CBRS: Should the enterprise and venue owners care?

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Analyst report

1. Why does CBRS matter?

Open access to 150 MHz of spectrum in the 3.5 GHz band in the US

With CBRS, the FCC opens 150 MHz in the 3.5 GHz band (3550 MHz-3700 MHz) for access to licensed users with a Priority Access License (PAL) and to registered users with General Authorized Access (GAA), alongside incumbents which will retain the rights to use the band. CBRS creates a framework for 4G and 5G deployments in this band, which is currently underused in the US. In many other countries, the 3.5 GHz band is reserved for 5G deployments.

Increase spectrum utilization and efficiency through spectrum sharing

With 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. For instance, WISPs can use CBRS to continue to use the band to provide broadband connectivity, mobile operators to add capacity in traffic hotspots, and venue owners and enterprises to improve indoor coverage – all concurrently, because their footprints are largely not overlapping.

Combine advantages of licensed and unlicensed access

CBRS is an ambitious attempt to combine the freedom of unlicensed access with the guarantees of licensed access, in a technology-neutral framework that can be shared by multiple technologies at each location. PAL users will have reliable access to their allocated channels, with the exception of exclusion zones where the use of the 3.5 GHz band is reserved to incumbents. GAA users will share the remaining spectrum using mechanisms for fair coexistence.

Combine public and private wireless infrastructure

PALs will mostly drive deployments of public networks, while GAA will encourage the deployment of private networks in the enterprise. OnGo solutions based on CBRS are designed to address both the needs of networks operators to integrate CBRS into complex wide-area networks, and the needs of enterprises and venue owners for networks that meet their performance requirements, but are easy to deploy – i.e., by combining the capabilities of LTE with the simplicity of Wi-Fi.

Boost indoor coverage and small cells

The CBRS spectrum-sharing framework and limited propagation of the 3.5 GHz band at the allowed power levels promote distributed topologies that cover limited areas and address location-specific connectivity needs (e.g., high traffic density, IoT). CBRS offers an alternative to footprint-wide macro-cell networks and supports sustainable, scalable business models for indoor small cell deployments funded and owned by enterprises and venue owners, which have so far eluded the US market.

CBRS is ready for commercial deployments

CBRS is a remarkable achievement, born of a collaboration of the ecosystem with the FCC that has been tense at times but produced a regulatory framework supportive of all potential users. The first GAA commercial deployments will be in early 2019, along with introduction of a restricted selection of devices. A major expansion of CBRS coverage will come with the allocation of PALs and the availability of CBRS smartphones. No date is set for PAL auctions, but the FCC should announce soon.

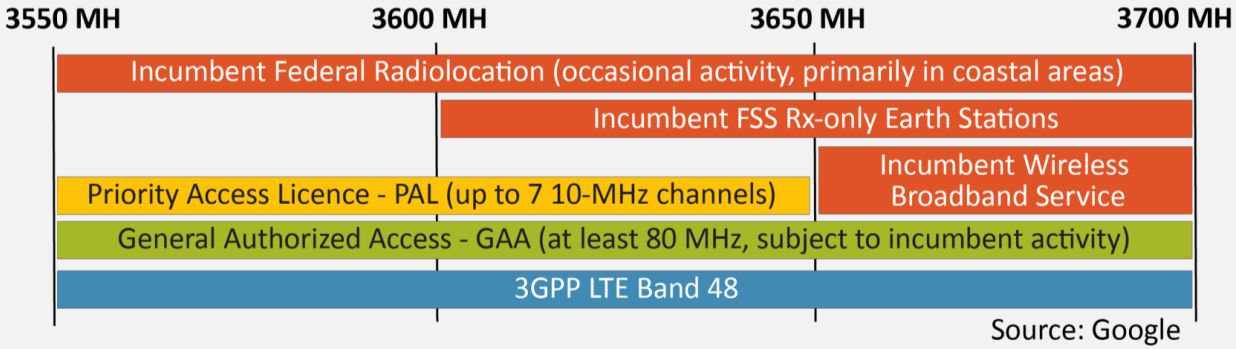
CBRS spectrum

Incumbent users (labeled in red in the figure below) include the military (3550–3700 MHz: coastal locations use 3650–3700 MHz, and terrestrial 3650–3700 MHz), satellite providers (3600–3700 MHz) and WISPs (3650–3700 MHz). 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. The SAS collects data on incumbent users from the Environmental Sensing Capability (ESC) to ensure that their access is protected from interference. WISPs will continue to have incumbent access to the 3650–3700 MHz band under the terms that are currently in place, without having to modify or replace the equipment they have deployed.

