



AN OVERVIEW OF CBRs STANDARDS AND COMMERCIALIZATION OF ONGO SERVICES

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Executive Summary

US CBRS 3.5 GHz band offers shared spectrum opportunity for a broader wireless ecosystem

For mobile operators, cable operators, MVNOs, NH providers, enterprise NPNs, and WISPs

CBRS Alliance drives the development and commercialization of OnGo™ shared spectrum solutions

Developed a set of detailed specifications and OnGo Certification program to enable the deployment of OnGo architecture and seamless interoperability for all NW components

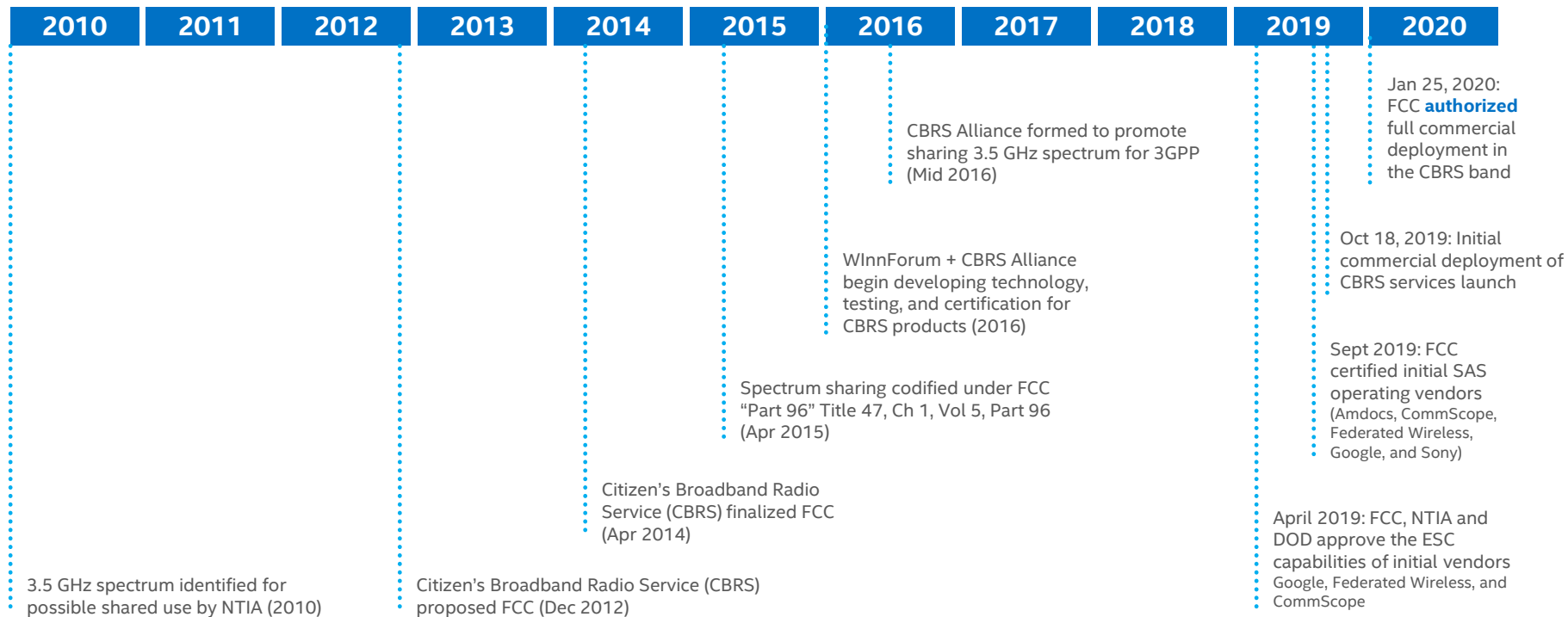
Latest, CBRS Rel 3 spec incorporates 3GPP 5G NR configurations to support 5G services in US 3.5 GHz

CBRS Rel 3 Aligns with 3GPP Rel15 spec, and Rel 4 with Rels 16 and 17

With a burgeoning ecosystem, Initial Commercial Deployments of OnGo services were kicked off in Oct 2019

Auctions for Priority Access License of the 3.5 GHz band are now complete

A Brief History of Citizens Broadband Radio Service (CBRS)



Organizations Primarily Focused on CBRS



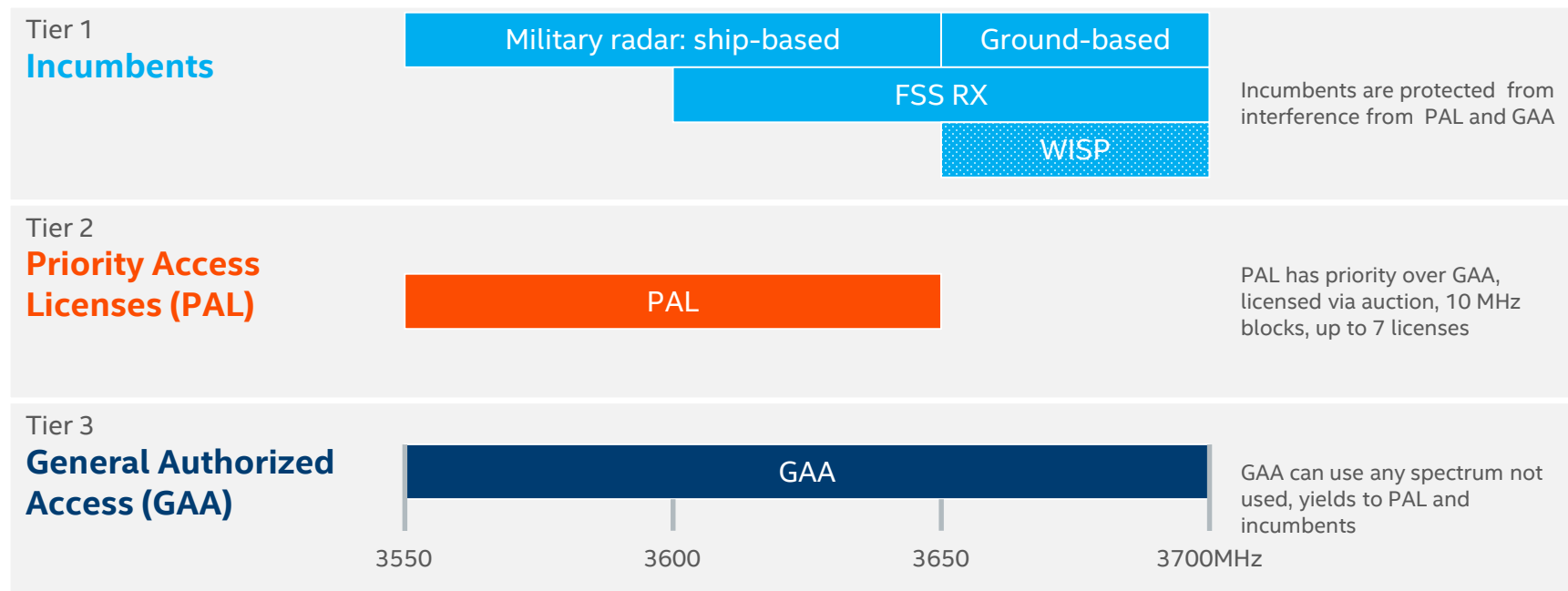
- Standards development organization
- Radio technology neutral
- Functionality and architecture for SAS and ESC
- Requirements, processes, and methods for protection of incumbent users
- Interoperability requirements and protocol definition
- Common framework for FCC testing and certification



