CBRS Explained

Abstract:

Citizen Broadband Radio Service (CBRS) is a shared spectrum service with three tiers of users. The three tiers in ranked order of priority are the incumbent access (IA), priority access license (PAL) and general authorized access (GAA). CBRS uses LTE TDD as the radio access method and is not a new radio technology. CBRS is a dynamic spectrum control scheme using short term leases to enable services. This paper will briefly discuss many of the technical issues pertaining to specific CBRS that are not LTE -TDD specific.

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Quick Overview:

Citizen Broadband Radio Service (CBRS) is finally here. CBRS functions as a shared spectrum service with three tiers of users as defined by the FCC in CFR47 part 96. The three tiers in ranked order of priority are the incumbent access (IA), priority access license (PAL) and general authorized access (GAA). The incumbents using IA are federal radiolocation services (radar) and wireless internet service providers (WISP) who have priority over everyone else. On September 18th, 2019 the FCC green lighted the use of CBRS spectrum for General Authorized Access (GAA).

CBRS spectrum is located in the 3.5GHz band which is also referred to as the innovation band. CBRS is lined up to enable non-traditional wireless carriers to use and offer services. Using CBRS non-traditional wireless carriers can potentially offer services at significantly lower costs than the cellular carriers. CBRS also allows private wireless systems to be built supporting campus and inbuilding applications. The entry for non-traditional wireless carriers and private networks foster innovations that have been hampered due to recurring access fees. CBRS is important because it can unleash the true potential for IoT in the Industrial, medical, building, automation and hospitality industries besides others.

However, CBRS is not a new radio technology but a radio technology that is governed by an active shared spectrum policy. The shared spectrum policy controller is called a spectrum access system (SAS) and is the unique component to a CBRS network. The SAS interfaces with the Citizen Broadband Radio Service Device (CBSD) which is an eNB or small cell in Figure 1. The SAS controls the CBSD that is using the CBRS spectrum to control when it can and cannot transmit. The SAS controls the RF transmission of the CBSD to protect users that have a higher priority in the shared spectrum process. The tiered priority for CBRS is where IA is higher than a PAL which is higher than a GAA. The protection however is by license or 10MHz and not for individual subscriber or IoT devices.

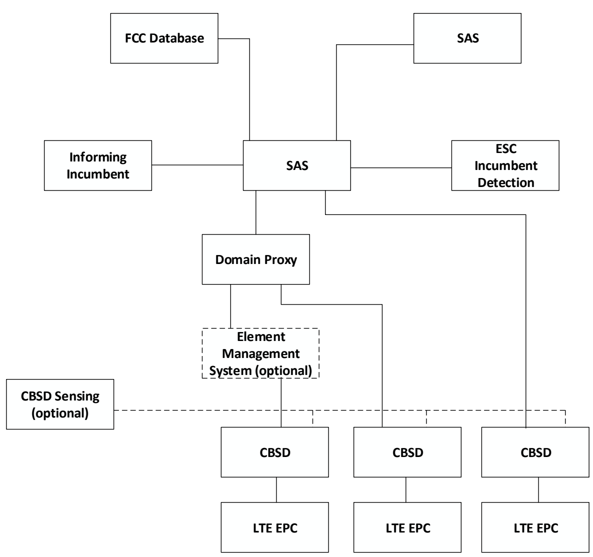

Figure 1: CBRS Reference Architecture Network

CBRS uses LTE wireless access technology that uses the LTE band 48 that is meant for Time Division Duplex (TDD) wireless access. CBRS using LTE can support LTE CatM and LTE NB-IoT besides other LTE capabilities. CBRS is also planned to support 5G in the near future offering a roadmap for future capabilities. For IoT applications CBRS using LTE technology opens up an entire ecosystem.

Presently there are several small cell providers for CBRS. Right now, there are smart phones which can operate in the CBRS band you can obtain. This is all great and there are more devices and infrastructure platforms which will be available in the interim.

The overall objective of this paper is to provide some clarity regarding many of the CBRS issues that need to be addressed when offering services using CBRS. However, RF coverage is not included in this paper since that is the primary focus of most of the other articles and papers. If there is good RF coverage CBRS service can be delivered otherwise it will not work.

Regardless of how the service is actually delivered and the mechanisms that are in place combining both LTE and CBRS unique functionality need to be understood. Because CBRS is new and incorporates a lot of topics with new platforms it is still evolving in terms of specifications and functionality. Since CBRS is about to begin commercial service offerings using GAA with a limited subscriber device eco system corrections to things forgotten and those learned requiring modifications will take place.

For example, how will 5G be rolled out into a CBRS environment as well as the Neutral Host capability. They are still undefined ensuring revisions and modifications going forward with a vast list of items that need to be clarified. However, we are here and waiting for everything to be solved which will mean lost market opportunities for new entrants.

So, what exactly is CBRS and how does the shared spectrum process work. This paper will begin to dive into some of the details of CBRS giving the reader a solid understanding of what CBRS is and how you can possibly utilize this new technology.

This is indeed an exciting time to be in wireless.

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CBRS

Radio spectrum is a limited resource and unfortunately technology cannot create new spectrum. However, technology can be used to improve the utilization of spectrum through spectrum sharing.
CBRS is a spectrum allocation scheme that uses spectrum sharing. CBRS however is not a new radio access technology. The CBRS band is 150MHz wide band in 3.5GHz spectrum from 3550MHz to 3700MHz.

CBRS commercial service will use LTE as the radio access method. There are numerous advantages with using LTE including roaming, enhanced security, low latency, high bandwidth and a large existing ecosystem. CBRS enables private LTE cellular networks to be deployed in a manner similar to Wi-Fi.

CBRS enables non-traditional wireless carriers to ~~use of~~ offer services. Using CBRS non-traditional wireless carriers can potentially offer services at significantly lower costs than the cellular carriers. CBRS also allows private wireless systems to be built supporting campus and inbuilding applications. The entry for non-traditional wireless carriers and private networks foster innovations that have been hampered earlier due to non-availability of commercial off the shelf technology (COTS) and recurring access fees.

Federal, state and local governments along with enterprise companies using CBRS will be able to build their own private LTE networks with COTS technology. By using COTS equipment versus more proprietary equipment a network can be purpose built at significantly less cost.

The CBRS frequency band is a shared spectrum band and there are three tiers of users as defined by the FCC in CFR47 part 96. CBRS's three-tier access system, multiple users share the spectrum, and because of the users' different location and needs, the overall efficiency and utilization of the spectrum will increase.

The three tiers in ranked order of priority are the incumbent access (IA), priority access license (PAL) and general authorized access (GAA). The incumbents using IA are federal radiolocation services (radar) and wireless internet service providers (WISP) who have priority over everyone one else. This spectrum is being used by U.S Navy, fixed satellite service (FSS) providers and utilities, hence FCC defined wireless broadband usage rules for interference protection and uninterrupted usage for these existing incumbent users from the commercial usage.

The CBRS spectrum use is governed by an active shared spectrum policy. The shared spectrum policy controller is called a spectrum access system (SAS) and is the unique component to a CBRS network. The SAS is an external entity to an LTE network and interfaces with an eNB or small cell controlling when the small cell or eNB can and cannot transmit using the CBRS spectrum. The SASs purpose is to protect incumbent users that have a higher priority in the shared spectrum process for interference from commercial users in the CBRS band.

The CBRS band is defined as LTE Band 48 which is really LTE Bands 42 and 43 that have been combined creating 150 MHz of spectrum allocation. LTE Band 48 is a Time Division Duplex (TDD) band meaning the CBRS devices transmit and receive information on the same LTE channel as Wi-Fi does. The LTE channel size for CBRS is 10MHz which affords a total of 15 possible channels of 10MHz in the CBRS band.

