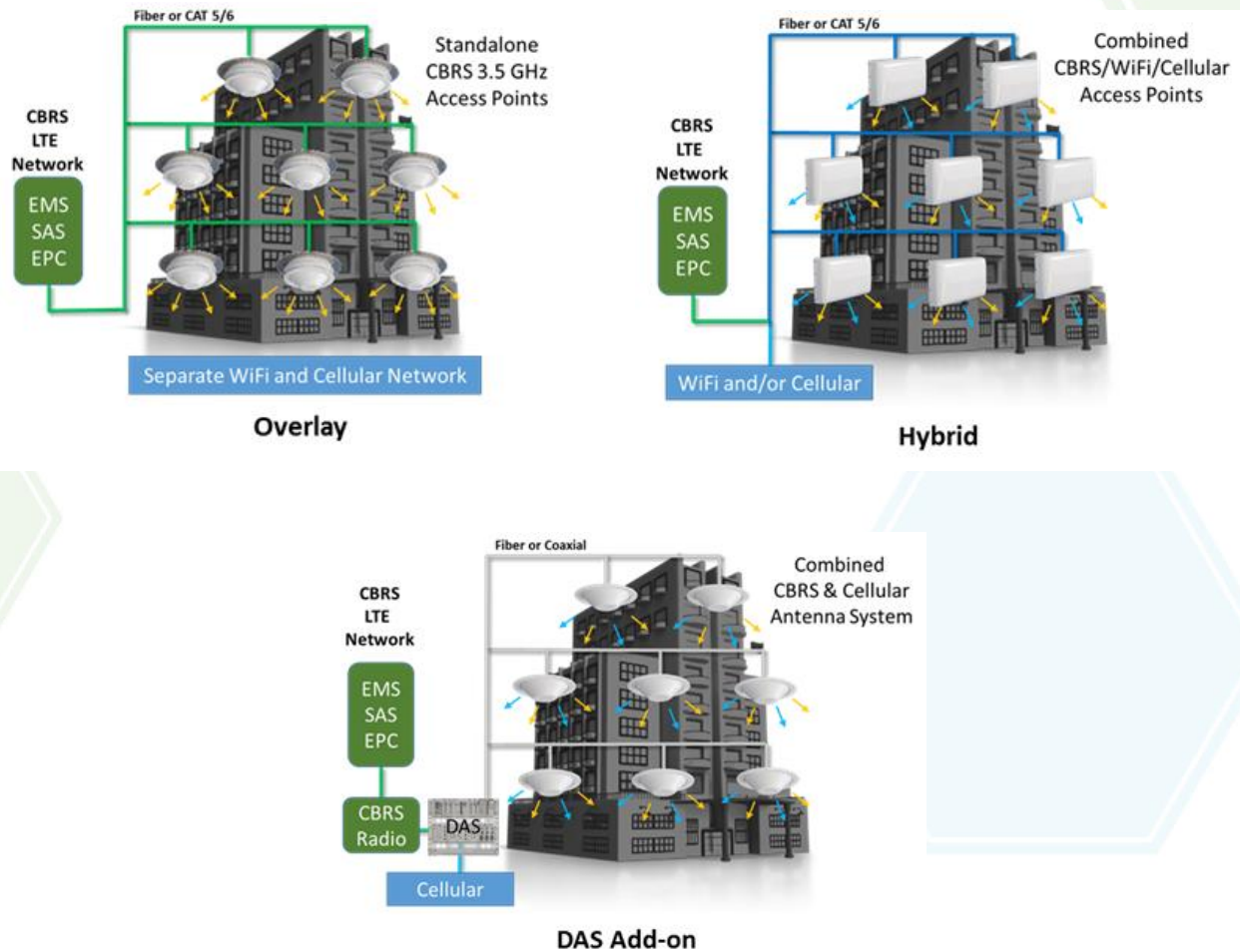


4.3 Possible Deployment Models

There are multiple ways in which CBRS spectrum can deploy within buildings to maximize existing infrastructure. A few illustrative models are shown below to help visualize how CBRS can deploy as either new/overlay, converged/hybrid or integrated connectivity infrastructure/DAS add-on. These models are not exclusive as vendors and suppliers are expected to have many innovative ways to provide a shared spectrum for in-building and property use.

Type	Description	Connection
Overlay	Individual and dedicated CBRS band radios	Fiber or CAT 5/6
Hybrid	CBRS band radios combined into common Wi-Fi and/or cellular radios units	Fiber or CAT 5/6
DAS Add-on	Inputs a CBRS radio source into a multi-band, multi-operator RF distribution system	Fiber or Coaxial

Figure 6: Deployment Models for an In-Building CBRS System Example



4.4 CBRS Frequency Bands

The CBRS operating frequency band is from 3.55 to 3.7 GHz, placing it between the commonly used Wi-Fi bands at 2.4 & 5 GHz. As a result, the coverage and propagation characteristics are slightly worse than the lower Wi-Fi band and better than the 5 GHz band. Where the 5 GHz band has greater bandwidth, it provides less penetration through physical barriers such as walls and other structures that the 2.4 GHz band usually passes through. Figure 7 below shows where the CBRS frequency exists in relation to both existing wireless bands for mobile, IoT, public safety, Wi-Fi and those planned for 5G in the US and Canada.

Figure 7: Existing and Anticipated Frequency Allocation and Types (US & Canada)

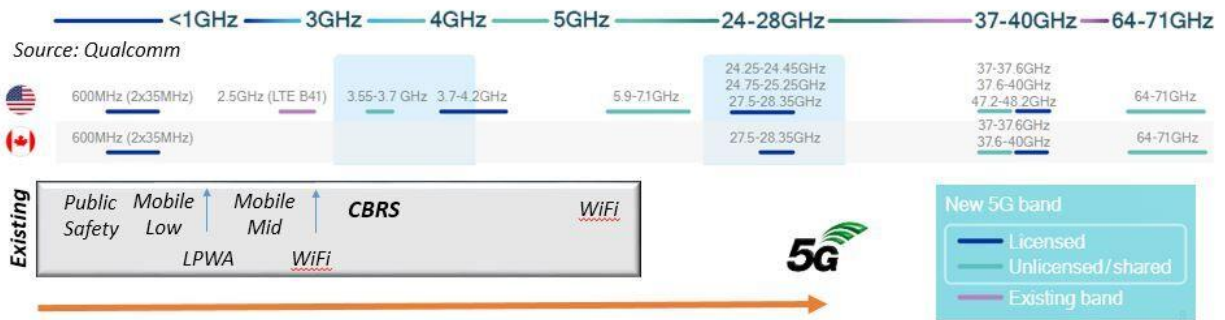
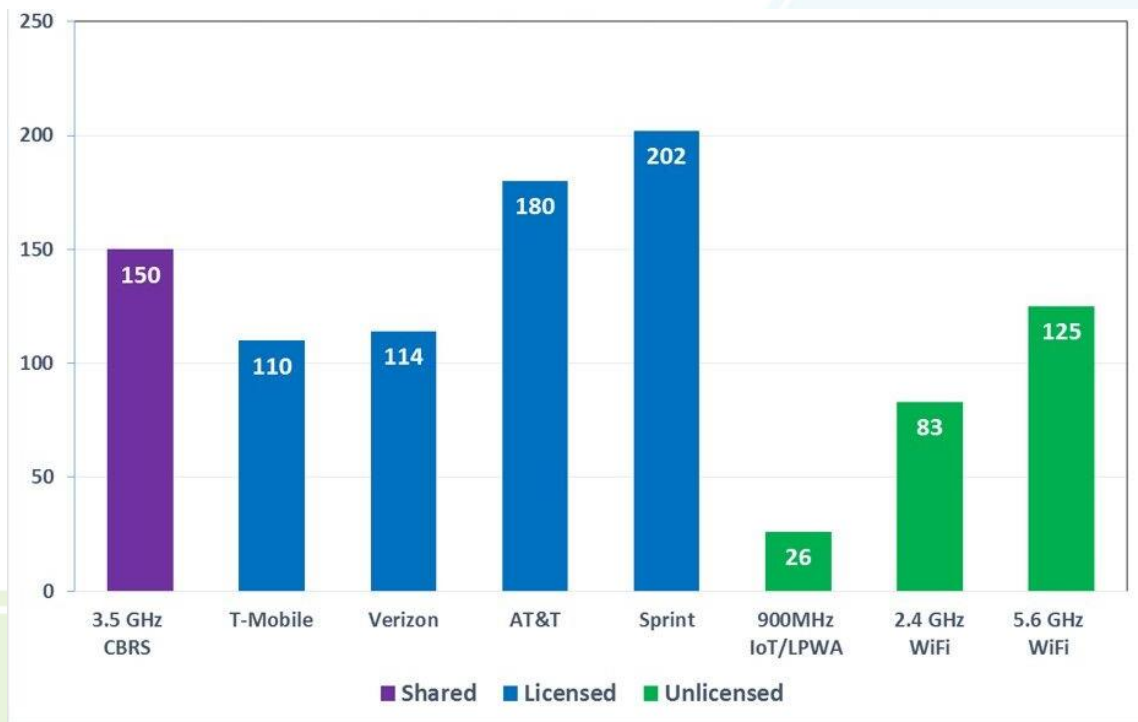