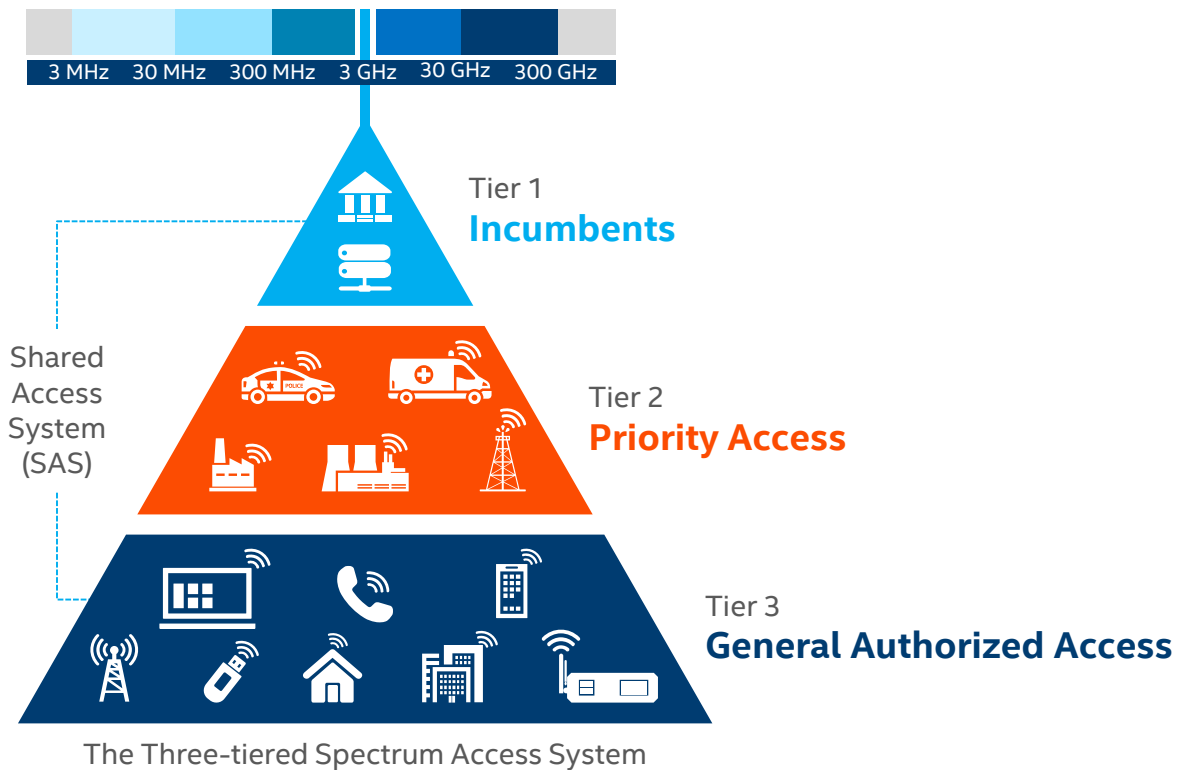
- Industry alliance
- Evangelize LTE and 5G based CBRS technology, use cases, and business opportunities
- Develop technical requirements for CBRS use cases
- Establish an effective product certification program for LTE and 5G equipment in the 3.5 GHz band ensuring multi-vendor interoperability

CBRS 3-tiered Spectrum Sharing in the US

Opens up 150 MHz spectrum for new commercial use without impacting incumbents



Spectrum Access System

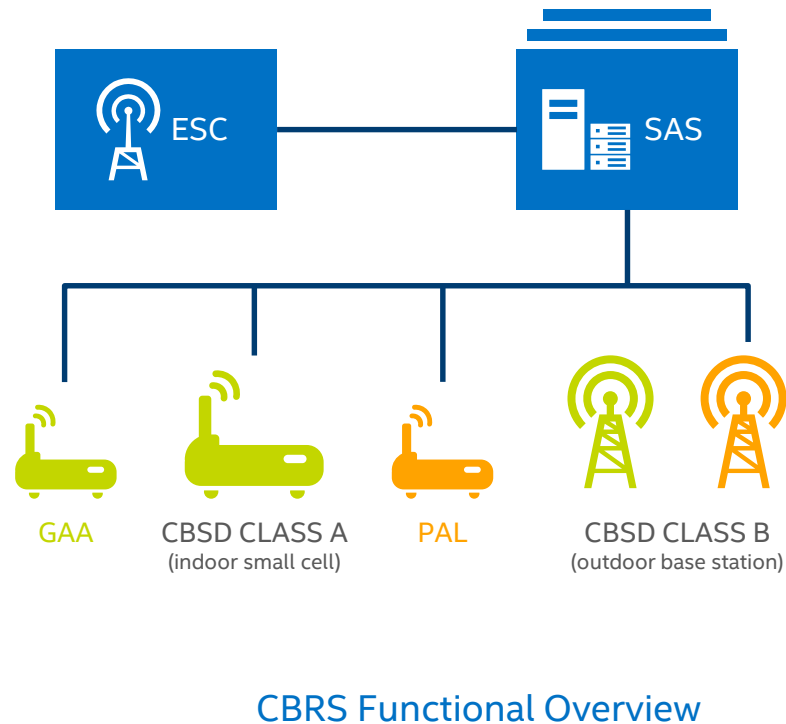
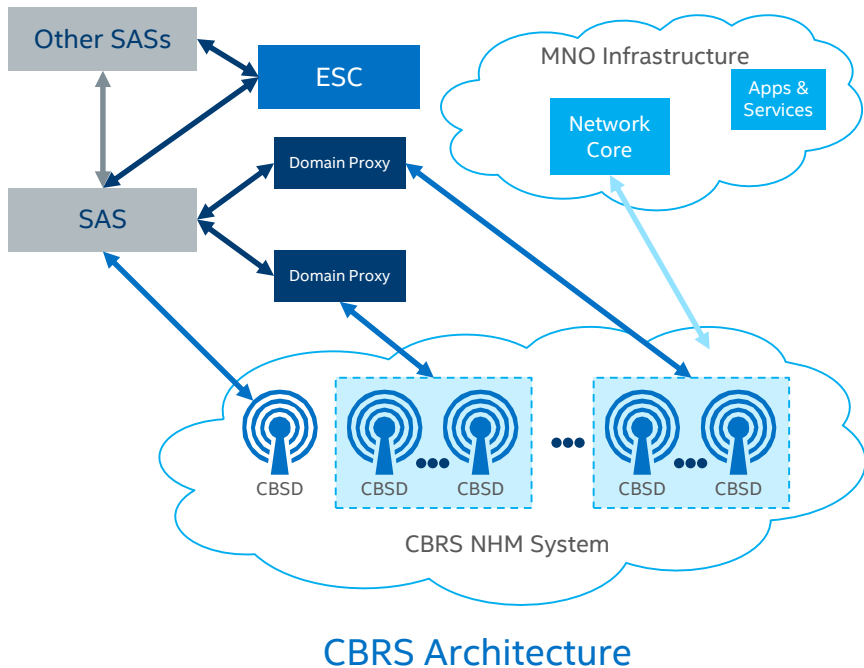