However, there are some caveats to the CBRS channels because CBRS is a shared spectrum band and has three tiers of users; IA, PAL and GAA. At this moment only the IA and GAA users are defined. On

September 5th the FCC put out a notice for proposed rulemaking (NPRM) regarding the PAL portion of CBRS. The PAL users and their spectrum allocations are expected to be finalized in the first quarter of 2020. CBRS rules allow CSBD users to request up to four of the fifteen 10 MHz channels that can possible be used in the CBRS band. However, for right now CBRS is available for commercial service offerings using GAA allocations.

The CBRS band has many objectives. One stated objective is CBRS will help expedite the deployment of 4G mobile networks primarily with the PAL licenses that have not been finalized. For IoT applications CBRS using LTE technology opens up an entire ecosystem. CBRS using LTE can support not only traditional mobility applications but LTE CatM and LTE NB-IoT capabilities. CBRS is also planned to support 5G in the near future offering a roadmap for future capabilities. For IoT applications CBRS using LTE technology opens up an entire ecosystem.

There presently are several small cell providers for CBRS. Right now, there are smart phones which can operate in the CBRS band you can obtain. This is all great and there are more devices and infrastructure platforms which will be available in the interim.

Regardless CBRS will play an important role in the democratization of wireless spectrum for IoT in the Industrial, medical, building automation and hospitality industries besides others. The democratization will occur by allowing new entrants to use and offer a wide range of wireless services previously relegated to the domain of the commercial wireless carriers.

CBRS Tiered Spectrum Sharing

CBRS spectrum availability is based on a shared spectrum approach which has three tiers of users defined in it. Each tier of users in the CBRS band has unique priority requirements over the next forming a tiered priority access scheme.

The three tiers of users in CBRS are as follows.

1. Incumbent access (IA) holders
2. Priority Access License (PAL) holders
3. General authorized access (GAA) holders

The rank is rather straight forward and is represented by the CBRS priority pyramid of Figure 2. Within the same geographic area, the IA holder has the most priority and can force a PAL or GAA to relinquish or move to another CBRS channel to protect the incumbent from being interfered with. The PAL license holder has priority over a GAA license holder. A GAA license holder will need to relinquish or move to another CBRS channel to protect an IA or PAL license holder.

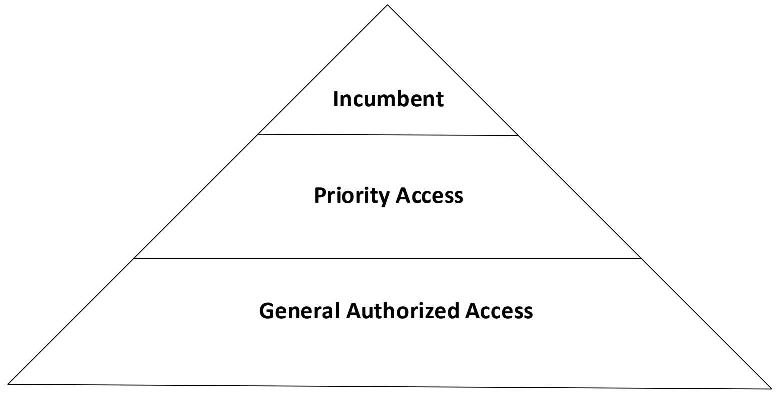


Figure 2: CBRS Hierarchy Pyramid

The decision for whom has priority either to relinquish or move to another CBRS channel is directed from the SAS shown in Figure 1.

What exactly is an IA, PAL, and GAA is best be described next.

a) Incumbent Access (IA): IA license holders have absolute priority over other type of allocation between 3550-3700MHz. Incumbents have unrestricted spectrum access and do not need SAS authorization to use it. They also are not required to inform the SAS of their use of the spectrum.

IA users include authorized federal users from 3550-3650 MHz in the CBRS frequency band which is primarily the US Navy. The Navy radar has a 1.6 MHz transmission bandwidth affecting up to two CBRS PAL or GAA channels at any time. Fixed Satellite Service (FSS) using 3600-3650MHz in the CBRS band for the space-to-Earth link. The third IA are wireless broadband licenses that are between 3650-3700MHz in the CBRS band and for a finite period they are grandfathered. Incumbent Access users receive protection against harmful interference from Priority Access Licensees and General Authorized Access users.

b) Priority Access (PA): The PA license holders consists of 10MHz channels which are licensed as a Priority Access Licenses (PALs) between 3550-3650MHz. The PAL allocation however does not include all of the CBRS frequency band. However, PAL licenses will completely overlap with IA radar signals. PALs are planned to be licensed on a county-by-county basis through a competitive bidding process. However, the PAL rules have not been defined right now and an FCC NPRM was issued on September 8th, 2019 seeking comment on clarifying the PAL bidding process and rules.

It is currently planned that the PAL licenses will only be issued on a county basis and will be 10-year licenses that are renewable. 100MHz of the CBRS band shown in Figure 4 defined for PAL use only 70MHz will be allocated in each county. A total of 7 PAL licenses will be made available per county with the maximum one PAL holder can have is 4 PAL licenses, 40MHz. The reason for the maximum of 4 PAL licenses is to prevent spectrum hoarding.

PAL licenses can also request from the SAS spectrum that is allocated for GAA usage to augment their capacity. However, the GAA assignments will not have the same level of priority as PAL.

However, a PAL licensee can partition and disaggregate their awarded PAL license(s). PAL licensees can also be partially assigned to another entity or outright transfer their licenses. A PAL license holder may enter into de facto transfer leasing arrangements for a portion of their licensed spectrum opening up secondary markets for use of the spectrum. Additionally, PAL license holders can also lease all or part of PAL the bandwidth or for a short duration of time.

No matter how the PAL license holder decided to utilize its spectrum asset it is still subject to buildout requirements. The buildout requirements are defined in CFR 47 part 96 along with the other PAL license rules.

c) **General Authorized Access (GAA)**: GAA users will have access to almost the entire 150MHz of the CBRS frequency band between 3550-3700MHz. The GAA channel size is 10MHz as is the case with PAL channels. GAA users are subservient to IA and PAL users resulting in their relinquishment of the RF channels to protect wither IA or PAL users. However, a GAA while being required to not cause harmful interference to IA and PAL users there is no such provision between other GAA users. No other GAA user will have priority over another GAA user which means that they all have to cooperate to co-exist.

One interesting issue is that GAA spans the entire CBRS band. The PAL licenses constitute 70Mhz of the 150MHz CBRS spectrum which means if all 7 PAL licenses are being used in a county then 80MHz can be counted on for GAA use. However, if there are less than 7 PAL licenses acquired in the auction process those PAL allocations are then converted to GAA use only in that county. Therefore if 5 PAL licenses for a county are auctioned then 20MHz is added to the 80MHz giving 100MHz of spectrum for exclusive GAA usage in that county. Of course, the IA will have preference over that repurposed 20MHz in this example.

With the CBRS GAA now becoming available the use cases for CBSDs using GAA spectrum versus PAL spectrum will be significantly different. GAA spectrum is meant for localized coverage primarily for inbuilding, factory and campus environments. The GAA use cases are for private communication systems, industrial controls and building automation. PAL use cases are expected to be used for more macro coverage applied to outdoor coverage supporting or competing against incumbent wireless operators.

Spectrum

CBRS has 150MHz of contiguous spectrum allocated to it. The CBRS band being150MHz in total begins at 3550 MHz and ends at 3700 MHz. CBRS is unique in that it is a shared spectrum approach that can be applied for many other spectrum bands freeing up underutilized spectrum for commercial applications.

Figure 4 shows the CBRS spectrum and the three tiers of users that share the CBRS band. The tiered users have a ranked priority with Tier 1 (IA) having priority over Tier 2 (PAL) and Tier 2 having priority over Tier 3 (GAA).