PAL access (yellow) is limited to licensed users in the 3550–3650 MHz portion of the 3.5 GHz band. The FCC is expected to announce a date for the PAL auction soon. Licenses will be assigned on a county basis (there are 3,200 counties nationwide), will last 10 years and will be renewable. In each market there will be seven PALs, each assigned a 10 MHz, unpaired, TDD channel. To avoid spectrum hoarding, no license holder can have PALs for more than 4 channels in the same location. License holders have to meet end-of-term performance requirements (they will lose the license if they do not use the spectrum), but can partition and disaggregate PALs and transact access in the secondary market. Small businesses, rural WISPs and qualifying tribal lands are eligible for bidding credits (15-25%).

All other users registered with a SAS can use the spectrum when the SAS determines that the spectrum is not in use by incumbent or PAL users with higher access priority. Channels throughout the overall band (3550–3700 MHz) are available for GAA (green): access to 70 MHz is shared with PAL users and subject to availability (PAL users have priority over GAA users), and access to the remaining 80 MHz is reserved to GAA access (but PAL users can also use this part of the band under the GAA provisions). At any location, GAA users will share the spectrum using network-based coexistence methods (see "GAA and network coexistence" below).

The CBRS band corresponds to 3GPP Band 48, defined for the US market, and overlaps Band 42 (3400–3600 MHz) and Band 43 (3600–3800 MHz).



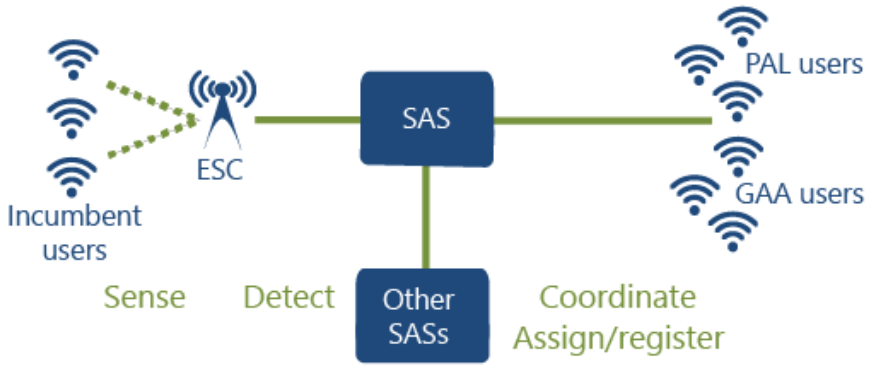
2. Spectrum coordination in the CBRS three-tier access system

CBRS's three-tier priority system allows multiple users to share the 3.5 GHz spectrum in a fair and efficient way, using sensing and coordination.

Incumbent users have the right to use the CBRS spectrum whenever they want at the locations assigned by the FCC. Access for incumbents such as satellite providers and terrestrial military radar stations is protected through exclusion zones, where PAL and GAA access is not allowed, and where incumbents have exclusive access to their allocated spectrum. Because of the propagation characteristics of the 3.5 GHz band and the limited number of incumbents, exclusion areas cover only a small part of the US territory.

Along the coast, however, incumbent users are military ships that are not in fixed locations. The ESC is a network of sensors that detects incumbent activity in the CBRS band along the coast and transmits this information to a SAS, which determines which part of the CBRS spectrum can be used by the two other tiers – PAL and GAA. PAL and GAA users are not allowed to use CBRS channels while they are in use by incumbent users.

Spectrum sensing and coordination in CBRS



Source: Senza Fili

CBRS and OnGo

In 2018, the CBRS Alliance launched the OnGo brand, with a certification program as its foundation, to promote the growth of an ecosystem for interoperable CBRS solutions based on 3GPP technologies – LTE today and eventually 5G. OnGo certified equipment from different vendors will interoperate seamlessly within the same network, and will work with the SAS for spectrum coordination straight out of the box. An enterprise will be able to purchase OnGo Citizen Broadband Radio Service Devices (CBSDs) and install them within their premises without having to deal with the complexities of carrier LTE. For GAA users, OnGo aims to provide an ease of deployment comparable to Wi-Fi. PAL users have to first secure the right to access the spectrum, but the deployment process is the same as for GAA – and, in fact, PAL users will likely use GAA and PAL access concurrently if they want access to more spectrum.