Powered by the CBRS Alliance

CBRS TECHNOLOGY AND SPECIFICATIONS

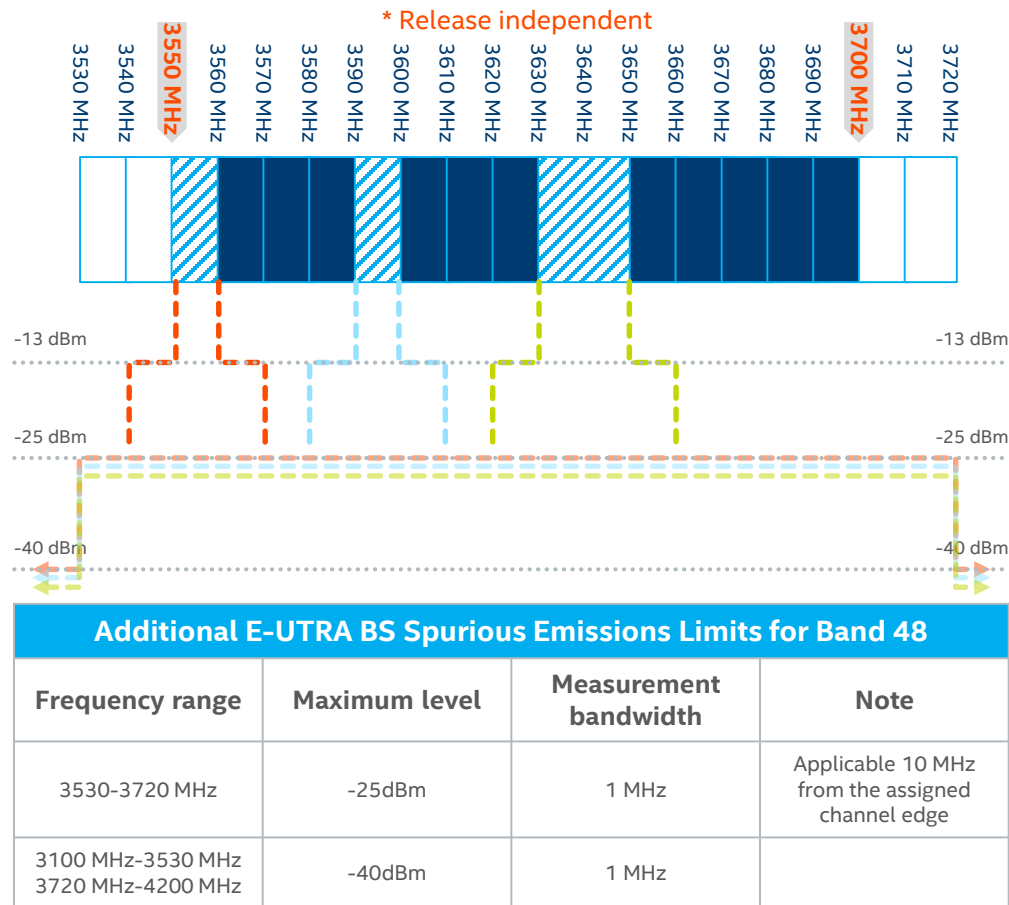
CBRS Architecture and Functional Overview



3GPP CBRS Bands

3GPP defined a new CBRS TD-LTE Band 48

- 3GPP Standards approved in December 2016 (Rel 14) for PAL and GAA operation
- Covers full CBRS range: 3.55 – 3.7 GHz, compliant with FCC emissions requirements
- Supports channel bandwidths: 5, 10, 15 and 20 MHz
- Signaling defined for UE to meet additional FCC requirements
 - UE power reduction for 15 and 20 MHz channel bandwidth



3GPP CBRS Band Combinations

Band 48 Intra-Band Carrier Aggregation

- Downlink aggregated bandwidth up to 100 MHz
- DL peak rates: 1 to 16 Gbps

Inter-band: Combinations with Downlink Aggregated Bandwidth Up to 100 MHz

- 71 combinations across two different bands
- 33 combinations across three different bands
- 3 combinations across four different bands
- One inter-band 2DL/2UL combination involving Bands 48 and 26 (FDD at 800 MHz)

Intra-band: 147 Band 48 Combinations

- 10 Band 48 intra-band contiguous (4) and non-contiguous (6) combinations
- 77 combinations across two different bands
- 48 combinations across three different bands
- 11 combinations across four different bands

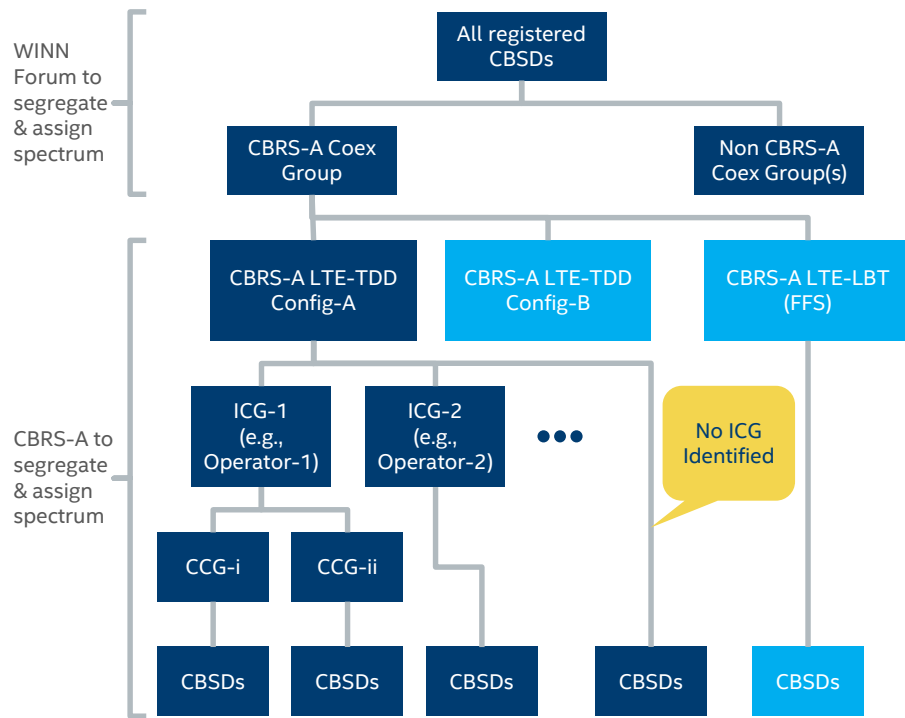
3GPP AGREED ON BAND 48 NR TO ACCOMMODATE 5G-NR IN CBRS BAND

EN-DC Band n48

- 3GPP approves configuration requirements for n48 uplink intra-band contiguous CA part of Rel 16 EN-DC specifications
- The aggregated bandwidth for n48 uplink CA is 20 – 40 MHz for both contiguous and non-contiguous CA
- 3GPP Standards approves to support EN-DC for DC_2A_n48A, 5A_n48A, 13A_n48A and 66A_n48A
- Also approves to extend the Class B upper limit to 100 MHz from 50 MHz for the aggregated channel bandwidth for n48

NR CA Configuration / Bandwidth Combination set								
NR CA configuration	CA configurations	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum aggregated bandwidth (MHz)	Bandwidth combination set
CA_n48B	Uplink	5, 10	10, 15, 20				40	0
		15, 20	5, 10, 15, 20					
	Downlink	10	50, 60, 80, 90				100	1
		15, 20	40, 50, 60, 80					
		40	40, 50, 60					
		50	50					

CBRS Alliance Coexistence Concept Definitions



- **CxG (Coexistence Group):** A group of CBSDs that abide by a common interference management policy which is used to coordinate their interference within the group.
- **CxM (Coexistence Manager):** A logical entity responsible for managing coexistence between GAA users within a CxG in coordination with SAS. A CxM may reside in a SAS.
- **ICG (Interference Coordination Group):** A group of CBSDs belonging to the same CxG indicating that they can manage their own interference within the group and do not need channel orthogonalization even if they have overlapping coverage.
- **CCG (Common Channel Group):** A group of CBSDs that are part of the same ICG requesting a common primary channel assignment.