Figure 8 below shows how significant the additional 150 MHz of bandwidth is in relation to the current allocation to MNO licensed network bandwidth and unlicensed bandwidth used for Wi-Fi. New spectrum coupled with the ability of CBRS to support both licensed and unlicensed applications makes it a valuable asset for wireless connectivity.

Figure 8: Bandwidth Depth by Provider or Technology (MHz)



Licensed bandwidth depth is US national average from reference: <https://www.fiercewireless.com/wireless/2017-how-much-low-mid-and-high-band-spectrum-do-verizon-at-t-mobile-sprint-and-dish-own>

4.5 Planning and Design Tools

Most of today's off-the-shelf Wi-Fi planning tools have the ability to plan and design CBRS networks. These tools typically include coverage prediction ("heat maps") and validation ("walk test").

Figure 9: Heatmap Example

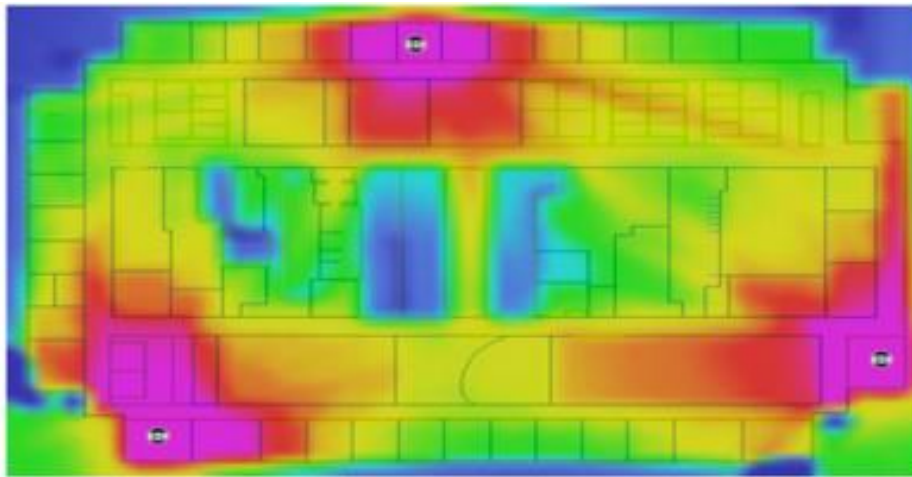


Figure 10: Walk Test Measurements Example

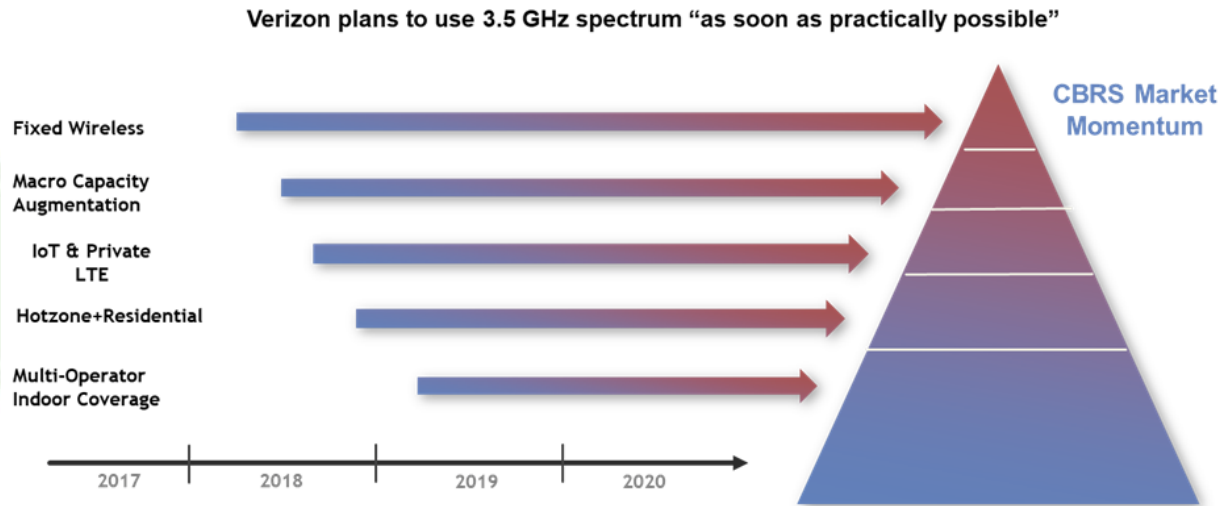


5 CBRS the FCC and Network Elements

5.1 Timelines

The CBRS Alliance expects the FCC to issue a final ruling and allow CBRS service by end of 2018.

Figure 11: CBRS Market Evolution



5.2 FCC Regulations

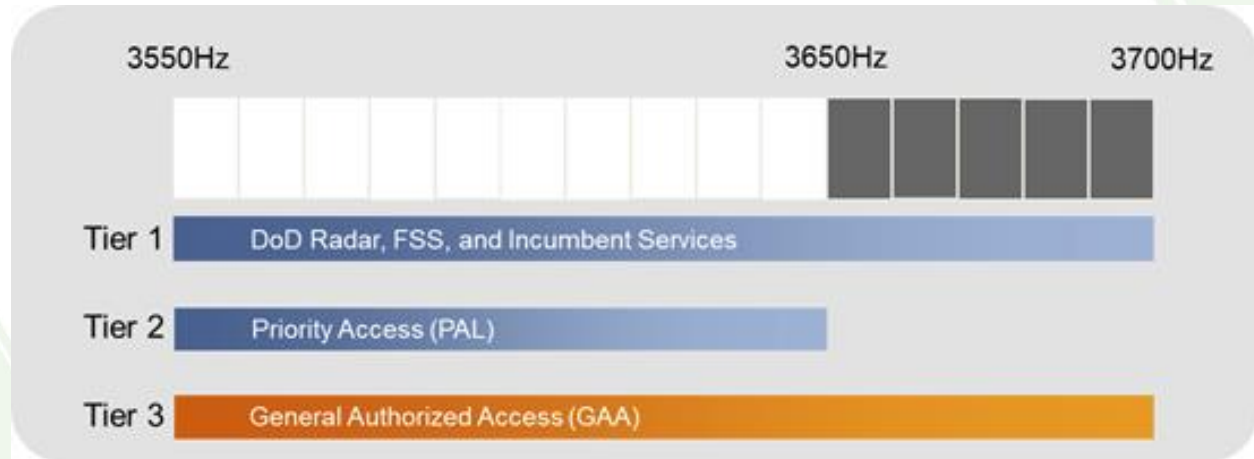
CBRS is a new and innovative scheme for allocating wireless spectrum in the United States. The goal of the new scheme is to strike an ideal balance between costly auctions for licensed spectrum, and the free, but interference-prone environment of unlicensed spectrum. The scheme and criterion for CBRS operations are codified in Part 96 of the FCC Rules and Regulations [WT Docket No. 12-354; FCC 16-55].