The OnGo certification program is open to vendors, which submit their equipment to independent test labs that are authorized by the CBRS Alliance. OnGo-certified products have passed tests for different configurations and against other OnGo products to ensure interoperability. Vendors can use the OnGo logo, and they receive an FCC ID that confirms the FCC certification. Like the Wi-Fi Alliance certification, OnGo certification reduces deployment costs and makes it possible for any OnGo device to connect to a network without having to repeat tests for interoperability within each network. Certification started in September 2018, and by the end of the year, Ericsson, Nokia, Ruckus/ARRIS, Sercomm and Telrad had certified OnGo products.

The SAS coordinates the use of available spectrum among users that request access. It authorizes access for PAL users in locations where there is no incumbent activity, then releases the remaining spectrum to GAA registered users that have sent in a request for access.

Both PAL and GAA users need authorization from the SAS to transmit. A PAL gives licensees priority over GAA users, but not exclusive access to a CBRS channel. Similarly, GAA users do not need a license, but do not have unconstrained access as they would have in unlicensed bands.

The SAS operates in real time, as PAL and GAA spectrum availability and demand change through time. In practice, however, the availability of CBRS spectrum to local users will be reliable and stable through time in most environments, especially in enterprises that have control over their premises and, hence, of the deployed equipment.

To ensure competition and fair access, the FCC framework encourages the coexistence of multiple ESCs and SASs. A SAS can use an independent ESC or operate its own ESC. SASs have to coordinate their activity to ensure they assign spectrum consistently and without conflicts.

In turn, PAL and GAA users are free to choose the SAS they want to work with. In most cases, especially for enterprise users, the SAS selection will accompany the vendor selection, because most equipment includes an optional subscription to one or more SAS providers.

GAA and network coexistence

GAA access is shared among registered users. The SAS assigns the spectrum available for GAA, but it does not coordinate access among GAA users at any given location. GAA users have to employ coexistence methods to ensure everybody gets fair access to the spectrum. Because CBRS is technology neutral, coexistence methods must work across multiple access technologies, but the FCC does not mandate a specific method to be used in the CBRS band.

In 2018, the IEEE released the 802.19.1 standard, which specifies methods for network-based coexistence that work across multiple access technologies and across networks operated by different entities. These methods can be used in the CBRS band, but are also applicable in the white space and 5 GHz unlicensed band.

Effective coexistence methods are essential to protect access for GAA users in the long term. Initially, however, they will be used sparingly, because there will be little or no contention (i.e., more users than channels available) in the early deployment stage.

Furthermore, an enterprise may not allow other CBRS users to install their equipment within the area it controls, and in this case the enterprise would be the only CBRS user within its premises and could manage any contention within its network.

However, enterprises and other users may want multiple CBRS networks at the same location. In that situation, network-coexistence methods are necessary to manage and reduce interference.

4. FCC, WInnForum, CBRS Alliance and OnGo

CBRS is the regulatory framework defined by the FCC for the use of the 3550–3700 GHz band in the US (3GPP Band 48) by any access technology that complies with the regulation. The FCC has set the ground rules for use of CBRS spectrum, but has left the wireless ecosystem flexibility in finding a fair way to coordinate spectrum access.