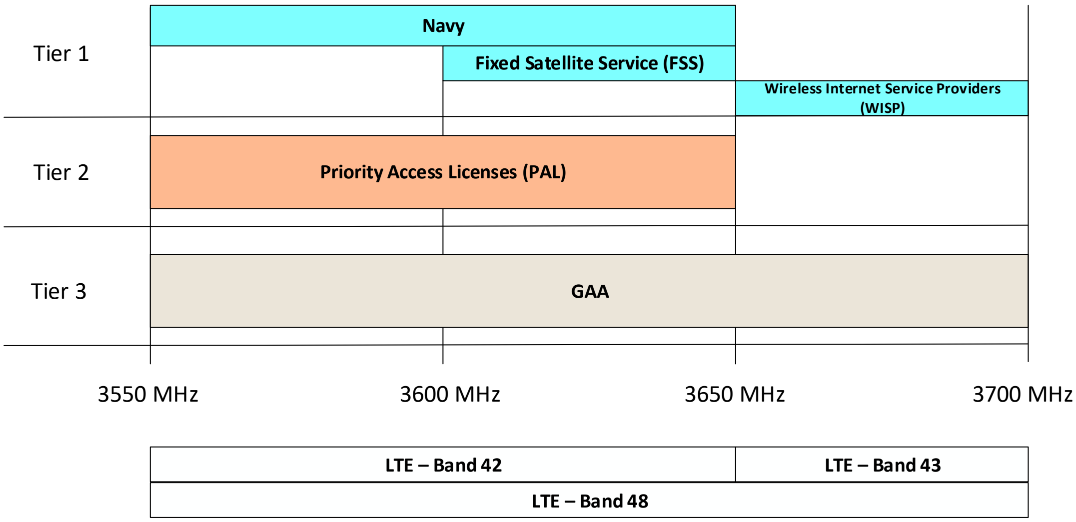


Figure 3: CBRS Spectrum

The CBRS band follow an ITU LTE band plan as indicated in Figure 3. LTE band 48 is made up of LTE bands 42 and 43. The LTE band 48 is broken into channels. The CBRS channel is a 10MHz Time Division Duplex (TDD) unpaired channel. There is a maximum of 15 10MHz TDD channels in the CBRS band.

However, CBRS has the flexibility of assigning the 10MHz allocation in 5MHz increments as shown in Figure 4. Therefore, based on the interference a 10MHz CBRS channel can be from 3600-3610MHz or 3595-3605MHz. It is even possible to have two RF carriers that are not adjacent be combined through carrier aggregation.

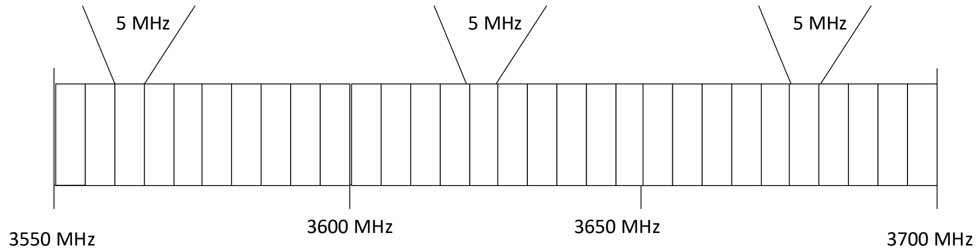


Figure 4: CBRS Channel (5MHz increments) 10MHz = 2x5MHz

The CBRS allocation scheme follows the following equation for a 10MHz channel allocation.

$[3550+(kk-1)*5, 3550+kk*5]$ where kk is from 1 to 30.

The reason for the CBRS channel allocation using the equation is to allow flexibility in the assignment of the CBRS channel due to interference mitigation.

CBRS is a 10MHz TDD LTE channel. Although LTE TDD has many possible configurations to best support uplink and downlink traffic patterns. CBRS however only has two approved LTE TDD channel configurations and they are a 6DL/2UL and 4DL/4UL. The LTE TDD approved CBRS channel configurations are shown in Figure 5. In Figure 5 D is downlink, U is uplink and S is a special subframe.

		Subframe number									
	UL:DL ratio	0	1	2	3	4	5	6	7	8	9
0	4:4	D	S	U	U	D	D	S	U	U	D
1	2:6	D	S	U	D	D	D	S	U	D	D

Figure 5: CBRS LTE TDD Channel configuration options

CBRS Architecture

CBRS is basically an LTE TDD system that has a dynamic spectrum allocation (DSA) scheme. The DSA scheme is controlled by a Spectrum Access System (SAS). The SAS defines which spectrum the LTE TDD CBSD, cell, will utilize. Once the spectrum assignment is done then everything functions like a normal LTE system with the exception of the spectrum monitoring and potential reallocation by the SAS to prevent interference with users in the CBRS band based on a tiered priority level.

CBRS uses LTE with some additional components as well as unique operating features. A CBRS network can be a private LTE system that is meant to be independent of a commercial wireless carrier. The CBRS network can also ROAM with a commercial wireless carrier. Additionally, a commercial wireless carrier can use the CBRS band to augment its capacity and coverage needs either by deploying their own CBSD nodes, leasing CBSD nodes or participating in a neutral host CBSD node.

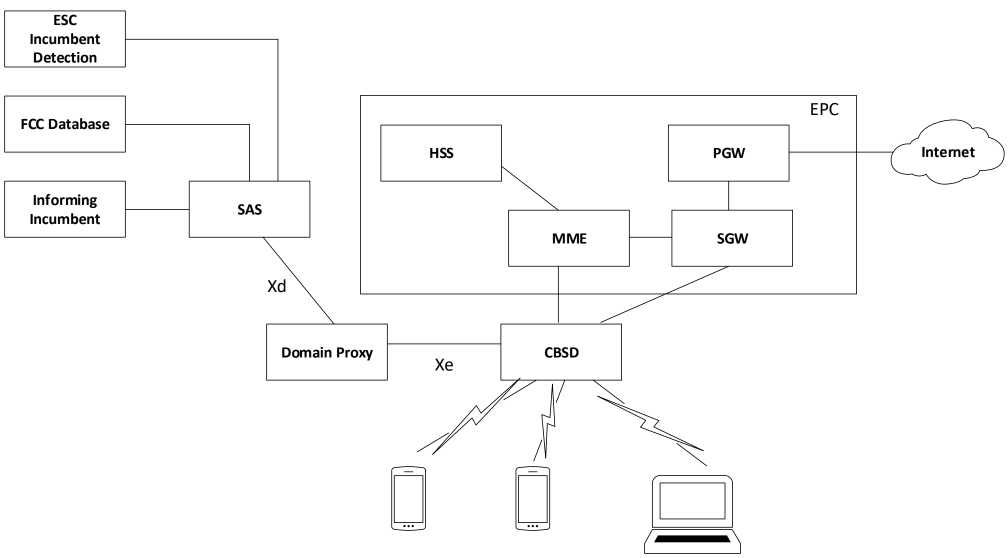


Figure 6: High Level Architecture

The diagram shown in Figure 6 representing a CBRS network with only one CBSD for drawing simplification upon closer inspection except for the spectrum assignment portion is an LTE TDD system.

The new components introduced in a CBRS network include:

- Spectrum Access System (SAS)
- Environmental Sensing Capability (ESC)
- Domain Proxy (DP)
- Citizens Broadband radio Service Device (CBSD)

The other components which the CBRS network interfaces to which are unique include the FCC data base and a method to inform incumbents though an API interface.

SAS (Spectrum Access System)

The SAS is the main control point for many CBRS networks. The SAS controls the grants, leases, for spectrum based on a three-tier process acting as a dynamic policy controller using a tiered priority access method for PAL and GAA allocations in the CBRS band. The SAS enables a tiered priority access scheme protecting the higher tier users from lower tier users using radio capacity in a geographic area which is by county or grid. The SAS enables the delivery of the grant or lease request for a CBSD to use spectrum resources.