The following table compares the main characteristics of licensed, unlicensed and CBRS spectrum allocation schemes:

Allocation Scheme	Licensed	Unlicensed	CBRS
Rights	Exclusive	None	Exclusive over lower user tiers (IU > PAL > GAA)
Cost	\$\$ Billions	Free	Free with SAS subscription
Enforcement	Legal	Power Limits, "Listen Before-Talk"	Power Limits, Spectrum Allocation Service (SAS)

In summary, CBRS rules allow three tiers of users to request the use of one or more 10 MHz channels in the 3550 to 2700 MHz band on demand based on their exact geographical location and RF conditions.

Figure 12: Three Tiers of Users



- **Incumbent Users (IU):** These users have the highest priority, but usually occupy only a small portion of the band or are limited to a very small and remote geographic area. CBRS uses a Spectrum Allocation Service (SAS) to find unused portions of the band in highly-localized areas by combining FCC registration records, a network of RF sensors (ESC) and detailed RF propagation calculations. Any spectrum deemed unused by the SAS is made available to lower tier users. Of the incumbent users, only the 19 US Navy aircraft carriers can move (along the coasts) and change the portion of the band they use (at most two of the 15 CBRS channels at a time). The SAS uses the Environmental Sensing Capability (ESC) network to detect where the ships are and which channel they are operating in, and then, adjust its unused spectrum database accordingly.
- **Priority Access License Users (PAL):** These users have higher priority than GAA users for a fee. The fee will be determined at auctions and will likely depend on the geographical size and length of the license, but it is expected to be much lower than the fees the mobile operators pay for licensed spectrum. The final rules for PAL size and duration are still being defined by the FCC as of the time of this writing. PAL licenses are only available in the lower 10 channels of the band, but only 7 of those can be purchased in any given local area. At most four channels can be owned by the same legal entity. It's important to note that PAL users get priority access to spectrum only where and while it is being used, as determined by the SAS. This means that if the SAS determines a PAL user is not using the spectrum in a certain location, such as inside a private facility, the facility owner is free to use the spectrum as a GAA user. This is known as the "Use it or Share it" principle, and it enables efficient use of spectrum resources while preventing spectrum hoarding.

- **General Authorized Access (GAA):** These users get free access to any part of the CBRS band that the SAS determines is not being used by IU and PAL users at a given time and location.

5.3 Spectrum Access System (SAS)

- Provides real-time spectrum management to avoid interference, protect incumbent users and enforce license rights
- Dynamically assigns channels and power level
- Includes Environmental Sensing Capability (ESC) to detect presence of federal systems; ESC receivers are to be constructed along entire US coastlines
- ESC is expected to be available at the commencement of the CBRS service; if not, substantial limits are on the use of the 3550-3650 band
- Non-federal use is permitted when federal systems are inactive, but must go idle within one minute if federal system activity is detected
- Operated by FCC-approved commercial provider(s). If multiple providers are approved, they must coordinate among themselves.
- As of July 2018, the FCC has not officially approved SAS service providers but notified the public of conditionally approving up to ten entities to manage the 3.5 GHz band that includes: Amdocs, Inc.; Comsearch; CTIA-The Wireless Association; Federated Wireless; Google, Inc.; Key Bridge; Sony Electronics, Inc.; Rivada Networks LLC; Nokia; Fairspectrum LLC and RED Technologies: <https://www.fcc.gov/document/35-ghz-sas-conditional-approval-public-notice>
- Citizens Broadband Service Device (CBSD) operators will pay for SAS access. Prices and terms are unsettled
- All CBSDs must always be in real-time communication with an SAS and comply with its instructions
- CBSDs may be further organized into coexistence groups that operate in a coordinated manner

5.4 Further Network Element Operating Restrictions

CBRS rules also dictate some technical criteria for operation. Some of this criteria includes:

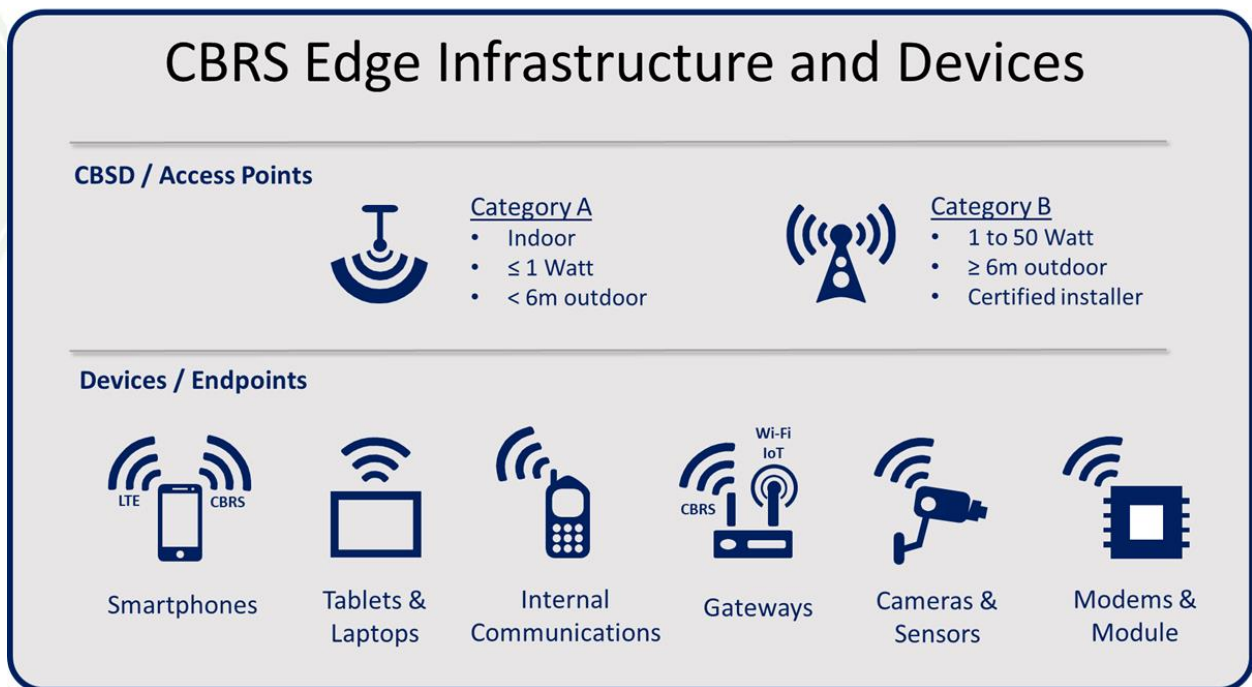
- Client devices can be fixed or mobile but are limited to 0.2W EIRP
- Base Station devices (access points) are limited to 1W EIRP indoors (Category A) and 50W EIRP outdoors (Category B)
- Base Stations must be fixed and report their exact GPS location to SAS before operating
- Base Stations must maintain a constant Internet connection to SAS and must stop transmitting within 10 minutes if the connection is lost
- Category B Base Stations (that are installed outdoors and at a height of more than six meters) require professional installation and certification of their locations

The rules for CBRS make it ideal for small cell deployments, especially indoors and in the more confined spaces found in the hospitality industry. CBRS enables facility owners or their managed service partners to deploy reliable LTE cellular networks the same way they deploy Wi-Fi today.