CBRS Spectrum Coexistence

CBRS Coexistence is aimed at defining rules to ensure fair and efficient use of CBRS Spectrum

- Coexistence of LTE/5G and non-LTE/5G technologies
- Coexistence of different LTE-TDD CBSD categories (low power vs. high power)
- Coexistence of different LTE-TDD NWs (Configurations & Operators)

CBRS Coexistence Specification Rel-1

- Co-channel spectrum optimization for LTE deployments
- Defines phase synchronization requirements
- LTE-TDD DL/UL configuration requirements
- Defines rules for bandwidth allocation among different LTE-TDD networks
- SAS-CBSD protocol enhancements such as coexistence grouping info, etc.
- GAA channelization

CBRS Coexistence Specification Rel-2

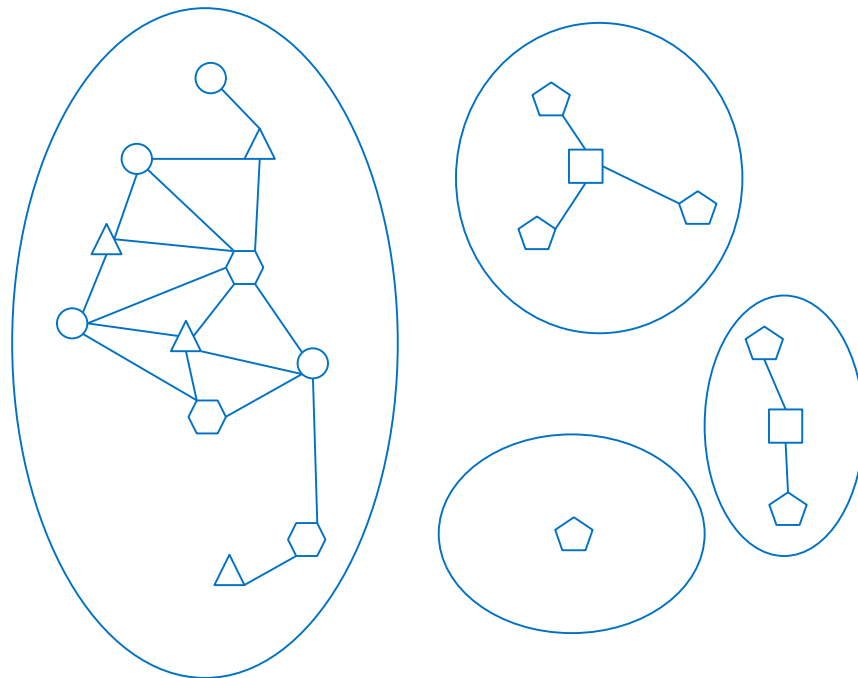
- Functional requirements for CxM to assign GAA spectrum resource to CBSDs
- Functional requirements for CxM to instruct CBSDs to use same LTE-TDD configurations in detrimental conditions
- Coexistence measurement reports and response between CBSDs to CxM, regarding the radio environment
- Assist CxM in GAA channel assignment to CBSDs
- Extend the SAS-CBSD protocol to facilitate new functional requirements of CxM and CBSDs

Graph Coloring Based GAA Resource Assignment: Graph Creation

Creation of LTE-TDD overlap graph

An “edge,” denoted by a line in the graph, is created between two CBSDs, each represented as a vertex in the graph, if they have coverage overlap with each other.

Creation of LTE-TDD connected set Connected sets are created in the LTE-TDD overlap graph to include CBSDs with direct or indirect interference relation with other CBSDs in a connected set.



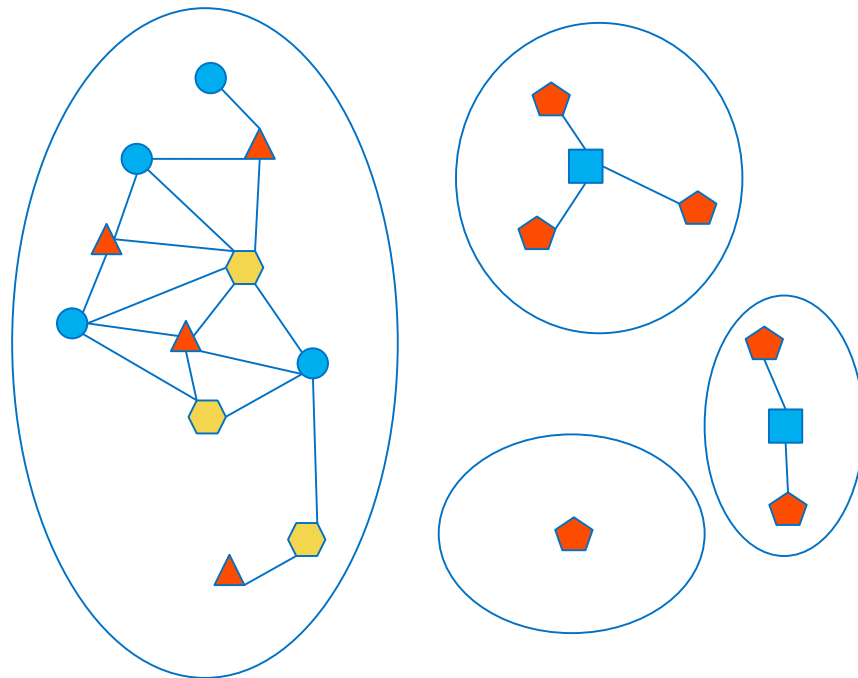
Graph Coloring Based GAA Resource Assignment: Graph Coloring

GAA channel assignment is performed independently in each connected set.

A group of CBSDs may indicate to the CxM the need for using the same channel.

The CxM colors vertices in an LTE-TDD connected set with minimum number of colors such that two vertices with an edge between them have different colors.

Available GAA spectrum is equally divided by the number of colors, and each CBSD is assigned the spectrum associated with its color.



Selection of LTE-TDD Configurations

For multiple overlapping LTE-TDD deployments to coexist, it is desirable for CBSDs in such deployments to use the same TDD configuration.

The CxM creates connected sets for TDD configuration determination by forming edges between CBSDs that have overlap of their respective -96 dBm/10 MHz contours.

All CBSDs in the same such connected set shall use the same TDD configuration. If conflict of TDD configuration happens, a mandatory TDD configuration (as shown in the table below) in the corresponding connected set is chosen and signaled by the CxM based on the majority voting among the fallback TDD configuration specified by CBSDs.