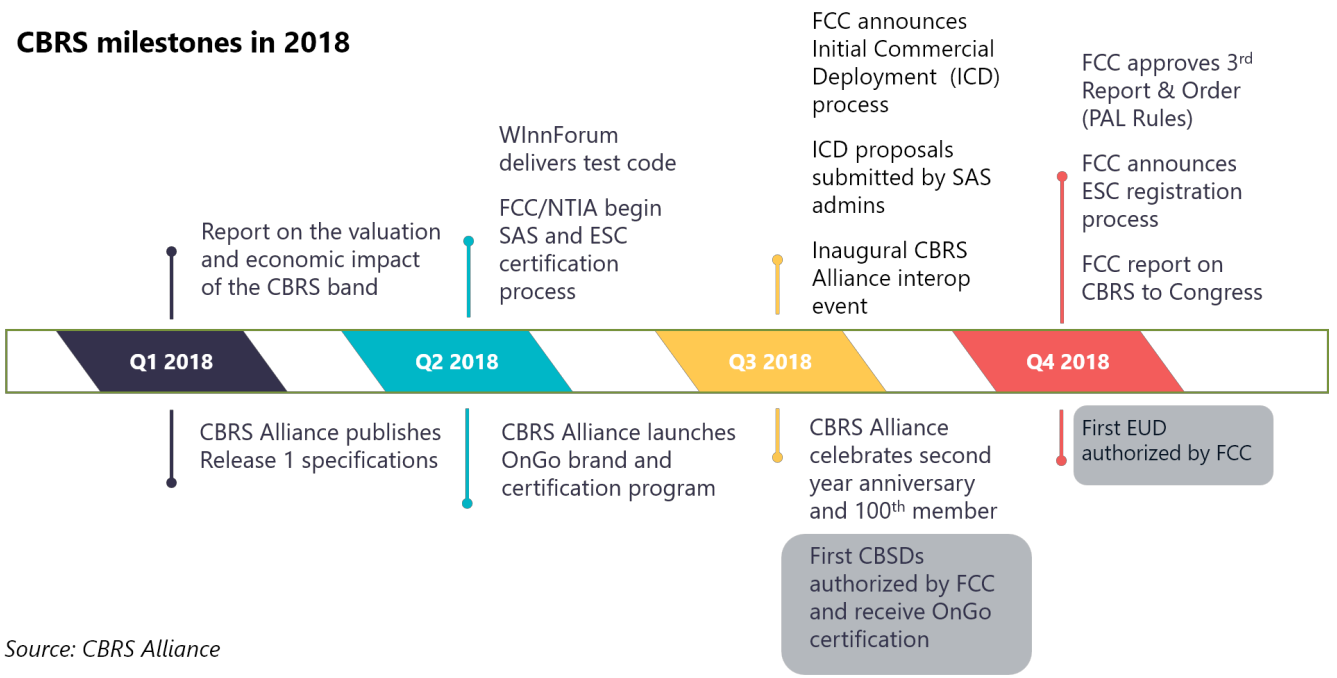
FCC certification is required for all CBRS products, and for SAS and ESC providers. In November 2018, Sierra Wireless became the first device vendor to receive the FCC certification. Federated Wireless, CommScope, Nokia and Google have received the FCC's SAS certification, and Federated and CommScope have received FCC ESC certification. The FCC announced the Initial Commercial Deployment (ICD) Process and received the initial ICD proposals in Q3 2018. The proposals open the way to the initial GAA commercial deployments, which are expected to ramp up in 2019. In Q4 2018, the FCC approved the Third Report & Order, which includes the revised PAL Rules (county-based, renewable 10-year licenses) and released a report on CBRS to Congress. The FCC will set up dates for the PAL auctions and manage the process.

The WInnForum and the CBRS Alliance have worked together to bring CBRS to market.

The WInnForum focuses on spectrum sharing mechanisms for CBRS that are agnostic to the access technology – i.e., not limited to 3GPP technologies. The scope of WInnForum is wider than CBRS and includes other countries, bands and ways to manage spectrum – such as software-defined radio, cognitive radio, and dynamic spectrum access.

The CBRS Alliance defines specifications and manages the certification program for OnGo. It also promotes the adoption of 3GPP technologies in the CBRS band, through its members' network, which includes vendors, carriers, service providers and SAS/ESC providers.

CBRS milestones in 2018



Source: CBRS Alliance

5. Benefits to the enterprise

CBRS was created to open the 3.5 GHz band to a wide range of users that include incumbent users, mobile operators, cable operators, other service providers, public entities, and possibly new entrants, in addition to the enterprise. Because many of the CBRS features stand to specifically benefit the enterprise, the largest impact of CBRS innovation may be on the enterprise.

LTE performance, Wi-Fi simplicity. CBRS brings to the enterprise the traffic management capabilities, capacity, latency, reliability, and security of LTE (and eventually 5G) that it needs for IIoT and other enterprise-based applications, including voice. However, in smaller and simpler enterprise networks, CBRS networks are less complex than large carrier-operated LTE networks. For enterprise users, CBRS solutions aim to provide an ease of deployment and operation comparable to that of Wi-Fi, and enable the enterprise to deploy standalone networks that can – but do not have to be – tied to a mobile operator network.