5.5 CBRS Devices

There are a wide variety of emerging commercial devices that will support CBRS. Components are now available with CBRS compatibility and can be found in some of the devices in Figure 13 below. A more comprehensive list of devices can be found in Appendix 8.2

Figure 13: CBRS Capable Premise Equipment, Devices and Endpoints Examples

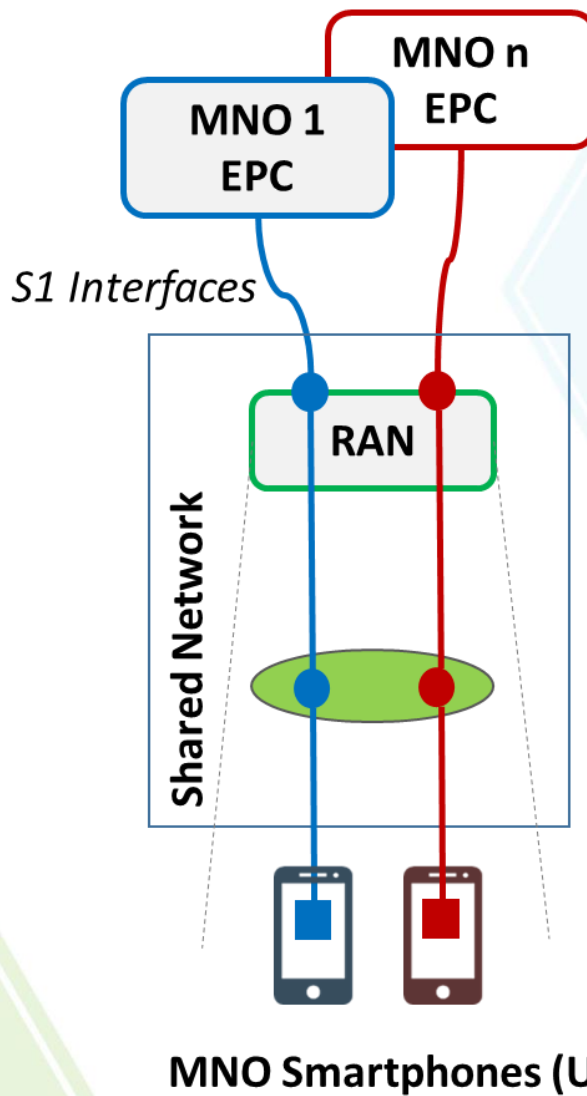


6 Public MNO Interface Considerations

6.1 Multi-Operator Core Network (MOCN)

The simplest option, as specified in 3GPP and referenced in CBRS Alliance specifications, is to connect using the S1 interface to one or more MNO core (MME/SGW) networks. This is referred to as a Multi-Operator Core Network (MOCN). In this approach, multiple PLMN-IDs are announced by the shared CBRS RAN (one for each MNO) and traffic is routed to the appropriate MNO core depending on which PLMN-ID the UE connects to. This approach currently is widely supported by many devices.

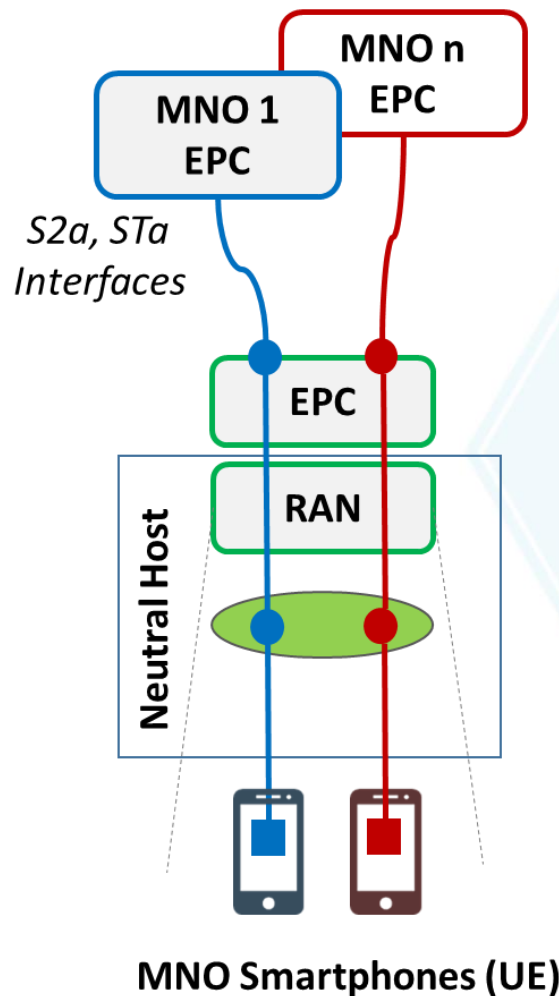
Figure 14: Multi-Operator Core Network Architecture



6.2 Neutral Host Architecture

A future approach, defined by the CBRS Alliance, is similar to Trusted Wi-Fi, where Wi-Fi networks are connected to the MNO packet core (PGW) using the S2a and STa interfaces. In this case, an additional core network is deployed on premise, on a private data center or in a private Cloud. The advantages are reduced load on the MNO's core network and fewer interfaces to it.

Figure 15: Roaming Interface Architecture

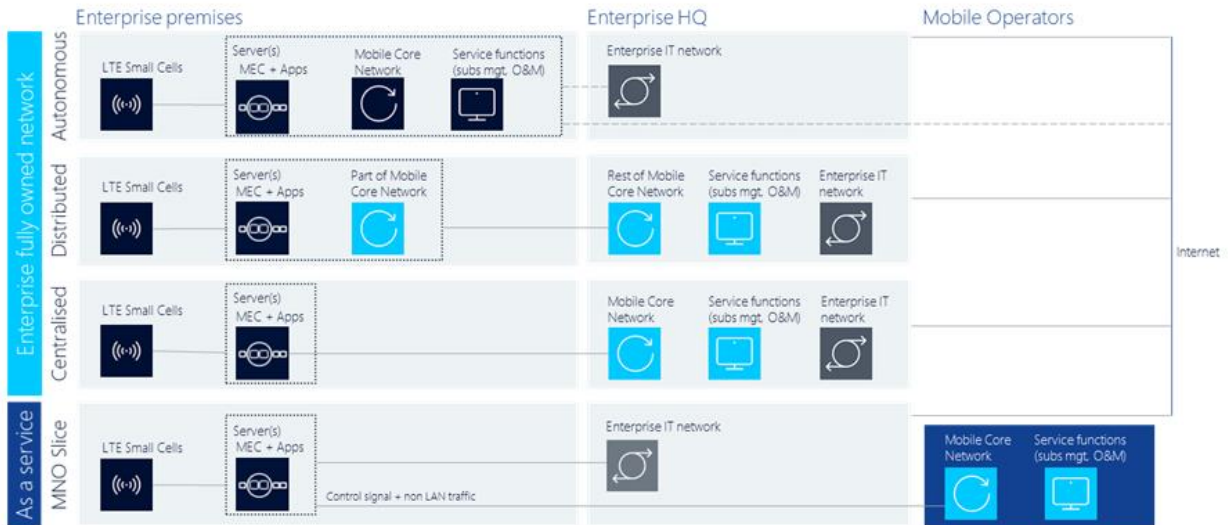


6.3 Private LTE & Core Networks

A number of Original Equipment Manufacturers (OEMs) are introducing technologies that leverage licensed, unlicensed and shared spectrums for the creation of robust, private, end-to-end networks for vertical industries. As shown in Figure 16 below, Nokia's solution uses LTE small cells, Multi-access Edge Computing (MEC) and core capabilities, along with global services expertise. An enterprise can deploy a fully functioning, autonomous and private LTE network to deliver the best possible experience for customers.