Uplink-Downlink Configuration	UL:DL ratio	Subframe Number									
		0	1	2	3	4	5	6	7	8	9
1	4:4	D	S	U	U	D	D	S	U	U	D
2	2:6	D	S	U	D	D	D	S	U	D	D

CBRS Network Architecture Enhancements

Deployments Targeted for the CBRS Band

- Neutral Host Networks (NHN)
- Multi-Services Operator (MSO)
- Mobile Network Operator (MNO)

Technical Specification Rel-1

- NHN Use Case
- Private Network and Hybrid Network Use Case
 - Stage 1: Requirements, Use Cases, and Definition
 - Stage 2+3: Architecture and Detail Specifications (Network Access Type, Authentication and NAS Signaling Design)

Technical Specification Rel-2

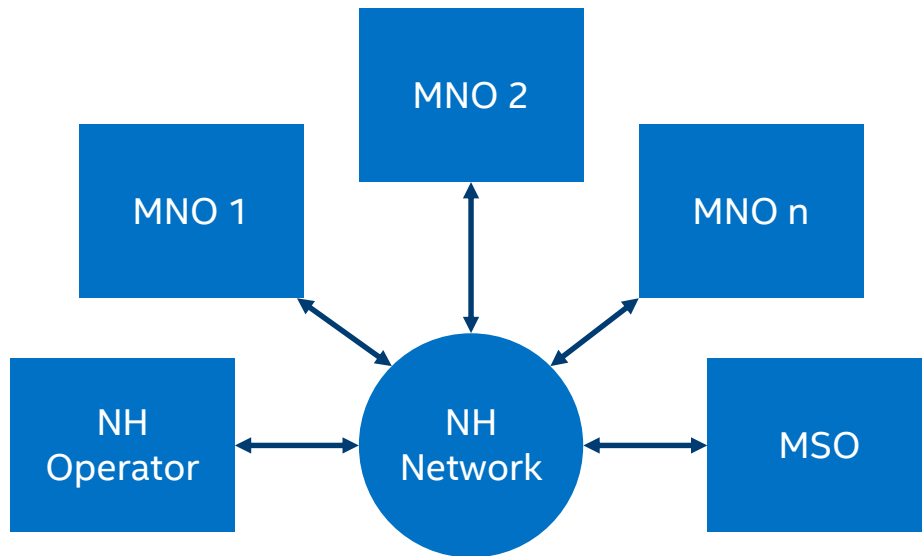
- NW architecture alignment with Shared HNI for NPN and NHN
- Requirements and Architecture for
 - Fixed Network Use Case
 - MSO Use Case
- CBRS Non-SIMM security framework

Technical Specification Rel-3

- Data roaming with shared HNI for NPN & NHN
- Support for 5G NR Extended Authentication
- EAP Credential Management
- Support for 5G NR NSA use cases
- Local Break Out in SP NHN Use Case

Neutral Host Network (NHN)

NHN is a network deployed and operated by an NH operator, who can be an independent entity, an MNO or an MSO where network resources are shared by multiple wireless service providers



CBRS Services – Key Functionaries

CBRS Network Operator

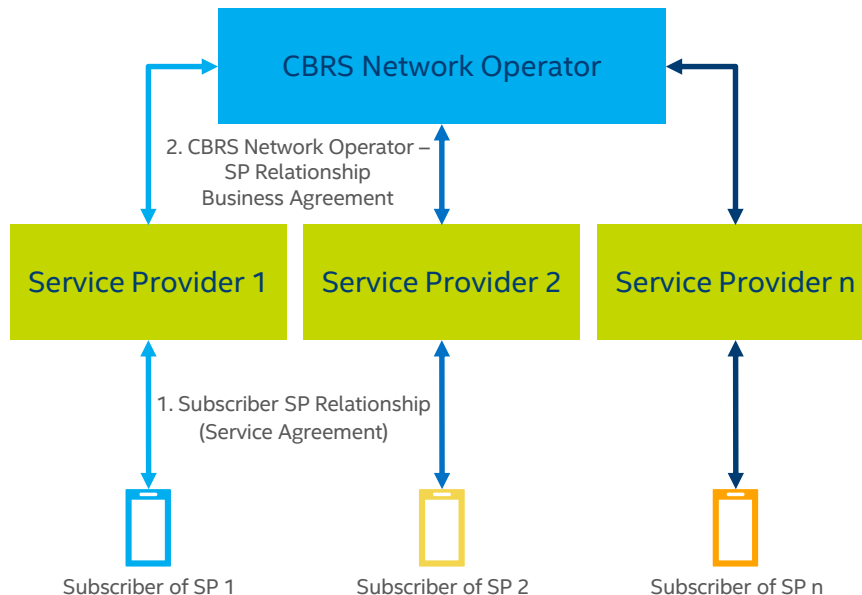
- Deploys a CBRS network to provide connectivity and enable services to subscribers of participating service providers
 - CBRS network operator may need to authenticate the subscriber, as well

Service Provider

- Has service agreement, authenticates, authorizes, and provides services to subscribers
 - MNOs, MSOs, or MVNOs
- A Participating Service Provider (PSP) is a service provider offering services via the specific Neutral Host

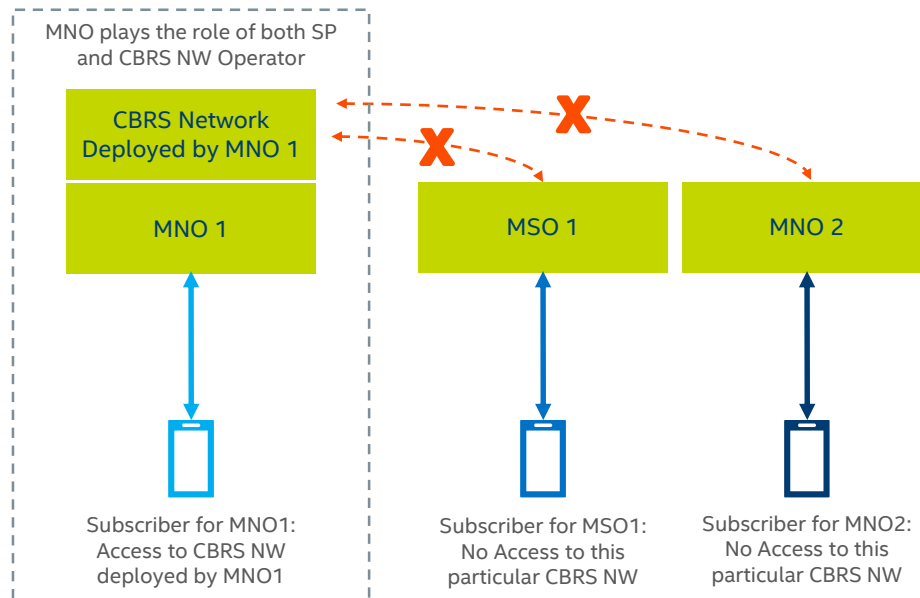
Subscriber

- Authenticated and authorized by one or more service providers
 - Could be a person or a device



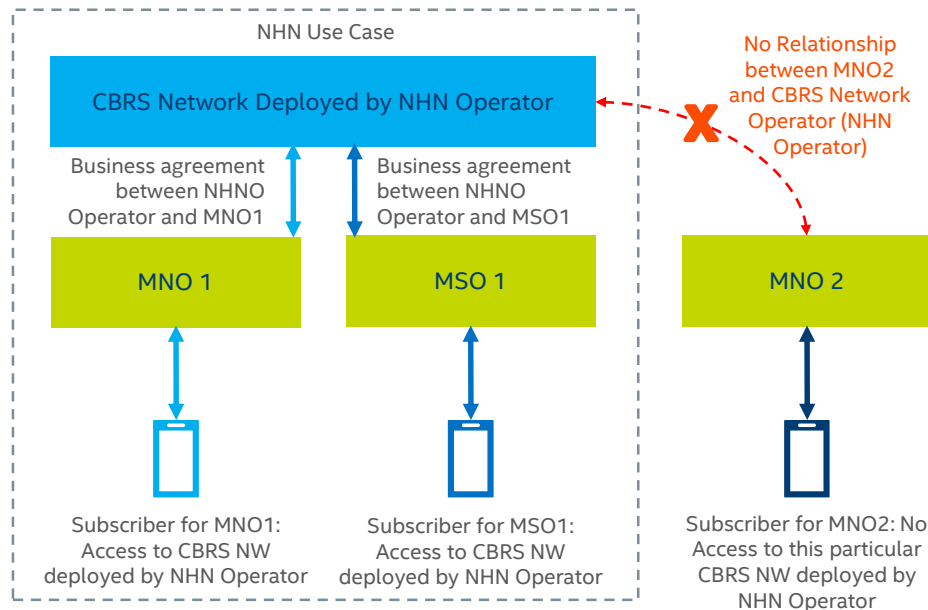
Service Provider (SP) Use Case

- SP deploys the CBRS network itself
- SP plays both roles of SP & CBRS Network
- Coverage extension through CBRS
- SPs could represent traditional MNOs and MSOs or other traditional types of SPs
- Uses traditional 3GPP architectures like S1 interface
- Connection to other SPs through roaming