The SAS spectrum policy enables many commercial users to share spectrum with incumbent federal and non-federal users of the CBRS band on a shared basis.

The SAS uses inputs from the ESC as well as RSSI measurements taken from CSBDs to determine the current state of the CBRS band for allocation and possible reassignment. This process is similar to that used by FirstNet in support of public safety users.

The SAS Administrators also have to respond to interference complaints from Fixed Satellite Service (FSS) licensees in the CBRS band.

There are several SASs that will be used across the US to manage CBRS spectrum allocations. Many SASs are needed to improve latency as well as manage the amount of transactions that take place since there are over 3200 counties in the US, each having its own CBRS spectrum management scheme.

The tiered priority access approach used by CBRS allows the incumbents to have unrestricted spectrum access and do not need SAS authorization to use it. Additionally, the incumbents are not required to inform the SAS of their use of the spectrum unlike CBSDs. Incumbents are granted ruthless preemption over PAL and GAA users in CBRS.

Presently there are several approved SAS Administrators for CBRS, and they are listed below in alphabetical order:

- Amdocs, Inc.
- CommScope
- Federated Wireless
- Google
- Key Bridge
- Sony Electronics, Inc. (Sony)

PAL and GAA have the ability to choose the SAS they will use in any market. However, it is envisioned that the particular SAS selected will be closely coupled to the CBSD vendor selected because most equipment includes an optional subscription to one or more SAS providers.

The functional depiction of a SAS is shown in Figure 7 in its relationship with CBRS elements.

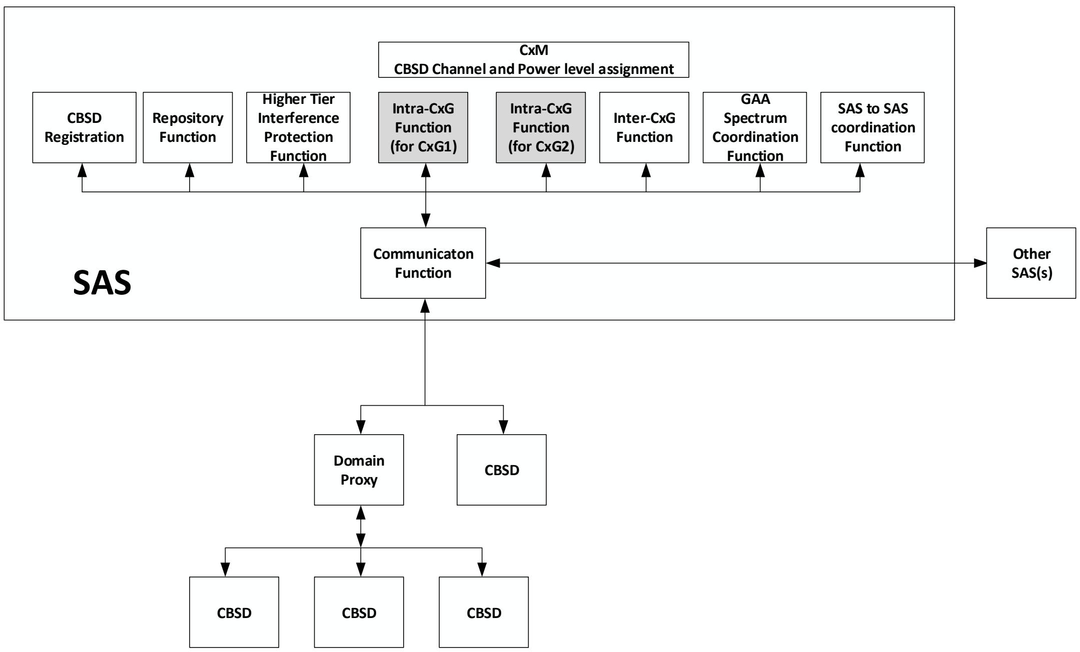


Figure 7: SAS functional depiction

A SAS can consist of several functional blocks shown in Figure 7.

a) CBSD registration Function is the functional block which registers and deregisters a CBSD from the network. It also is responsible for assigning the userID and grantIDs.

b) Repository Function is a functional block that stores various data records and datasets that are retrieved from External Databases that the SAS interfaces with. The Repository Function can also store the results of Higher Tier Protection Function by county IDs assigned to CBSDs, both the Intra and Inter Coexistence Groups (CxG) Functions.

c) Higher Tier Protection Function is a functional block that receives ESC feeds and CBSD interference data. The higher tier interference protection function then uses this information to protect incumbent and PAL license holders.

d) Intra-CxG Coordination Function is a functional block that coordinates the CBRS spectrum within a specific CBRS Group (CxG). A CxG group are CBSDs which are logically grouped together. For example, CBSDs on the same floor of a building can be grouped as a CxG. The Intra-CxG Coordination Function can be moved outside of the SAS domain in an optional configuration with CBRS.

e) Inter-CxG Coordination Function is a functional block that coordinates the CBRS spectrum between CBSDs belonging to different CxGs.

Inter- and Intra-CxG Coordination Functions can also do:

- Identification of Potential Interference Relationship between CBSDs
- Generation of the Recommended Channel Information
- Interference Resolution by changing CBSD channels being used

f) GAA Spectrum Coordination (GSC) Function coordinates the use of GAA Resources among different CxGs to minimize interference from GAA Resources. With GAA CBSDs are grouped in CxGs where each group will manage the interference within its own group.

With GAA groups of CBSDs are often on the same channel, and this grouping information is defined by the following group types:
• Coexistence Groups (CxG).
• Interference Coordination Groups (ICG)
• Common Channel Groups (CCG)

The GSC performs the inter-CxG interference coordination for GAA spectrum users. CBSDs are configured as a particular CxG. To complicate things a little more a CxG can be part of a one or more Interference Coordination Group (ICG)s. What is important is CSBDs in an ICG group are capable of managing interference among themselves.

A CBSD be part of a Common Channel Group (CCG) which are a subset of the CBSDs for an ICG. In the CCG all CBSDs use the same channel assignment issued from the CxM.

A critical assumption with GSC with both Inter and Intra CxG coordination is that all the LTE-TDD CBSDs use the same TDD configuration use the same time reference for synchronous transmissions and receptions for all sub carriers to minimize CBSD to CBSD or UE to UE interference.

With CBRS although the SAS assigns the spectrum available for GAA it does not coordinate access among GAA users at any given location. That is why GAA users have to employ coexistence methods. At this time there is no spectrum method used for intra or inter GAA coordination.

However, to use CBRS spectrum both PAL and GAA users need to obtain authorization from the SAS in order to transmit. SAS operates in real time because PAL and GAA spectrum availability and demands are constantly changing. GAA spectrum availability is a concern however the availability of CBRS spectrum is expected to be reliable and stable through time primarily in inbuilding applications.

In summary the SAS coordinates the use of available spectrum among CBSDs that request access. The SAS authorizes access for PAL users in locations where there is no incumbent activity and makes available the remaining spectrum to GAA registered CBSDs.

ESC (Environmental Sensing Capability)

The ESC is essentially a collection of sensors that detect incumbent usage and alerts the SAS to clear parts of the CBRS band for the priority users. The sensors are typically deployed along the coast to detect the presence of Navy radars. However, the ESC sensors can be located inland in support of other functions.

ESCs can and will detect any incumbent, federal frequency use, in and adjacent to the CBRS frequency band and make this information available to the SASs in real time. Based on the ESC information provided the SAS can determine the CBRS channels that a PAL and GAA can utilize.

A SAS can use an independent ESC or have its own ESC in a CBRS license area. There can also be multiple ESCs in a CBRS license area.

Domain Proxy:

The Domain Proxy (DP) is a dynamic spectrum coordinator that implements the grant or lease information from the SAS and administers it to the CBSDs under its control. A DP essentially communicates with the SAS on behalf of multiple individual CBSDs or networks of CBSDs

The domain proxy is able to aggregate messages from several CBSDs to the SAS and can receive aggregated messages from the SAS to be distributed to CBSDs.