Figure 16: Private LTE Architecture & Core Solutions

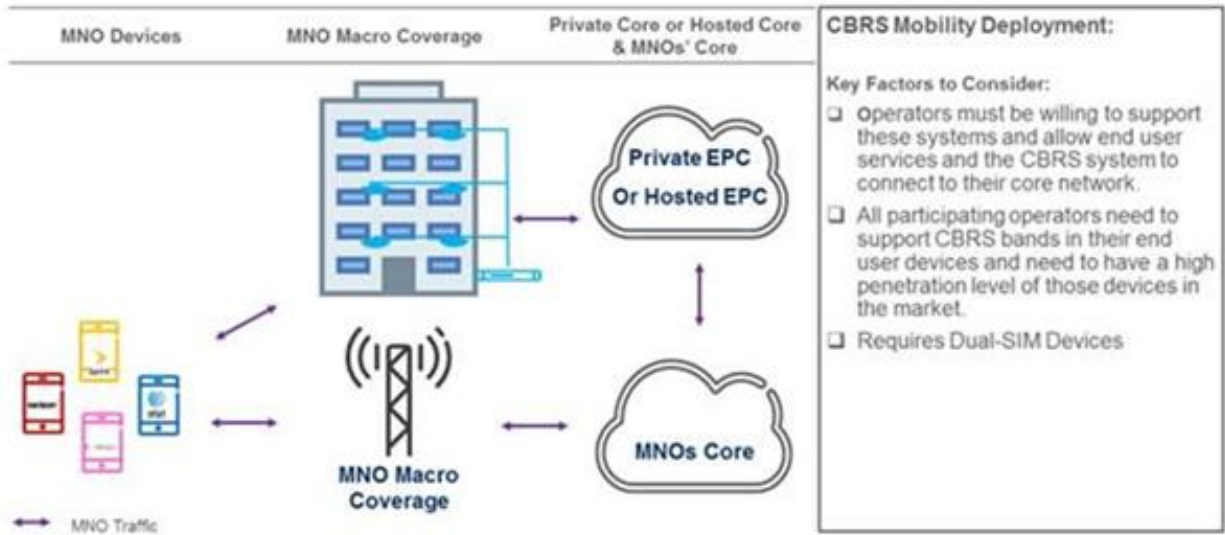
Bringing flexibility & simplifying LTE networks complexity



Source: Nokia CBRS Architecture

The hotel property, or CBRS network operator will need to have a system deployed which includes SAS functionality and either a private or hosted core network. It will also be necessary for the hotel or the hosted network provider to have an agreement in place with each MNO to allow the CBRS system to connect to their core network.

Figure 17: CBRS Neutral Host Roaming



Private networks based on LTE can take advantage of many of the evolved packet core features that are currently deployed in the wireless service provider's networks. The packet core

allows for standards-based central coordination of all the LTE base stations to create highly synced, secured and connected services across multiple sites. The separation of the control plane and the user plane in a coordinated LTE network allows the EPC to manage connected end user devices both for rules-based access between all of the base stations and end user devices connected to the EPC. In addition, it also allows the owner of the EPC to create and manage the service within the network down to the individual node or end user.

The EPC can be housed in a data center and leveraged to give centralized users access to network elements such as media gateways for VoIP or video conferencing, packet gateways for a single point of access to the public Internet, CDN access for hosted applications or video, and specialized services tailored to hotel guests and back office applications without risk of a non-authorized crossover. The EPC also allows for the monitoring and data collection occurring within the LTE network. Depending on the evolution of the CBRS ecosystem, the hotel-owned EPC will be the logical interface between the Private LTE network and the wireless operator's LTE network.

EPC vendors such as Ericsson and Nokia have developed the software and hardware needed to properly scale from small networks of a few hotels, to large solutions capable of managing an entire portfolio of hotels with an international footprint. The EPC ecosystem is evolving to allow a number of commercial options to best fit a hotelier's financial and technical needs.

These options include:

- The ability to directly purchase the hardware and software for datacenter deployment and management by a hotel's in-house IT staff
- Hosted cloud-based solutions which allow for a fully managed and elastic option
- A hybrid which allows for the hardware and software to be capitalized with the ongoing operations to be managed as a service to avoid adding specialized personnel to the hotel's IT staff

7 Conclusion

The coupling of LTE, the CBRS band and novel spectrum sharing solutions provide the platform for hoteliers to control their wireless access destiny. Soon, a property's network will enable them to manage and control the user experience; be it a guest, visitor, tenant, employee or IoT device.

By establishing a CBRS network based on LTE, natural interoperability is assured with current LTE standards-based network elements. From cellular-like services to Private LTE functionality, the network can seamlessly integrate with today's networks, the next 5G networks and the overarching heterogeneous (hetnet) networks of the future.

This white paper is the culmination of the HTNG CBRS for Hospitality Workgroup and the CBRS Alliance with the goal to communicate to hoteliers the capability and promise of this new band and ecosystem. This document should help readers understand the current state of the CBRS ecosystem, particularly where the standards and legal requirements are still being completed. The next deliverable of HTNG's CBRS for Hospitality Workgroup is to create a set of sample business models based on hospitality use cases that rely on applications that have a positive return on investment.

8 Appendix

8.1 Glossary

8.1.1 General

- **ARPU (Average Revenue Per User):** The average amount of money a subscriber spends each month on their wireless service.
- **CAGR (Compounded Annual Growth Rate):** A formula used to calculate the growth rate over a period of time.
- **Churn:** The percent of subscribers who discontinue wireless usage with the carrier in a given month.
- **CPGA (Cost Per Gross Addition):** The average marketing, handset subsidy and other costs incurred by an operator to acquire a new subscriber.
- **Penetration:** The percentage of a country or region's population that has adopted a given technology or service.
- **Postpaid:** The traditional method of service billing where the customer receives a bill at the end of the month detailing what they owe for the month's usage. Postpaid plans are generally packaged with service contracts that provide phone subsidies.
- **Prepaid:** A method of paying for wireless service prior to use, either by purchasing a bucket of usage at the beginning of the month, or drawing from an account with stored value on a per usage basis. Prepaid plans generally forgo service contracts or credit checks and are unlikely to provide phone subsidies.