Neutral Host Network (NHN) Use Case

- CBRS in a venue, public space, or a large area provides service to users of multiple MNOs
- NHN Operator and a SP establish a business agreement
 - to provide services to participating SP's subscribers
- NHN operator plays the role of CBRS Network Operator
- MNO1 and MSO play the role of SPs
- Both MNO1 and MSO1 could be Participating Service Providers (PSPs)

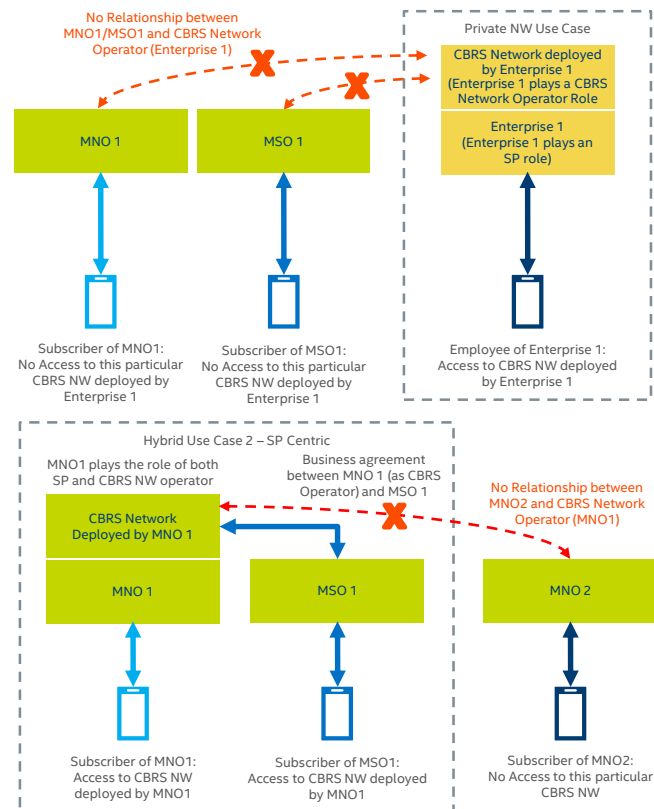


Private and Hybrid Network Use Case

Provides service to employees, machines, and other devices, as authorized by the private network provider

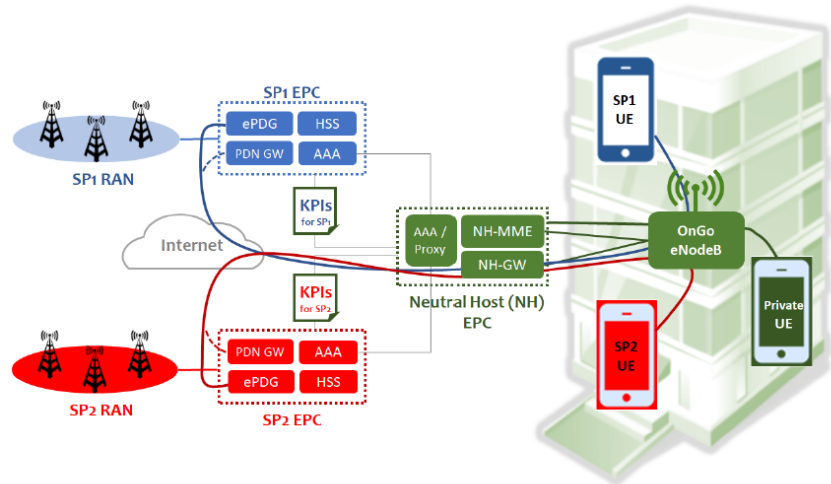
The private network operator plays roles of both SP and CBRS Network Operator, with no business relationship with MNOs or MSOs

- Industrial, mining, off-shore or other isolated environments
- Fixed networks
- Private enterprise network
- Private residential networks
- Wireless backhaul
- Industrial IoT



Typical NHN Use Case

- NHN Operator bridges gap between large projects with direct SP involvements and numerous smaller projects
- Serves mid-market indoor venues with low-cost solutions eliminating the need for complex multi-operator business models
- In CBRS, a small cell can serve all operators instead of installing multiple, operator-specific small cells at each site
- NHN Operators with ownership of Spectrum, Core and RAN can aim for simple commercial arrangements with indoor venue owners and SPs
- ~30 B sq ft of US commercial floor space has poor mobile coverage



Note: Data paths of subscriber devices for Service Providers 1 and 2 are illustrated in respective blue and red lines (a solid line to ePDG via the Internet in "untrusted" mode or a dotted line directly to PDN GW in "trusted" mode).

CBRS Coexistence: Technical Specification Release 3

Addresses LTE and 5G-NR Coexistence

- Cell Phase Synchronization of LTE and NR TDD Networks
 - Rules defined based on 3GPP standards for LTE Cells and NR Cells
- TDD configuration Rules for LTE-TDD and NR-TDD CBSDs
- Addresses CxG and CxM operation and requirements for LTE/NR interworking
 - Specifies options for LTE and NR coordination between CxGs of same and different CxMs.
 - Investigate radio and coexistence issues associated with provisioning of adjacent LTE and NR carriers
 - NR-NR coordination, e.g., between networks
- Anchor carrier configurations (primary vs secondary cell choices) using licensed LTE
- GAA Channelization and SAS-CBSD Protocol Extensions

CBRS Specification: Goals for Release 4

Enhancements to support for NSA
and SA NR within the Band 48/n48

PAL coexistence requirements

AAS support for LTE and NR in
CBRSA (dependencies on
WInnForum specifications)

VoLTE UE support
VoLTE IMS roaming support

Flexible TDD configuration support
for all viable CBRSA business use
cases

CxM enhancements based on
deployment information exchange
Enhancements to CxM functionality
supporting ICG, CCG optimizations

Extended Authentication Protocol
for NR SA
Enhancements to measurement
support for NR