Out-of-the-box solutions. CBRS vendors offer to reduce LTE complexity with small cell solutions that work out of the box and do not need a carrier-grade core network. Large enterprises may decide to deploy sophisticated CBRS networks, but most enterprises need equipment they can install and operate without having a dedicated CBRS team. To this end, most OnGo vendors offer or plan to offer equipment that has built-in SAS connectivity and core and network management capabilities, which may be cloud based or run on premises. With these solutions, an enterprise will still have work to do – e.g., deal with RF planning and backhaul – but all the network components will come with the CBSD, along with the tools to configure the network.

Wireless networks customized to the enterprise's needs. Building and operating any wireless network – Wi-Fi, LTE or 5G – is expensive. But increasingly enterprises see this investment as essential, because it is often the only way to get the network they need for their IIoT and other enterprise-specific applications and services. Only rarely can an enterprise get a mobile operator to pay in full for a network customized to meet its needs. Understandably, mobile operators cannot profitably fund all the in-

The enterprise in the wireless ecosystem

In telecoms, the enterprise is typically considered a customer, and as such is a recipient of a service provided by a third party, which usually owns the telecom infrastructure.

The enterprise's stake in the wireless infrastructure has increased and continues to increase, however, with the emergence of IoT and IIoT, and the reliance on wireless to run business and to connect employees and visitors. Good wireless coverage and connectivity – and control over wireless performance – have become critical. Many enterprises are ready to take an active role in funding, deploying and operating on-premises wireless networks, leveraging the experience they gained with Wi-Fi and extending it to cellular technologies such as LTE and 5G.

Wireless technologies are getting more deeply embedded in the enterprise processes and services, and, concurrently, the enterprise is morphing into an active player in the wireless infrastructure ecosystem.

But what counts as the enterprise in the context of the wireless ecosystem? The definition we use here – and that is becoming common in wireless – is broad: it encompasses entities that have control over some real estate, often including in-building locations. In contrast, service providers or network operators offer services and/or own wireless infrastructure over a footprint or locations where they do not have control over the real estate.

In addition to what we commonly consider an enterprise (e.g., office buildings, campuses, factories, warehouses, a mining site, a farm, or a commercial harbor), this definition includes venue owners (MUD, retail, business), hospitals, educational institutions, utilities, transportation hubs, stadiums, retail centers, and public entities.

The enterprise includes a very diverse set of players with varying requirements, but with a shared desire and need to take on a more active role in wireless. CBRS – and more specifically GAA – helps different types of enterprises to achieve this goal, by enabling private networks and neutral host models.

building and outdoor infrastructure within all, or even most, enterprise locations, and where they do, they will retain control of the network unless they have ad hoc agreements with the enterprise. By deploying a private or neutral host network, the enterprise can retain control over the network's architecture and performance, and manage network resources and traffic as it sees fit.

For instance, in a manufacturing plant, an enterprise may decide to have an area with very dense, high reliability, URLLC infrastructure to support its robotics applications, and an office area with higher capacity but less stringent latency requirements. It can use network slicing and edge computing to make sure its IIoT applications get priority over other traffic, and to optimize the use of network resources. Furthermore, it can decide how to manage third-party traffic from operators or other service providers without disrupting its own traffic.

With GAA, 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.

On-premise networks. Even if some network management functions may be cloud based, CBRS enterprise networks will mostly use a Wi-Fi-like distributed architecture, in which most of the processing and storage will be local to the enterprise.

On-premise networks give the enterprise more power and flexibility in managing security. Also, it is an ideal environment for edge computing and network slicing, which allow the enterprise to run and manage its applications locally, thus minimizing latency and optimizing performance. Edge computing and network slicing can extend beyond CBRS, and work across all the wireless networks within the enterprise – e.g., Wi-Fi, MulteFire, LTE and 5G – creating an integrated, multi-RAT environment within each enterprise location.