8.1.2 Device Types

- **Embedded Modem:** A modem that is internally embedded in a device to give the device mobile broadband access. Most laptops and netbooks can be configured to come with embedded modems.
- **Ereader:** Ereaders are portable devices specifically designed for reading digital books, newspapers, magazines and other literary content. Though ereaders may perform a variety of functions, their focus on reading differentiates them from other devices. Examples include the Amazon Kindle, the Sony Reader and the Barnes & Noble Nook.
- **Feature Phone:** A conventional cellular phone for calls, SMS and other simple tasks with an ordinary, 10-digit keypad and usually, a camera.
- **Portable Modem:** A modem packaged in a portable form such as a USB Dongle or ExpressCard that can be used to give compatible devices mobile broadband access.
- **Smartphone:** A cellular phone that uses a recognizable operating system with an advanced web browser and the capability to install third party applications. Common smartphone operating systems include Apple's iOS, RIM's BlackBerry OS, Palm's webOS, Google's Android, Microsoft's Windows Mobile, and Nokia's Symbian Platform.
- **Tablet:** A portable computing device that, unlike laptops or netbooks, uses a touch screen as its primary method of input, not a mouse and keyboard. Tablets are

generally larger than smartphones, but smaller than laptops. One example of a tablet is Apple's iPad.

- **Texting Phone:** Similar to a feature phone, except has a full QWERTY keyboard, virtual or physical, for convenient messaging. Texting phones often have support for email, some form of web access and a music player.

8.1.3 Services

- **CAT-M1:** also LTE-CAT-M1, one of the 3GPP low power wide area network (LPWAN) radio technology standards to support IoT (or eMTC Machine Type Communications) with 1Mbit/s up and downlink capacity, narrow bandwidth (1.4MHz) and low power to extend battery life.
- **NB-IoT:** also LTE-CAT-NB1, similar to CAT-M1 above, yet narrower bandwidths (250Kbit/s up/down) and higher latency (1.6-10 sec.).
- **IM (Instant Messaging):** a form of live, text based communication between two or more users. A plethora of IM services exist and two users generally must be using the same service in order to chat. Popular IM services include AOL IM (AIM), Yahoo! Messenger, Google Talk (GTalk/GChat), and MSN Messenger.
- **IMS (IP Multimedia Subsystem):** a framework originally developed by the 3GPP for delivering multimedia services over an all-IP network, such as voice calling, messaging, video calling, IP TV or IP radio.
- **IoT (Internet of Things):** consists of devices that have been made intelligent through an ability to **communicate** and **interact** with the **physical world**.
- **MMS (Multimedia Messaging Service):** an improved version of the popular SMS that allows for the inclusion of larger amounts of text, images, audio and even video.
- **NFC (Near Field Communications):** a high frequency wireless technology used at an extremely short range. NFC is often implemented in wallet style cards (such as credit, identification or mass transit cards) as an alternative to magnetic strips. This allows users to make so called "blink" transactions where their card is held in front of a card reader instead of being slid through it. NFC chips can also be embedded in mobile devices to allow the device to make blink transactions.
- **SMS (Short Message Service):** often referred to as text messaging or simply "texting," SMS is a text-based communication service used to send short messages (generally under 160 characters in length) between mobile phones.
- **QoS (Quality of Service):** is the description or measurement of the overall performance of a service, such as a telephony or computer network or a cloud computing service, particularly the performance seen by the users of the network. To quantitatively measure quality of service, several related aspects of the network service are often considered, such as packet loss, bit rate, throughput, transmission delay, availability, jitter, etc.
- **VoIP (Voice over IP):** a term used to describe any service that provides voice communication over a network with IP-based architecture. This could refer to services such as Skype, which provide voice calling over the Internet's IP network, or a voice service for a carrier that is being delivered over an all-IP mobile network.

8.1.4 Network Technology

- **1G (First Generation):** a generic term to describe analog mobile telecommunication technologies such as AMPS (Advanced Mobile Phone System) and TACS (Total Access Communication System).
- **1X:** shorthand for CDMA2000 1X (also known as IS-2000), a 2.5G, CDMA-based technology developed by Qualcomm that builds on cdmaOne and is capable of peak data rates of 153 Kbit/s. 1X can be upgraded to 1X Advanced, which increases voice and data capacity.
- **2.5G:** a term used to describe mobile communication technologies evolved from 2G technologies that served as a transitional step to 3G networks, such as EDGE and 1X, which achieved higher voice and data capacity than their 2G counterparts.
- **2G (Second Generation):** a generic term to describe early digital mobile communication technologies, such as cdmaOne, GSM and iDEN.
- **3G (Third Generation):** technically used to describe technologies that fulfill the ITU's IMT-2000 requirement, but in practice a generic term to describe advanced wireless technologies that are capable of high data rates, such as UMTS and EV-DO.
- **3GPP:** Third Generation Partnership Project is a collaboration between multiple telecommunication associations, known as the Organizational Partners, with the principle goal of making a globally applicable 3G mobile phone system specification based on evolved GSM specifications. The 3GPP is designed to work within the scope of the IMT-2000 specs. Today, 3GPP is principally tasked with the development of LTE and LTE-A specifications.
- **4G (Fourth Generation):** used to describe technologies that fulfill the ITU's IMT-Advanced specifications, such as WiMAX 2 and LTE Advanced. 4G technologies have flexible channel bandwidths, peak speeds of 100 Mbit/s when mobile and 1.5 Gbit/s when fixed, high spectral efficiency, smooth handoff between different network types and a flat, all-IP network architecture. In practice, 4G is also used to describe technologies that nearly meet these requirements such Mobile WiMAX and LTE.
- **5G (Fifth Generation):** Initially, the term was defined by the ITU IMT-2020 standard, which required a theoretical peak download capacity of 20 gigabits. More recently, the industry standards group 3GPP has included any system using NR (New Radio) software. The 3GPP standards do not require any particular performance level. ITU has divided 5G network services into three categories: enhanced Mobile Broadband (eMBB) or handsets, Ultra-Reliable Low-Latency Communications (URLLC), which includes industrial applications, autonomous vehicles and Massive Machine Type Communications (MMTC) or sensors. Initial 5G deployments will focus on eMBB and fixed wireless, which makes use of many of the same capabilities as eMBB. 5G will use a spectrum in the existing LTE frequency range (600 MHz to 6 GHz) and also in millimeter wave bands (24-86 GHz). 5G technologies have to satisfy ITU IMT-2020 requirements and/or 3GPP Release 15; while IMT-2020 specifies data rates of 20 Gbit/s, 5G speed in sub-6 GHz bands is similar to 4G.