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USE CASES

OnGo: a Range of Use Cases

MNO

- Network Densification
- Capacity expansion



MSO

- Wireless MVNO Offload
- Smart Home



Neutral Host/MSP

- Cost-effective DAS alternative
- Venues, MDUs, Dorms,



Enterprise

- Private LTE Networks
- Industrial IoT



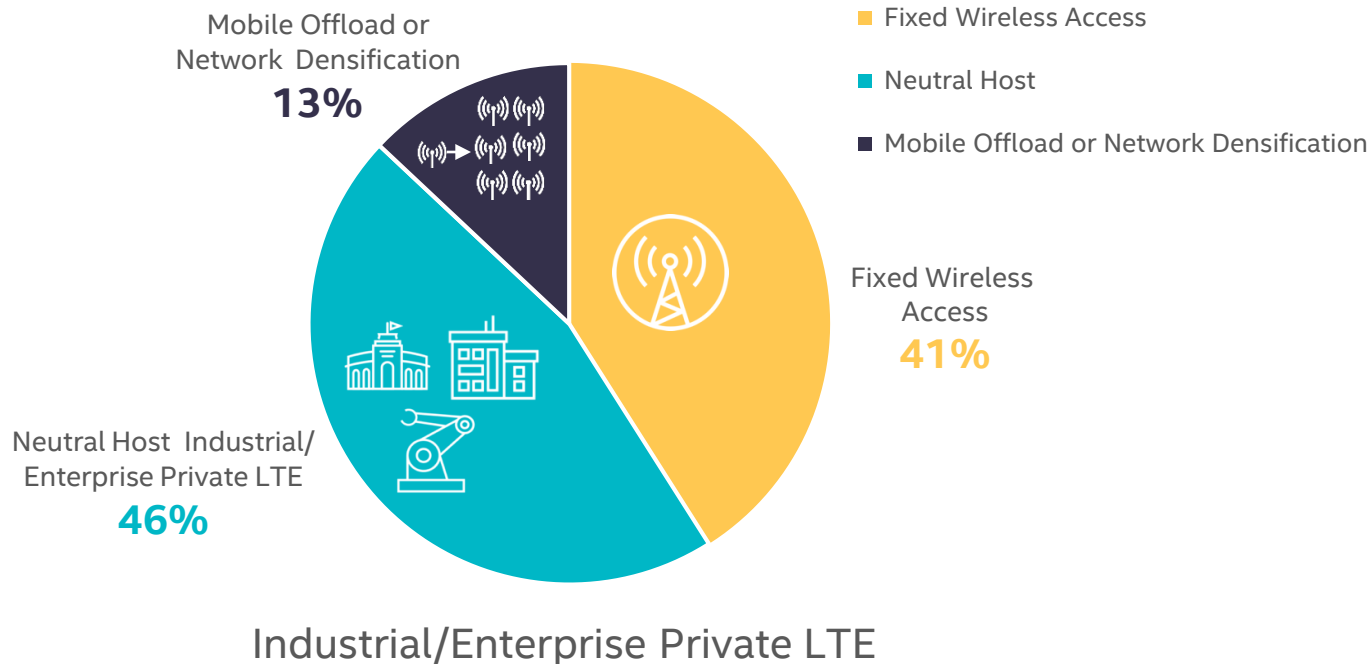
WISP

- Incumbent band users
- Rural Broadband



The Imminent Impact of OnGo

Initial commercial deployments by use case*



*Sample data from one SAS Admin Proposal
Slide provided by CBRS Alliance: OnGo



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CERTIFICATION AND DEPLOYMENT



OnGo Status of CBSD Certification

OnGo™ Certified Devices			
VENDOR NAME	DEVICE NAME	DEVICE TYPE	CERTIFICATION DATE
Motorola Solutions	SLX4000	CBSD + DP	11-Mar-20
Motorola Solutions	SLX2000	CBSD + DP	11-Mar-20
Sercomm USA Inc.	Genesis OC3505A	CBSD	4-Mar-20
BLinQ Networks	FWC-122HG-35, FWC-122-35	CBSD-CPE	25-Jan-20
SpiderCloud Wireless	SCRN-330-4148	CBSD+DP	9-Jan-20
Airspan Networks	AirVelocity 1500	CBSD+DP	4-Dec-19
Airspan Networks	AirSpeed 1000	CBSD+DP	4-Dec-19
Airspan Networks	AirHarmony 4200	CBSD+DP	4-Dec-19
Baicells Technologies Co., Ltd.	MBS1105	CBSD+DP	4-Dec-19
Baicells Technologies Co., Ltd.	MBS31001	CBSD+DP	4-Dec-19
Baicells Technologies Co., Ltd.	MBS1100	CBSD+DP	4-Dec-19
OUCELL	SC-220	CBSD+DP	17-Sep-19
ip.access Limited	E61	CBSD+DP	17-Sep-19
JMA Wireless	XR19AX35WM2/48Y	CBSD+DP	9-Sep-19
CommScope	Ruckus Q910 (P01-Q910-US02)	CBSD	25-Jun-19
Samsung Electronics America	SOL230-48D	CBSD	29-Apr-19
Accelleran	E1012	CBSD	18-Mar-19
Nokia	AZQC	CBSD+DP	21-Mar-19
CommScope	Ruckus Q710 (P01-Q710-US02)	CBSD	21-Mar-19
Telrad Networks	CPE8100	CBSD+DP	21-Feb-19
Telrad Networks	CPE9000	CBSD+DP	21-Feb-19
CommScope	Ruckus Q410 (P01-Q410-US01)	CBSD	19-Feb-19
Nokia	FW2QADPM01	CBSD	18-Feb-19
BLinQ Networks	FW300i	CBSD+DP	15-Jan-19
Telrad Networks	BreezeCOMPACT1000	CBSD+DP	19-Dec-18
Ericsson	RD 4442 B48 / KRY 901 385/1	CBSD+DP	12-Oct-18
Ericsson	Radio 2208 B48 / KRC 161 711/1	CBSD+DP	12-Oct-18
Nokia	FW2QMBOM1	CBSD	27-Sep-18
Sercomm USA Inc.	P208	CBSD	19-Sep-18
CommScope	Ruckus Q710 (P01-Q710-US00)	CBSD	12-Sep-18
CommScope	Ruckus Q910 (P01-Q910-US00)	CBSD	12-Sep-18

VENDOR NAME	DEVICE NAME	DEVICE TYPE	AUTHORIZATION DATE
AMIT Wireless	4G CBRS WAN Extender	LTE Router	4-Mar-20
Apple Inc.	iPhone 11	Mobile Phone	11-Sep-19
Apple Inc.	Apple iPad A2068	Tablet	18-Mar-20
Billion Electric Co.	BEC RidgeWave® 6900R21	LTE Outdoor Router	
Billion Electric Co.	CBRS Cat. 12 module	LTE Module	12-Aug-19
Billion Electric Co.	LTE Module BEC-CBR56	LTE Module	12-Nov-19
Cradlepoint	AER2200	LTE Router	7-Mar-19
Cradlepoint	MC400	LTE Module	7-Mar-19
Dejero Labs Inc	Radio Module	DEJ565 Radio	18-Oct-19
Digi International	Digi WR54	LTE Router	11-Dec-18
Encore Networks	EN2000	LTE Router	25-Jul-19
Encore Networks	EN4000	LTE/HSPA+ Router	25-Jul-19
Getac	Radio Module EM7511U	Embedded Module	30-Apr-19
Green Packet	LTE Residential Outdoor CPE	ODU CPE	12-Aug-19
Google	Google Pixel 3	Mobile Phone	2-Jan-19
Hewlett Packard	LTE Module EL3007565	LTE Module	31-Jan-19
Inseego	MD8000	Cellular Module	10-Jan-20
Inseego	5G MiFi M1000	Wireless Hotspot Modem	18-Nov-19
Inseego	MiFi M1000 5G Hotspot	Wireless Hotspot Modem	17-Jun-19
Inseego	8800L Global LTE Mobile Hotspot		
Lenovo	Yoga 5G	Notebook	23-Mar-20
LG Electronics USA	V600TM	Portable Handset	27-Feb-20
LG Electronics USA	V50 ThinQ 5G	Portable Handset	31-May-19
LG Electronics USA	LG G8X	Portable Handset	18-Sep-19
LG Electronics USA	LG G8 ThinQ	Mobile Phone	10-May-19
LG Electronics USA	LG G8 ThinQ	Mobile Phone	15-Feb-19