Private networks and neutral host networks. The enterprise knows private networks well – most enterprise Wi-Fi networks are private networks – and many large enterprises with DAS have experience with neutral hosts. What is new with CBRS is that it encourages any enterprise – large or small – to deploy private and neutral host networks that use LTE small cells outside licensed cellular bands. By giving the enterprise ownership and control over the infrastructure, these deployment models

CBRS, LTE/5G and Wi-Fi

Whenever a new wireless access technology appears, there is an unavoidable, heated debate about whether it will replace others or will fail. In most cases, the new technology will coexist with the existing ones and what the debate should focus on instead is how the different technologies will coexist and support each other.

For instance, Wi-Fi and Bluetooth share 2.4 GHz and complement each other: you may use a Bluetooth headset to listen to music on a phone that is connected to the home network through Wi-Fi using the same band. Similarly, CBRS will complement licensed LTE small cells and DAS, and Wi-Fi in the enterprise – as well as new technologies such as MulteFire, which uses LTE in the 5 GHz unlicensed band. The reason is simple: the enterprise needs multiple technologies and multiple bands to meet their wireless connectivity needs.

Differences in the capabilities of different technologies give the enterprise the flexibility to choose which technology is best suited for each of the applications and services it deploys.

For instance, an enterprise may run applications that require tighter traffic control, mobility support, higher reliability and lower latency – such as URLL and other IIoT applications – over CBRS, and more bandwidth-intensive video traffic over Wi-Fi. Mobile voice traffic may be routed through the local licensed LTE small cell network, if there is one.

The decision on how to allocate traffic across networks will depend to on the networks that are available, on the applications that are active, and on the traffic load that users generate. Decisions that reflect the enterprise wireless strategy can be made for the long term, but decisions that depend on the changes in network conditions and load are more effective if done dynamically, in real time. To enable this, co-located wireless networks not only have to coexist, they need to be integrated so that traffic can be managed for the entire wireless infrastructure, instead of independently for each network.

provide an innovative framework for the enterprise to take a more active role in the wireless ecosystem.

The two network models – private networks and neutral-host network – are not mutually exclusive and hybrid models may eventually dominate. An enterprise may work with a neutral host to operate its private network, with different ownership and control agreements. Mobile operators, MSOs or other players may also work with the enterprise to deploy and operate the CBRS network or to act as neutral host.

Private networks	Neutral host networks
Owned and paid for by the enterprise	Mostly owned and paid for by the neutral host, but in some cases the enterprise may pay for and own the network, with the neutral host deploying and operating the network
Deployment and operations by the enterprise, system integrator or other third party	Deployment and operations by the neutral host
Primary goal of the network is to support enterprise or tenant applications. Visitor, mobile operator and service provider access are secondary targets and revenue opportunities	Primary network target is to provide access to the enterprise, tenants, mobile operators and service providers
Direct enterprise control over network deployment, performance, operations	Lower, less direct burden on enterprise resources
Timing and funding set by the enterprise	Less involvement in network deployment and operations
Customized and optimized to meet enterprise requirements	Developed in cooperation with the enterprise to ensure that the network meets the enterprise's requirements
Access to the network gated by the enterprise	Roaming relationships with service providers managed by neutral host

6. Innovation from enterprise CBRS networks

The many benefits that CBRS offers the enterprise will drive the deployment of private networks and neutral host networks that use CBRS. But perhaps more importantly, CBRS in the enterprise may become a catalyst for an ecosystem-wide transformation that changes the roles of spectrum and real estate, traffic management, and the connectivity fabric.

Spectrum sharing makes spectrum utilization more efficient

Spectrum is a limited resource that is mostly allocated to specific users (e.g., licensees or military) and/or for specific uses (e.g., satellite or radar). In most bands, the spectrum is underutilized because those who have access to the spectrum usually need it only in some locations and at specific times.

Even heavily trafficked licensed cellular and unlicensed bands are not used at capacity throughout the footprint and throughout the day, especially as we move from high-density urban locations toward rural areas. Even new technologies such as 5G and Wi-Fi 6 cannot keep up with the increase in traffic, from both human users and IoT applications, without access to new spectrum or better spectrum reuse. And this is where spectrum sharing and densification play a major role.

Technology cannot create new spectrum, but, with spectrum sharing, it can increase the utilization of the spectrum that is available, allowing new users to opportunistically use the spectrum resources that incumbent users do not need. The technology and capabilities to share spectrum have evolved to a crucial point: as CBRS shows, regulators have started to push for it, and incumbent users have started to accept it in the bands allocated to them.