The DP also can perform Intra-CxG coordination for interference migration and capacity control for CBSDs using GAA.

Figure 8 shows functional blocks that comprise the DP.

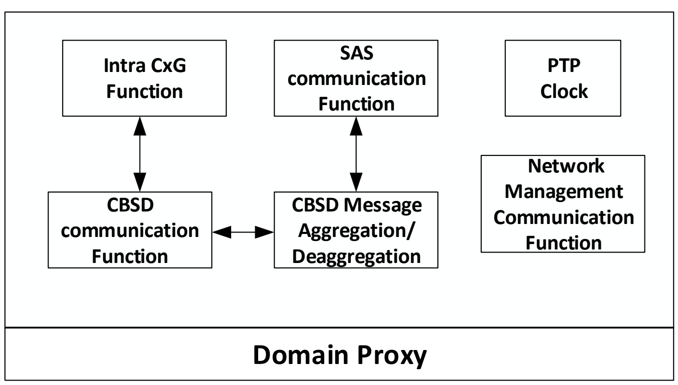


Figure 8 Domain Proxy Functional Blocks

CBSD (Citizens Broadband radio Service Device):

A CBSD is the radio access point for a CBRS network. In a CBRS network there can be thousands of CBSDs. A CBSD is an LTE eNodeB with some additional capabilities. The eNodeB can be a full eNodeB or a Remote Radio Head (RRH) that is connected back to the Base Band Unit (BBU). In later releases of CBRS the CBSD will be a 5G nGR using a radio unit (RU), distributed Unit (DU) and a centralized unit (CU).

The CBSD can have the ability to measure RF interference. This function is supposed to be optional however it is essential for GAA operation.

A CBSD is the radio access point for CBRS devices using PAL or GAA spectrum assignments. Figure 9 is a depiction of the functional blocks of a CBSD. The CBSD functions are additional capabilities beyond a typical LTE eNodeB.

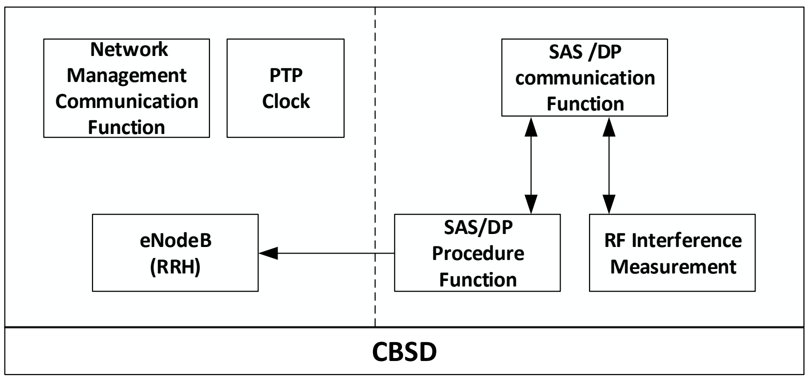


Figure 9: CBSD Functional Blocks

CBSDs can be either category A or category B devices. Examples of category A devices include access points, femto cells etc. which can operate either indoors or outdoors with lower antenna gain than category B devices. Category B devices are for outdoor use only with higher EIRP/antenna gain.

Table 2 below is a brief summary of the differences between CBSD categories.

Category	A	B
EIRP (per 10MHz)	30dBm	47dBm
Location	Indoor/outdoor <6m AGL	Outdoor
Certified (professional install)	No	Yes

Table 2: CBSD categories

GAA can be used for both indoor and outdoor coverage. GAA devices have lower power than PAL capable devices. However, GAA CBSDs will be used for indoor only until the PAL auctions have concluded and PAL usage begins.

It is important to note that with CBRS the use of relays or repeaters is not allowed. More specifically CBSDs cannot utilize a mesh network using CBRS spectrum.

User Equipment (UE)

With CBRS there are five (5) UE profiles that are defined. Most of the UE profiles have two sims, usims, or a single sim. However, UE profile 1A and 5 have no-sim profiles which require a different method for authentication to gain access to the TDD LTE system in CBRS.

A CBRS end user device is a typical consumer device like smartphone or an IoT device, NB-IoT or CatM.

The end user device has a maximum EIRP of 200 mW, similar to regular cellular handsets used on commercial wireless licensed frequency bands.

The number of CBRS capable devices is growing constantly. The following URL can be used to quickly determine the present ecosystem of UE devices that support the CBRS band.

www.cbrsalliance.org/certification/

However, if the application is IoT the sim method becomes very important since there is typically only one sim for NB and CatM. The bottom line is that the UE capabilities with regards to authenticating on the CBRS network is a very important consideration when determining what services and functions you want to deliver. Obviously, the UE selected needs to support the service or services you are delivering with CBRS capabilities.

CBRS Identifiers

These are numerous identifiers which are applicable to CBRS. The CBRS specific identifiers are userId and grantId. The userId identifies to the SAS who the CBSD network owner is. The grantId identifies the specific spectrum grant, or lease, given by the SAS which the DP implements. There are also the CxG identifiers which define the GAA grouping and interactions.

The rest of the CBRS identifiers are identifiers used in any LTE wireless network. However, these LTE identifiers used in a CBRS network need to be not only defined but, in most cases, secured through a third party like the CBRS Alliance.

The identifiers that are LTE related for CBRS are:

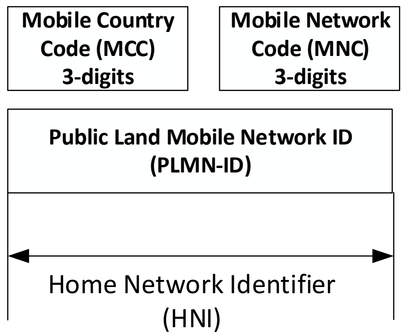
- PLMN ID
- Network ID
- IMSI
- MME ID
- ECGI

There of course are other identifiers that reside in both an LTE and CBRS network. However, the above 5 need to be understood for a CBRS service deployment.

PLMN ID

The Public Land Mobile Network (PLMN) ID is the home network identifier (HNI). The UE reads the broadcast message from the LTE control channel and determines if the network that the CBSD is associated with matches the PLNM ID list in the UE uSIM/eSIM.

The PLMN ID is made up of both a three-digit mobile country code (MCC) and a two- or three-digit mobile network code (MNC). An example of a PLMN ID is shown in Figure 10.



315-010

Figure 10: PLMN-ID

However, for CBRS presently there is only one PLMN for all CBRS operators. The PLMN ID used for CBRS is 315 – 010 and is shared with all other CBRS networks.

CBRS-NID – Network ID

The Network ID for CBRS is amply called the CBRS-NID. The CBRS-NID is a CSG-ID or closed subscriber group ID in LTE. The reason for CSG-ID /CBRS-NID is because every network has the same PLMN ID. Therefore, to differentiate each network a separate CBRS NID is needed and this is achieved by defining a CSG-ID for each operator or location.

The CBRS-NID should be by location facilitating possible transfer of the assets later.

So, for CBRS there is a common CBRS PLMN-ID and a specific enterprise or network NID, CSG-ID.

The CBRS-NID is assigned by the CBRS Alliance and can be purchased by members and non-members of the CBRS Alliance. There is a setup fee as well as a yearly maintenance fee per CBRS-NID. As of September 27, 2019, the Assignment Fee(setup) is $25 and a $15 annual maintenance fee per NID.

IMSI

The International Mobile Subscriber Identifier (IMSI) is also important to CBRS operation. Each UE whether it is a smart phone or IoT device needs to have its own IMSI to function in a CBRS LTE TDD network. However, a UE can have several IMSIs if it has two uSIMs where each uSIM is associated with a different PLMN.

The format of an IMIS is shown in Figure 11.