VENDOR NAME	DEVICE NAME	DEVICE TYPE	AUTHORIZATION DATE
Motorola Mobility	5G Moto Mod	Mobile Phone	15-Feb-19
Motorola Solutions	NITRO Two-Way Radio	Push-To-Talk	28-May-19
Multi-Tech Systems, Inc.	MultiConnect eCell	LTE Ethernet Bridge	11-Dec-18
OnePlus Technology	OnePlus 7 Pro 5G	Mobile Phone	22-Nov-19
OnePlus Technology	OnePlus 7 Pro	Mobile Phone	15-May-19
OnePlus Technology	OnePlus 7T	Mobile Phone	27-Sep-19
Qualcomm	QGM8180xRF	Module	8-Aug-19
Samsung Electronics	XCover Pro	Mobile Phone	3-Feb-20
Samsung Electronics	Samsung Galaxy Note 10+ 5G	Portable Handset	15-Nov-19
Samsung Electronics	Samsung Galaxy S10e, S10, S10 5G	Mobile Phone	14-Feb-19
Samsung Electronics	Samsung Galaxy Note 10+	Mobile Phone	27-Jul-19
Sercomm USA Inc.	Adventure Wingle	LTE WIFI USB Dongle	6-Dec-19
Seowon Intech	LTE Outdoor CPE	Outdoor CPE	17-Jun-19
Sequans Communications	Cassiopeia CB610L	Embedded Module	7-Feb-20
Sierra Wireless	AirPrime® EM7565	Embedded Module	30-Oct-18
Sierra Wireless	RV55	Rugged LTE Router	30-May-19
Suzhou Aquila	Module LG750	Module	16-Aug-19
Telit Communications	PCI Express Mini Card, LTE CAT.18	Data Card	7-Mar-19
Telrad Networks	LTE Outdoor CPE9000	Base Station Transceiver	31-Aug-19
Telrad Networks	BreezeCOMPACT LTE	Base Station Transceiver	6-Feb-19
Xplore Technologies	Radio Module EM7511	Embedded Module	8-Apr-19
ZyXEL Communications	4G LTE-A Pro Outdoor Router	LTE Router	30-Apr-19

OnGo Commercialization Update



Sept 2019

Inseego, a cellular radio equipment (modem/gateway/router) provider partnering with Ruckus, a CBRS small cell AP provider.

- Inseego plans to pursue a commercial partnership with Ruckus to sell bundled CBRS solutions to enterprise customers looking to operate on private LTE networks.

Sept 2019

AT&T announced selection of Samsung and CommScope for its fixed wireless deployments using spectrum in the CBRS band, with commercial rollouts slated for late 2020.

- AT&T said it will start by using LTE in the 3.5 GHz band, then shift to 5G.

Sept 2019

Major cable operators have also expressed interest in the CBRS band, with Charter Communications, Comcast, and Altice USA all conducting tests at 3.5 GHz.

Sep 2019

[JMA](#) announced deployment of a CBRS private LTE network for American Dream complex in East Rutherford, NJ. American Dream is revolutionizing the retail and entertainment space with its first of its kind destination for fashion and luxury retail, fine-to-casual dining and entertainment.

Sep 2019

[JMA](#), leader of edge-based communications technology, announced CBRS based X-RAN virtual baseband and Cell Hub radio product line. JMA's high capacity, scalable radio systems are ideal for deployment into buildings, campuses, metro areas, and entertainment venues in both enterprise private networks or for mobile operator use.

OnGo Commercialization Update (3)



Oct 2019	<u>Connectivity Wireless</u> , a leading system integrator, and JMA, an innovator of 4G and 5G software-based technology, announced plans to deploy private LTE NW using CBRS for Angel Stadium in Anaheim, CA
Oct 2019	<p>Inland Cellular, a small company serving southeastern Washington and north central Idaho, partnering with ExteNet systems to provide CBRS LTE fixed wireless network.</p> <ul style="list-style-type: none">▪ A commercial rollout is targeted for 2020 with ExteNet's virtualized LTE EPC with Nokia's RAN equipment.
Jan 2020:	Quantum Wireless deployed a new broadband cellular network at the five-star Faena Hotel and Faena Forum in Miami Beach, along with an OnGo private LTE network using CBRS for the nation's largest sporting event.
Jan 2020	Microsoft and Nokia collaborate to accelerate digital transformation and Industry 4.0 for communications service providers and enterprises.

OnGo Commercialization Update

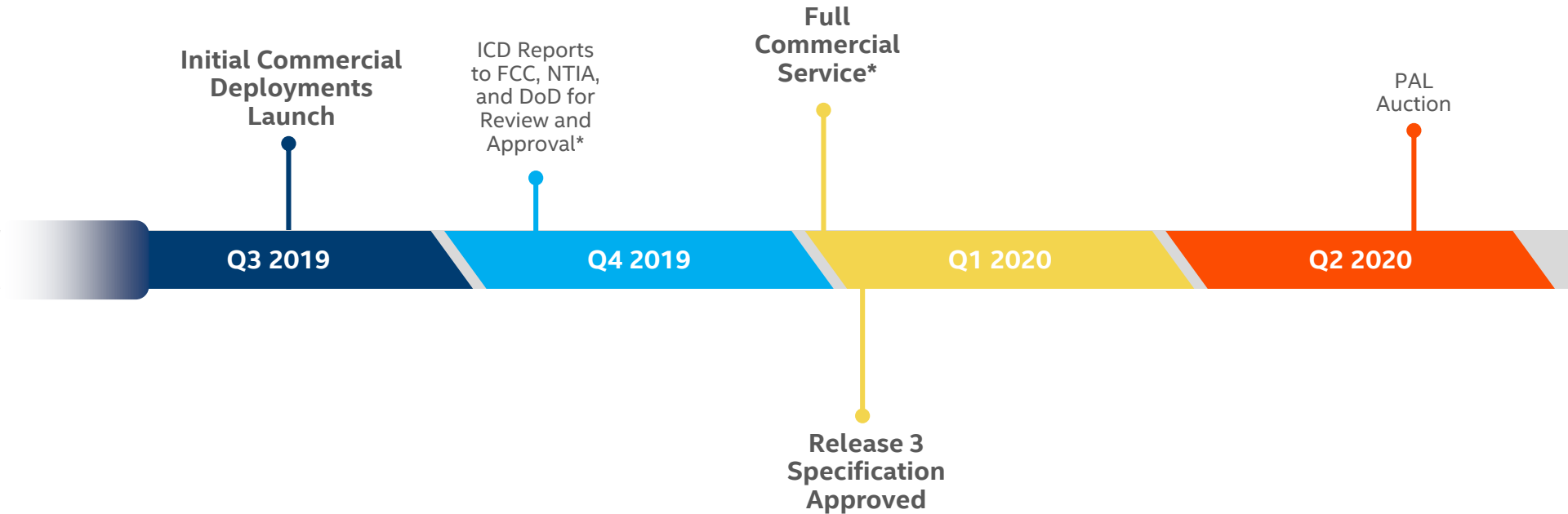


Jan 2020: Celona, a wireless networking company that provides 5G/LTE cellular technologies and enterprise IT infra, announced results from real-world deployments with eight new organizations delivering a dedicated “express lane” for mission-critical business applications in crowded outdoor venues, Industrial IoT, campus-wide connectivity, and video applications.

Jan 2020 Federated Wireless brings 4G/5G private networks to U.S. enterprises with Microsoft Azure Marketplace.

- Announced Connectivity-as-a-Service offering for enterprises to buy and deploy private 4G and 5G networks.
- E2E Managed Services include discovery, planning, design, build, operation, and support.
- > 31 customers currently offering commercial services and another 50 in development.
- Customer base includes companies in telecom, energy, hospitality, education, retail, office space, municipal, and residential verticals.

What Happens Next?



* CBRS Alliance Estimate