- **CBSD:** Citizen's Broadband Service Devices, also known as simply Base Station or Access Point. CBSDs can be Category A (1W EIRP limit) or Category B (50W EIRP limit, outdoors only).
- **CDMA (Code Division Multiple Access):** an FDD approach to wireless communications where each transmission is digitized and then tagged with a code. The mobile phone is then instructed to decipher only a particular code to pluck the right conversation off the air. The process can be compared in some ways to an English-speaking person picking out in a crowded room of French speakers the only other person speaking English.
- **cdmaOne:** a CDMA-based 2G network technology developed by Qualcomm that is also known by its technical name, IS-95, or just CDMA for short.
- **DAS:** Distributed Antenna System is a network of spatially separated antenna nodes that are connected to a common radio and provide wireless service within a geographic area or structure.
- **DRS:** A Distributed Radio System is a system of radios that connect directly to MNO base stations via fiber or CAT5 cable using standard 3GPP protocols. The system is coordinated with the outdoor network to better manage and mitigate interference for one or more service providers. This system is generally appropriate for medium-sized venues and buildings.
- **E-UTRAN:** Evolved UMTS Terrestrial Radio Access Network is the air interface for LTE.
- **EDGE (Enhanced Data rates for Global Evolution):** a 2.5G technology for GSM and TDMA networks that offers peak mobile data downlink speeds of up to 384 Kbit/s in end-user devices.
- **EIRP (Effective or Equivalent Isotropic Radiated Power):** the product of antenna gains and transmits power in a given direction relative to an isotropic radiator (which is equal in all directions). EIRP is typically stated in dBi and measured or calculated in the highest gain direction(s) of the antenna stating the highest radiated power envelope.
- **EMS:** Element Management Systems are the systems and applications used to manage network elements on the network element management layer (NEL) of the Telecommunication Management Network (TMN) model.
- **eNode B:** E-UTRAN Node B is the base transceiver station hardware in LTE networks. Node B uses the WCDMA/TD-SCDMA as the air interface technology. eNode B is therefore the enhanced version of Node B.
- **EPC:** Evolved Packet Core is the core IP processing functionality for LTE and beyond, as defined by the SAE (System Architecture Evolution).
- **EV-DO:** shorthand for CDMA2000 1xEV-DO (also known as IS-856), a CDMA-based 3G technology developed by Qualcomm and supported by the 3GPP2 that builds on 1X and supports entirely packet based networks. The first iteration of the technology, Rel. 0, can be upgraded to Rev. A, Rev. B, Rev. B Multi-Carrier with a hardware upgrade, and even EV-DO Advanced. Rev A, the most deployed version of the technology, is capable of peak rates of 3.1 Mbit/s in a 1.25 MHz channel.

- **FDD (Frequency Division Duplex):** segregates uplink and downlink operations into two spectrum bands of equal width (paired spectrum bands), which are separated by one or more other bands to avoid interference.
- **Fixed WiMAX:** the common name for 802.16d, since it does not support client or terminal mobility.
- **GAA (General Authorized Access):** The GAA tier is licensed by rule to permit open, flexible access to the band. GAA users will be allowed to use the 150 MHz band without any interference protection from other CBRS users. GAA users are permitted to use any portion of the 3550-3700 MHz band not assigned to a higher tier user and may also operate opportunistically on unused PA channels. Their frequency assignment is dynamically controlled by the SAS database.
- **General Authorized Access operators:** The third-tier GAA permits access to 80 MHz of the 3.5 GHz band that is not assigned to a higher tier. GAA operators receive no interference protection from PA or Tier 1 operators, and must accept interference from them.
- **GPRS (General Packet Radio Service):** a technology for data transmission on GSM networks.
- **GSM (Global System for Mobile Communications):** a TDMA based 2G air interface technology used throughout the world.
- **GWCN (Gateway Core Network):** one of the three main approaches to network sharing where the interworking takes place at the core network level.
- **HETNET:** Heterogeneous Network is a network connecting computers and other devices with different operating systems and/or protocols. In wireless, HetNet indicates the use of multiple types of access nodes, including macrocells, picocells, femtocells and/or Wi-Fi, in order to offer wireless coverage in an environment with a wide variety of wireless coverage zones.
- **HSPA:** High Speed Packet Access is an amalgamation of High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) that supports increased peak data rates of up to 14 Mbit/s in the downlink and 5.76 Mbit/s in the uplink. Evolved HSPA (also known as HSPA+) is a wireless broadband standard defined in 3GPP release 7 and 8 of the WCDMA specification that provides data rates up to 84 Mbit/s in the downlink and 22 Mbit/s in the uplink (per 5 MHz carrier with MIM) technologies and higher order modulation.
- **HSS:** Home Subscriber Server is the central network database that contains user-related and subscription-related information. The HSS provides mobility management, call and session establishment support, user authentication and access authorization. The HSS is based on pre-Rel-4 Home Location Register (HLR) and Authentication Center (AuC).
- **IA (Incumbent Access):** IA users include authorized federal and grandfathered Fixed Satellite Service users currently operating in the 3.5 GHz Band. These users will be protected from harmful interference from priority-access and general authorized-access users. IA users are primarily military ship-borne radar, military ground-based radar and fixed-satellite-service earth stations that receive but do not transmit.

- **Incumbent Licensees:** Consists of the incumbent federal users and fixed satellite service (“FSS”) operators. These incumbents will have complete interference protection from the two lower CBRS tiers.
- **iDEN (Integrated Digital Enhanced Network):** a 2G TDMA-based mobile communications technology developed by Motorola that provides users with the benefit of Push-To-Talk (walkie talkie style) communication.
- **IMS:** IP Multimedia Subsystem is an architectural framework for delivering Internet Protocol (IP) multimedia services, originally designed by the 3GPP as a part of the vision for evolving mobile networks beyond GSM.
- **IP (Internet Protocol):** typically an IP address is a numerical label assigned to each device connected to a computer network that uses the Internet Protocol for communication. An IP address serves two principal functions: a host or network interface identification and location addressing.
- **LAA (License Assisted Access):** a variant of LTE-Unlicensed standardized by 3GPP that adheres to the Listen Before Talk (LBT) protocol that enables LTE to coexist in unlicensed and shared frequency bands.
- **LSA (License Shared Access):** a concept developed within the European regulatory framework that is an approach to allow the application for shared spectrum authorization . This is similar to the ASA (Authorized Spectrum Access) in the US, similar to the new CBRS service in the 3.5GHz band.
- **LTE (Long Term Evolution):** a OFDMA based 3GPP standard, generally branded as 4G, that uses an all-IP flat network architecture and is capable of peak downlink speeds 100 Mbit/s and uplink speeds of 50 Mbit/s when deployed in a 20 MHz channel, and even higher rates if used with MIMO to deploy LTE in multiple channels. LTE is generally FDD, but also has an TDD implementation, TD-LTE.
- **LTE-Advanced:** a 3GPP standard that builds off LTE, offering even greater channel flexibility and peak data rates of more than 1 Gbit/s.
- **MIMO (Multiple Input Multiple Output):** the use of multiple antennas at both the transmitter and receiver to increase spectral efficiency and link reliability.
- **MME:** Mobile Managed Entity is the key control-node for the LTE access network. It is responsible for idle mode UE (User Equipment) tracking and paging procedures including retransmissions.
- **Mobile WiMAX:** the common name for 802.16e, since the technology includes support for high-speed client mobility. Mobile WiMAX networks are not backwards compatible with Fixed WiMAX networks and offer peak speeds of up to 40 Mbit/s in a single 20 MHz channel.
- **MOCN (Multi-Operator Core Network):** one of the three main approaches to network sharing where all of the network elements are shared for interworking, including spectrum, except the core networks.
- **MORAN (Multi-Operator RAN):** one of the three main approaches to network sharing where the baseband and RF are shared, yet there is an independent RRM (Radio Resource Manager) and service deployment.