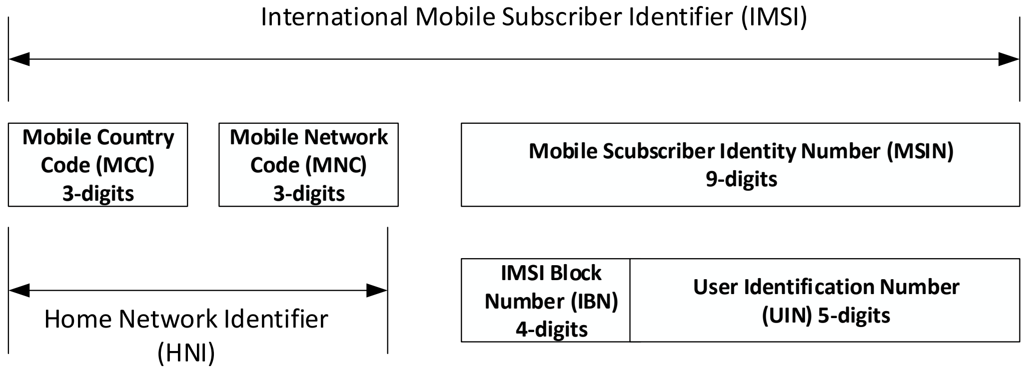


Figure 11: IMSI

With an IMSI the MCC and MNC, as the Home Network Identifier (HNI), is used to identify a shared CBRS HNI. The shared HNI for CBRS is 315-010. The HNI is the PLMN ID that is broadcasted by the LTE TDD control channel.

The mobile subscriber identify number (MSIN) consists of both an ISMI block number (IBN) and a User Identification Number (UIN).

Since the HNI is already defined for CBRS the IBN is what is applied for to obtain unique IMSI numbers. There is a total of 10k IBN numbers available and within each IBN there can be 100k unique numbers.

However, there are a few IBNs which are already defined. There currently are two IBNs set aside.

- 0000 – Unassignable
- 9999 – Test Purposes

When ordering IMSIs they are obtained in blocks of 10k numbers. However, to order IMSIs, rather IBNs, you need to provide some justification to prevent hoarding numbers. There is an application fee which right now is $325 and a yearly maintenance fee of $325 per block. The following link describes in detail the process of obtaining a range of IMSIs.

https://www.atis.org/01_committ_forums/ioc/docs/IMSI-CBRS-Guidelines_v1.1.pdf

MME IDs

In an LTE network the MME is part of the authentication and mobility process. Each MME in an LTE network has four identities which define it.

- MME code (MMEC)
- MME Group Identity (MMEGI)
- MME identifier

- Globally Unique MME Identifier (GUMMEI)

The MMEC uniquely identifies the particular MME. The particular MME can be part of an MME pool. A group or pool of MMEs is assigned an MMEGI. The MMEC and MMEGI are both used to create a MMEI. A MMEI uniquely identifies the MME within a particular CBRS network. The MMEI relationship with the MMEC and MMEGI is shown in Figure 12. The MMEI can serve multiple CBRS NIDs.

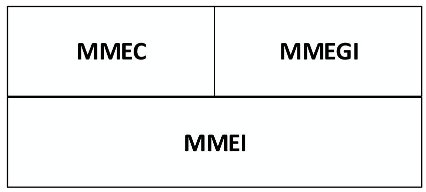


Figure 12: MMEI

The GUMMEI is obtained by combining the MMEI with the PLMN-ID. The GUMMEIs purpose is to uniquely identify the MME anywhere in the world. The GUMMEI is important for roaming and other functions. Figure 13 shows the relationship between the PLMN-ID and the MMEI for creating the GUMMEI.

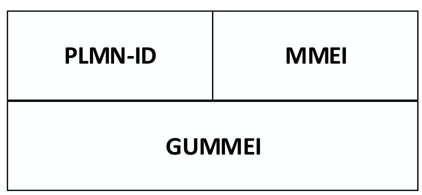


Figure 13: GUMMEI

The GUMMEI however is assigned by the CBRS Alliance if you do not have a GUMMEI already. The only reason you would already have a GUMMEI is if you had an LTE network or were leasing EPC core network functions from a third party.

A GUMMEI assignment can be purchased by members and non members of the CBRS Alliance. There is a setup fee as well as a yearly maintenance fee per GUMMEI. As of September 27, 2019, the Assignment Fee (setup) is $75 and a $50 annual maintenance fee per GUMMEI where a total of 256 MMEGIs are provided per GUMMEI.

At this time, it is unclear if a CBRS provider utilizes containers for rolling out localized EPCs how the GUMMEI allocations will work based on the non-SaaS assignment scheme.

EUTRAN Cell Global Identifier (ECGI)

The ECGI is how you identify an LTE cell or sector and it made up of three unique identifiers. The ECGI is a globally unique ID and is made up using HNI (PLMN ID), E-UTRAN cell identity (Cell ID) and the eNB ID.

The Cell ID which typically ranges from 0 to 503 in value is unique and is used to distinguish the LTE cell from its surrounding neighbors. The Cell ID of course needs to be unique. In a large CBRS network it is possible to have many Cell IDs of the same value, but these are further differentiated with the use of eNB ID.

In Figure 14 eNB ID and Cell ID are combined to form an ECI. The ECI is used to identify the particular cell within a PLMN.

The ECI and the PLMN-ID are combined to form the ECGI as depicted in Figure 14. The ECGI is very unique and can be used to identify the cell anywhere in the world.

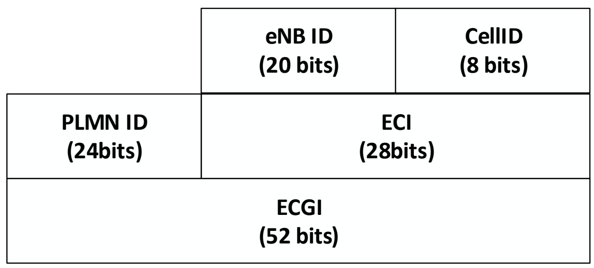


Figure 14: ECGI

The ECGI assignment is another item that is purchased by members and nonmembers of the CBRS Alliance. There is a setup fee as well as a yearly maintenance fee per ECGI as the CBRS alliance references it. However, the ECGI assignment is really an eNB ID since there is only one shared PLMN with CBRS. Additionally, there is only 256 Cell IDs that are associated with an eNB ID as per the CBRS alliance.

As of September 27, 2019, the Assignment Fee (setup) is $1 and a $1 annual maintenance fee per ECGI/eNB ID for a total of 256 Cell IDs.

Tracking Area ID

A Tracking Area ID (TAI) is another important identifier in an LTE network. Each tracking area has two main identities. The tracking area code (TAC) identifies a tracking area within a particular network. The TAC is used to manage registrations and paging as well as handling dormant UEs which is very applicable to IoT.

The TAI which defines a unique global tracking area id is made by combining both the PLNN-ID and the TAC as shown in Figure 15.

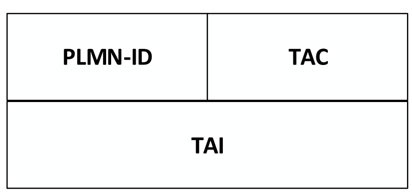


Figure 15: TAI

The TAI assignment is another item that is purchased or rather obtained by members and nonmembers of the CBRS Alliance. There is no setup fee or yearly maintenance fee with the TAI. However, the TAI only enables 6 TACs per IBN. This may be good for enterprise and inbuilding applications. However, for PAL deployments this may prove difficult as the CBRS alliance references it.

How does CBRS work:

Now that we have dispensed with a lot of technical issues with CBRS the question that most likely arises is how does this work. Because CBRS is a dynamic policy controller for an LTE network the LTE functionality will not be covered. However, what will be covered next are some of the unique functions of a CBRS network.

With CBRS the unique actions taken by a CBSD involves:

- Registration of the CBSD
- Spectrum Inquiries
- Grants (temporary spectrum leases)
- Heartbeat
- Relinquishments – surrendering of the RF channels

To start with, the CBSD needs to register with the SAS in order for to use the CBRS spectrum.

Therefore, when a CBSD is powered on, it must register with SAS. The CBSD however must first find a SAS it can register with. Once it finds a SAS to use it then provides its device category (A or B), its geographic location, whether it is allowed to use PAL spectrum or just GAA. This registration will be coordinated through the Domain Proxy.

The SAS then authorizes the device based on a set of factors like the availability of CBRS band in the location reported by the device, category of the device, FCC compliance of the device and other factors. The authorization is then passed back to the DP which in turn lets the CBSD know the channel and power level in which it can operate. Also, during CBSD operation, SAS can change the frequency or adjust the power levels of the device to protect higher priority levels. The DP can also make channel adjustments as well to protect uses in the same tier.

For example, when there is detected incumbent usage by the ESC, an alert will be sent to SAS which then takes necessary frequency reallocation decisions to clear channels, if occupied by PAL or GAA. In case there are no available channels, GAA users will be asked to relinquish their spectrum. SAS also manages interference protections from tiers 2 and 3 into tier 1, within tier 2 and from tier3 into tier 2 (where tier 1 – incumbent, tier 2 – PAL and tier 3 – GAA).

Figure 16 is helpful in understanding what information is sent between the CBSD/DP and the SAS.

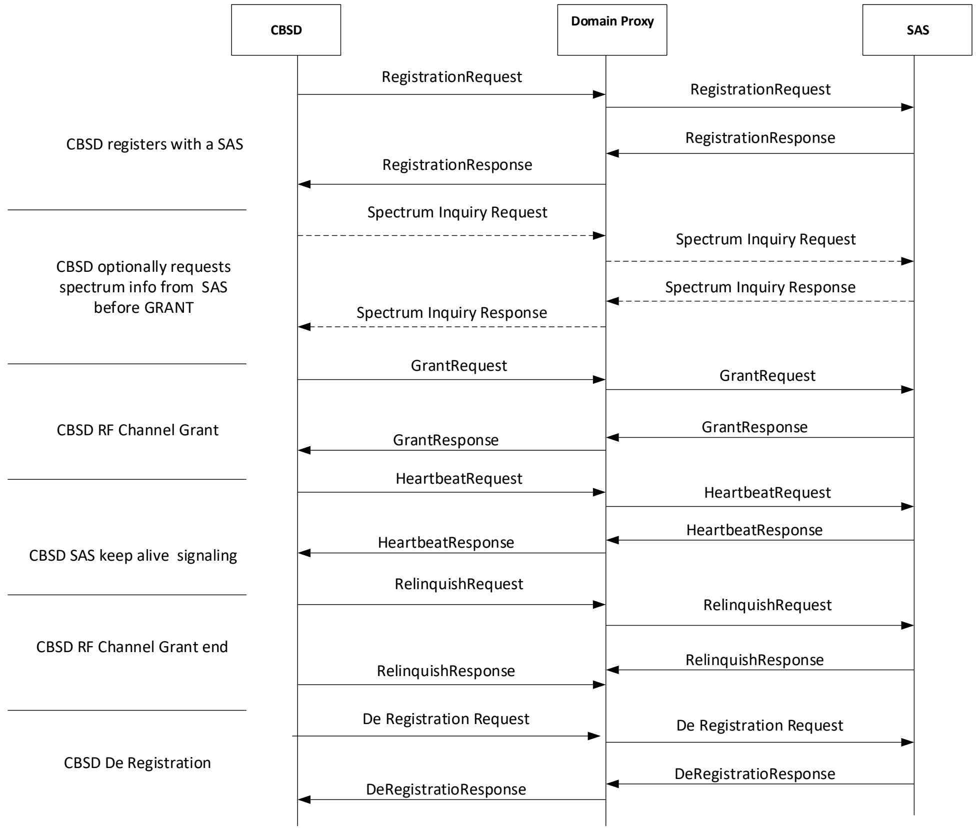


Figure 16 CBSD and SAS Messaging

The details of what is contained in each of the messages can be found in Appendix A. However what follows is a brief description of each of the major processes.

Registration: All CBSDs need to be registered with the SAS in order to be allowed access to the CBRS spectrum. Registration is typically done via a DP. The registration is achieved after the SAS associated with the CBSD has been found to communicate with and the SAS authenticates the CBSD. When there are numerous CBSDs that need to be registered at the same time the DP organizes this into an array.

The SAS will respond to the registration put forth either for the individual CBSD or a group of CBSDs. If the response is a group of CBSDs then the SAS will organize the response in an array to the DP. The DP then will then send the registration responses to the appropriate CBSD.

The registration response for the CBSD contains the cbsdID which is used and a key identifier for all subsequent communication.

Spectrum Inquiry: With a Spectrum Inquiry the CBSD is asking to know what spectrum is available for use according to the SAS. The spectrum information is used to help determine what the CBSD will request in the Grant Request message.

Grant Request: The Grant Request is where the CBSD asks for spectrum to use. The Grant Request can contain information obtained from the Spectrum Inquiry or it can ask for spectrum anywhere in the CBRS band. The SAS knows the particulars of the CBSD asking for the spectrum due to the cbsdID that is sent along with the request.

Grant Response: The Grant Response is sent in response to the Grant Request. The Grant Response has specific parameters including time of the grant/lease to start and end, the frequency range it can use as well as power levels. Included in the grant response is the grantID and a heartbeat interval. However just getting a Grant Response with a grantID does not authorize the CBSD to begin transmitting. The CBSD upon getting a positive Grant Response needs to have gone through one heartbeat cycle/procedure.

Heartbeat Request: The heartbeat request message is used to manage the spectrum used by the CBSD. The heartbeat process allows for the suspension and or termination of the Grant itself. The CBSD initiates the heartbeat process before the expiration of the heartbeat time interval or as soon as it receives a successful grant response by sending a heartbeat request. The heartbeat request has the cbsdID as well as the grantID. The time interval with the heartbeat is the duration of time the CBSD is allowed to use the CBRS spectrum and hence the reason the CBSD sends the heartbeat request before the expiration of the heartbeat interval timer has expired.

Heartbeat Response: The heartbeat response basically restarts the heartbeat time interval and allows the CBSD to continue transmitting. However, the time interval can be changed in the response to the CBSD as well as the particular channel frequency the CBSD is using. The response can also suspend or terminate the Grant.

Relinquish: The relinquish process begins from the CBSD and occurs when the CBSD decides it no longer needs to use the CBSD spectrum. The CBSD in the process identifies itself with the cbsdID and grantID. Upon receiving the CBSD relinquish response the CBSD stops transmitting, can happen earlier, and the spectrum that was being used is now made available for other CBSDs to utilize.

DeRegistration: The CBSD can deregister itself from the SAS. There are many reasons why deregistration can take place including picking a different SAS provider. The CBSD can also be deregistered due to maintenance reasons or simply because the device is being decommissioned.

CBRS Usecases

With the GAA being made available now CBRS gives enterprises a cost-effective way to own, deploy, dimension and manage standalone cellular networks on premises, in a spectrum band that is clean and does not require an expensive license.

With small businesses having access to the spectrum that is currently unavailable to them, CBRS enables several use cases that may not have been possible due to RF coverage, recurring access costs, network autonomy and others.

If CBRS can be used to help solve your particular situation the objective of what you need to solve needs to be clearly defined. Upon defining the objective determining if CBRS is the right fit will be answered by determining where your solution fits within the CBRS ecosystem

The CBRS ecosystem can be broken down into three roles. The three roles involved in CBRS service use cases are the Service Provider, CBRS Network Operator, and the Subscriber.