- **MVNO (Mobile Virtual Network Operator):** the common name of a mobile network operator whose mobile services are actually on other licensed operator networks.
- **MulteFire:** is an LTE-based technology for small cells operating standalone in unlicensed or shared spectrum. MulteFire is envisioned to broaden the LTE ecosystem to new markets and new entities without licensed spectrum and deployments ranging from enhanced consumer experience for local area mobile broadband to private deployments for the industrial IoT.
- **NGMN:** Next Generation Mobile Networks Alliance is an industry association founded to develop a common solutions view of next generation wireless networks.
- **OFDMA (Orthogonal Frequency Division Multiple Access):** an advanced method of wireless communication that uses complex channel division methods to achieve minimal interference, high spectral efficiency and efficient use of MIMO.
- **PAL (Priority Access Licenses):** PAL users are allowed to have priority access licenses (PALs) between 3550-3650 MHz acquired through a competitive bid process conducted by the FCC. PAL users are protected from harmful interference from users in the general authorized access tier. They are assigned specific frequencies within their service area, and their frequency assignment should not be dynamically controlled by the SAS database. The PA layer could provide critical access to users at hospitals, utilities and government departments as well as MNOs. PAL users receive priority authorization for three years to operate within designated geographic areas with PALs. At the end of the term, the PAL will automatically terminate, may not be renewed, but may be reapplied for. License areas and terms for PALs are still being finalized by the FCC.
- **Priority Access Licensees:** PA licensees can aggregate up to four PA channels in any census tract at any given time. PA licensees must provide interference protection for Tier 1 incumbent licensees and accept interference from them. However, PA licensees are entitled to interference protection from GAA operators.
- **PGW (PDN Gateway):** PDN Gateway provides connectivity from the user equipment (UE) to external packet data networks by being the point of exit and entry of traffic for the device. A UE may have simultaneous connectivity with more than one PGW for accessing multiple PDNs. The PGW performs policy enforcement, packet filtering for each user, charging support, lawful interception and packet screening. PGW also provides for mobility between 3GPP and non-3GPP technologies such as WiMAX, CDMA 1X and EvDO.
- **RAN (Radio Access Network):** the physical radio layer at the front of each wireless network that provides the RF connection to the end user device.
- **S1 Interface:** The 3GPP defined single interface between the LTE RAN and the EPC. The S1 is comprised of the S1-CP (control plane) and S1-UP (user plane) and the signalling protocol is S1-AP.
- **S-GW:** Serving Gateway routes and forwards user data packets and acts as the mobility anchor for the user plane during inter-eNodeB handovers. The S-GW also manages mobility between LTE and other 3GPP technologies (terminating S4 interface and relaying the traffic between 2G/3G systems and PGW).

- **SAE:** System Architecture Evolution is the core network architecture of 3GPP's LTE wireless communication standard.
- **SAS (Spectrum Access System):** a continually updated database of CBRS users and sensors, their priority level, geo-location, operating parameters and additional detailed information. The SAS is designed to enable spectrum sharing by integrating the user information and allocating interference-free operating parameters of a requested new user.
- **SGSN:** Service GPRS Support Node is responsible for the delivery of data packets from and to the 2G and 3G mobile base stations within its geographical service area. Its tasks include packet routing and transfer, mobility management (attach/detach and location management), logical link management and authentication and charging functions.
- **SON:** Self-Organizing Network has been defined by the 3GPP and NGMN as a framework for functions on future radio access networks that make it easier to plan, conx, manage, optimize and correct radio networks.
- **TDD (Time Division Duplex):** a method of separating a channel's uplink and downlink signals by assigning each unique time slots, allowing use of a single, unpaired block of spectrum.
- **TDMA (Time Division Multiple Access):** a TDD method of wireless communication that allows many users to access a single radio frequency channel without interference by allocating unique time slots to each user within each channel.
- **UMTS (Universal Mobile Telecommunications System):** the 3GPP's standardized CDMA based approach to 3G cellular systems. UMTS includes technologies such as W-CDMA (Wideband CDMA), HSPA (High Speed Packet Access), and HSPA+. In a 5 MHz channel, HSPA+ can reach peak download speeds of 21 Mbit/s, or even higher if deployed with MIMO.
- **Wi-Fi:** Wireless Fidelity is a wireless network for connecting computing devices, as defined by IEEE 802.11 in the 2.4 GHz, 3.6 GHz and 5 GHz frequency bands.
- **WiMAX (Worldwide Interoperability for Microwave Access):** refers to set of implementations of the IEEE's 802.16 wireless network standards supported by the WiMAX Forum, which certifies vendor equipment to ensure interoperability. WiMAX requires an all-IP, network architecture, makes use of OFDMA, and generally uses unpaired, TDD spectrum.
- **WiMAX 2:** the common name for 802.16m, which is expected to be the first truly 4G WiMAX technology capable of mobile data speeds up to 120 Mbit/s in a single 20 MHz channel. 802.16m will succeed 802.16e, and it is backwards compatible.

8.2 List of Compatible CBRS Devices (as of August 2018)

The following list of devices is a sample of those that currently support 3.5GHz and may support CBRS with a software update when the FCC begins device certification later in 2018.

8.2.1 Smart Phones and Tablets

- Essential PH-1

- Apple iPhone X, iPhone 8 and iPhone 8 Plus [https://www.apple.com/iphone/LTE/\(Japanmarket\)](https://www.apple.com/iphone/LTE/(Japanmarket))
- Samsung Galaxy S9/S9+ [https://www.frequencycheck.com/models/GN4L0/samsung-sm-g965f-galaxy-s9-td-lte-galaxy-s9-plus-samsung-star-2\(Japanmarket\)](https://www.frequencycheck.com/models/GN4L0/samsung-sm-g965f-galaxy-s9-td-lte-galaxy-s9-plus-samsung-star-2(Japanmarket))
- LG V30 [https://www.frequencycheck.com/models/OYWDP/lg-v30-td-lte-128gb-l-01k-lg-joan-qvr\(Japanmarket\)](https://www.frequencycheck.com/models/OYWDP/lg-v30-td-lte-128gb-l-01k-lg-joan-qvr(Japanmarket))
- Sony XPERIA SZ [https://www.frequencycheck.com/models/vWk91/sony-xperia-xz-premium-td-lte-g8188-pf11-sony-maple-ss\(Japanmarket\)](https://www.frequencycheck.com/models/vWk91/sony-xperia-xz-premium-td-lte-g8188-pf11-sony-maple-ss(Japanmarket))
- Sharp AQUOS D [https://www.frequencycheck.com/models/vnMKx/sharp-aquos-r-compact-td-lte-sh-m06-sharp-w-095\(Japanmarket\)](https://www.frequencycheck.com/models/vnMKx/sharp-aquos-r-compact-td-lte-sh-m06-sharp-w-095(Japanmarket))

8.2.2 *IoT Devices*

- Sierra Wireless EM7565

8.2.3 *Mobile Hotspots and Getaways*

- [ARRIS NVG-558 Home Gateway](#)
- BEC Technologies CPE
- ZMTel CPE
- [JatonTech CPE](#)
- [BaiCells Atom Indoor CPE](#)
- Infomark MiFi
- Sercomm MiFi
- [Sierra Wireless MG90 Rugged Gateway](#)

8.2.4 *CBSDs*

- BaiCells Atom Outdoor CPE
- Corning SpiderCloud CBRS SCRNs and Services Node
- Ericsson Radio Dot RD4442
- Ericsson Radio 2208
- JMA Wireless CellHub
- Nokia Airscale Micro RRH
- Nokia FlexiZone Multiband Indoor BTS
- Nokia FlexiZone Multiband Outdoor BTS
- Ruckus Q710 Indoor LTE Access Point
- Ruckus Q410 Plug-in LTE Access Point
- Ruckus Q910 Category A Outdoor LTE Access Point
- Ruckus Q930 Category B Outdoor LTE Access Point
- Seowonintech Outdoor CPE

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<ul style="list-style-type: none"> • In Building Cellular 	Russell Vest, ExteNet
In Building Deployment	Juan Santiago, Ruckus Networks Lori Blair, Ericsson
<ul style="list-style-type: none"> • CBRS Network Hierarchy 	Juan Santiago, Ruckus Networks Lori Blair, Ericsson
<ul style="list-style-type: none"> • Possible Deployment Models 	Kurt Jacobs, JMA Wireless
<ul style="list-style-type: none"> • CBRS Frequency Bands 	Kurt Jacobs, JMA Wireless
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