Service Provider (SP): The CBRS SP authenticates and authorizes its subscribers on the CBRS network either using PAL licenses or GAA. The SP is directly responsible for providing services to their subscribers.

There however are many different forms the SP can be. The SP can act as a Mobile Network Operator (MNO), Mobile Virtual Network Operator (MVNO), Private Network Provider (PNP).

CBRS Network Operator (CNO). The CNO essentially deploys a CBRS network to provide the connectivity and facilitate the delivery of services from the SP. The network topology for a CNO varies depending on the business model objective. Examples of different CNO topologies include macro cell coverage, public venues (malls, airport and city squares), enterprises, hotels, commercial buildings, and factories. A SP can also be a CNO.

The Subscriber in CBRS is the person, organization and device that is receiving services via a CBRS network. The subscriber is authenticated and authorized by one or possibly more SPs it has a service agreement with. The subscriber after being authenticated and authorized is then provided the relative service from the SP via the CNO.

Neutral hosting or Neutral Hosting Network (NHN) is part of the CBRS roadmap. However, NHN is presently slotted for late 2020 or 2021.

CBRS will complement IoT systems already in place for hospitals, building automation, and industrial factories. CBRS will also complement licensed 5G and LTE small cells, DAS, and enterprise Wi-Fi networks.

Some specific market segments that can benefit from CBRS with GAA alone include:

- Healthcare –hospitals, rehab centers, doctor offices and home care, access control, DAS alternative
- Hospitality (hotels) – building automation, access control, video security
- Utilities- SCADA system, power line control
- Security - video, security and surveillance
- Government – security, access control, building automation
- Enterprise- security, access control, building automation, DAS alternative

The above uses for CBRS is just a small sample of what a GAA device(s) can do to solve a particular use case.

Useful links:

WInnForum focuses on spectrum sharing mechanisms for CBRS that are agnostic to the access technology

www.wirelessinnovation.org

CBRS Alliance defines specifications and manages the certification program for OnGo.

www.cbrsalliance.org

The FCC also is a very good source of information especially pertaining to rules and regulations for this frequency band.

www.fcc.gov

Summary

Citizen Broadband Radio Service (CBRS) is finally here. CBRS is a shared spectrum service with three tiers of users as defined by the FCC in CFR47 part 96. The three tiers in ranked order of priority are the incumbent access (IA), priority access license (PAL) and general authorized access (GAA). The incumbents using IA are federal radiolocation services (radar) and wireless internet service providers (WISP) who have priority over everyone one else. On September 18th, 2019 the FCC green lighted the use of CBRS spectrum for General Authorized Access (GAA).

CBRS spectrum is located in the 3.5GHz band which is also referred to as the innovation band. CBRS is a not a new technology but a shared spectrum scheme that uses LTE TDD as the technology to connect subscribers through a CNO to a SP. The CBRS consists of ECS, SAS, DP and CBSD. The SASs function is to provide a dynamic policy control for CBRS spectrum usage by granting temporary leases for CBSDs to use. The DP manages the local CBSDs by providing some dynamic spectrum control primarily for GAA users. The CBSDs are the cell sites that use the CBRS band for the duration of the short-term lease.

CBRS enables non-traditional wireless carriers to potentially offer services at significantly lower costs than the cellular carriers. CBRS also allows private wireless systems to be built supporting campus and inbuilding applications. The entry for non-traditional wireless carriers and private networks foster innovations that have been hampered due to recurring access fees. CBRS is important because it can unleash the true potential for IoT in the Industrial, medical, building, automation and hospitality industries besides others.

I trust that you found this article useful.

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Who we are:

NGC is a consulting team of highly skilled and experienced professionals. Our background is in wireless communications for both the commercial and public safety sectors. The team has led deployment and operations spanning decades in the wireless technology. We have designed software and hardware for both network infrastructure and edge devices from concept to POC/FOA. Our current areas of focus include 4G/5G, IoT and security.

The team has collectively been granted over 160 patents in the wireless communication space during their careers. We have also written multiple books used extensively in the industry on wireless technology and published by McGraw-Hill.

Feel free to utilize this information in any presentation or article with the simple request you reference its origin.

If you see something that should be added, changed or simply want to talk about your potential needs please contact us at info@nextgconnect.com or call us at 1.845.987.1787.

Appendix A (SAS-DP/CBSD communication)

Registration Request			
userID	NGC		
fccID	NGC123		
cbsdCategory	A (inbuilding)		
callSign	KA2YRN		
airInterface			
radioTechnology	E-UTRA (LTE)		
cbsdSerialNumber	NGC2001		
measCapability	RECEIVED_POWER_WITHOUT_GRANT		
installationParam			
latitude	41.296697(+/- 50m)		
longitude	-74.465808 (+/- 50m)		
height	5 (+/- 3m)		
heightType	AGL		
indoorDeployment	true, false-outdoor		
antennaAzimuth	boresight in horizontal plan in degrees (CBSD A-opt B-required)		
antennaDowntilt	0 (range +/- 90)		
antennaGain	3 (dBi)		
eirpCapability	10 max ERIP (dbm)		
AntennaBeamwidth	degrees (360 for omni)		
antennaModel	used to ID an external antenna		
groupingParam			
groupId	Example – group -1		
groupType	INTERFERENCE_COORDINATION		
groupId	Example – group -2		
groupType	INTERFERENCE_COORDINATION		
CpiSignatureData			
professionalInstallerData			
cpiId	8459871787CS (CPI ID)		
cpiName	Clint Smith		
installCertificationTime	2019-09-30T11:30:00Z		
CbsdInfo			
Vendor	Name of cbsd vendor		
Model	cbsd model		

softwareVersion			
hardwareVersion			
firmwareVersion			

Registration Response			
cbsdID	NGC1		
measReportConfig			
response	Success/failure		

SpectrumInquiryRequest			
cbsdID	NGC1		
inquiredSpectrum	range of frequencies CBSD is seeking info on in Hz		
measReport	means for report measurement results		
lowFrequency	Hz		
highFrequency	Hz		

SpectrumInquiryResponce			
cbsdID	NGC1		
availableChannel	channel available for CBSD		
frequencyRange	Hz		
channelType	PAL, GAA		
ruleAppplied	regulatory rule (FCC Part 96)		
maxEirp	max EIRP permitted for Grant with the frequency range- dBm		
response	PAL or GAA		

GrantRequest			
cbsdID	NGC1		
operationParam			
maxEIRP			
operational Frequency Range	desired frequency range		
lowFrequency	Hz		
highFrequency	Hz		
groupingParam			
groupId	Example – group -1		
groupType	INTERFERENCE_COORDINATION		
groupifo	Group1 info		
groupId	Example – group -2		
groupType	INTERFERENCE_COORDINATION		
groupifo	Group2 info		
measReport	CBSD can report measured results		

GrantResponse

cbsdID	NGC1		
grantID			
GrantExpireTime			
heatbeatInterval	max time between heartbeat requests (sec)		
measReportConfig	CBSD can report measured results		
operationParam			
lowFrequency	Hz		
highFrequency	Hz		
ChannelType	PAL, GAA		
response	PAL, GAA		

HeartbeatRequest			
cbsdID	NGC1		
grantID			
grantRenew			
operationState			
measReportConfig			

HeartbeatResponse			
cbsdID	NGC1		
grantID			
transmitExpireTime	when CBSD stops transmitting within 60 seconds after the expiretime		
grantExpireTime			
heartbeatInterval			
opeationParam			
lowFrequency	Hz		
highFrequency	Hz		
measReportConfig			
response	• success (ok to transmit) • terminated-grant (stop transmitting) • UNSYCH_OP_PARAM -indicate CBSD is out of Synch with the SAS and stop		

RelinquishRequest			
cbsdID	NGC1		
grantID			

RelinquishResponse			
cbsdID	NGC1		
grantID			
response	Success – channels returned for others to use		