Spectrum sharing goes beyond a higher spectrum utilization: it changes how we consider spectrum as an asset, and increases spectrum efficiency.

Licensed bands are exclusively assigned to specific users or tasks. In unlicensed bands, everybody has equal access rights. Spectrum sharing creates an alternative framework that aims at increasing spectrum efficiency, by recognizing that different users have different rights and needs to use the spectrum. Spectrum becomes primarily a resource available to those who need it and have the capabilities to use it, rather than an asset in the hands of an exclusive licensee, who decides how much to use it.

This approach may not be as effective as unlicensed spectrum in increasing the bits of traffic transmitted, but it is more efficient in ensuring that the highest priority, highest value traffic goes through reliably and that spectrum resources don't lie fallow.

This spectrum and traffic coordination can be done – as increasingly it will be – in a dynamic, real-time fashion that is not defined a priori (as it was in the initial spectrum sharing arrangements), but depends on time and location: i.e., traffic and network conditions, and demand from users.

In this context, a SAS or similar entity that coordinates access among multiple users with different access rights and needs does more than execute the regulatory mandate to ensure fair sharing of the spectrum: it optimizes spectrum utilization across all the users that have the capability and need to access it.

More spectrum available to the enterprise

Perhaps more important, this approach enables new players to use shared spectrum in an opportunistic way, without the need to buy expensive licenses. The enterprise is going to be a major beneficiary: it will have the ability to greatly expand its wireless spectrum assets and deploy wireless applications and services, without depending on spectrum licensees (mostly mobile operators). The enterprise will continue to engage with mobile operators and other service providers, but the relationship will become more flexible and open to new arrangements.

More specifically, this will encourage a more intensive spectrum use to address non-overlapping coverage needs. For instance, a mobile

operator may have extensive coverage in its footprint, but may not find it cost effective to increase coverage or capacity at a remote mining site or in a warehouse, because it does not see a good ROI. However, the mining or warehouse company is more likely to find it worthwhile to invest in improving the wireless infrastructure with an on-premises private network. The company may either retain or expand its relationship with mobile operators, or open its private network to operators for roaming.

A private network or a neutral host network benefits both the enterprise (i.e., better support for internal applications) and the operator (i.e., offload of macro traffic, improved indoor/remote area access for its subscribers).

Finally, small cells will take off in the US

CBRS enterprise networks will also promote densification because they will be fertile ground for the deployment of small cells. This is valuable for the US market, where the deployment of small cells has been much slower than expected. CBRS private networks address many of the challenges of LTE small cells in licensed bands.

The business case for operator-driven in-building small cells has been a difficult one. Deploying and operating small cells in an enterprise environment is expensive and requires intensive effort by operators, because operators prefer not to share licensed-spectrum infrastructure. They need to deploy and operate networks in an environment that, unlike the macro network, they do not control and is difficult to access.

With CBRS, the enterprise can build a network that does not interfere with an operator's macro network. In most cases, the enterprise can build and operate an on-premises network at a lower cost than an operator because it has access to its own premises and can leverage its existing telecom infrastructure.

Because the enterprise can offer access on a roaming or wholesale basis to multiple operators, CBRS private or neutral host small-cell networks are a good deal for operators, too, because they get better in-building coverage and a channel to offload traffic from the macro. Mobile operators can take advantage of network sharing without having to deal with other operators directly or share licensed spectrum with them. In turn, wholesale and roaming agreements will bring additional revenues to the enterprise, and enable it to recoup some of the capex and opex of the CBRS network.

Spectrum sharing beyond CBRS

Spectrum sharing is now used only in the US in the 3.5 GHz band with CBRS, but it may extend to other bands and other countries. In the US, the expected release of the 6 GHz band for unlicensed access creates another opportunity for spectrum sharing in underused bands, while respecting the rights of incumbents. In Europe, Germany, the Netherlands and other countries have engaged in trials to explore CBRS-type sharing models.

Spectrum sharing may also work in licensed bands, where the spectrum owner – most often the mobile operator – may lease out unneeded portions of its spectrum in the secondary market. This approach may work well in millimeter wave spectrum, which one entity might use indoor for user or IoT access, and another entity might use for point-to-point links, without interfering with each other.

Real estate control gives the enterprise more control over the wireless infrastructure

Both shared spectrum and unlicensed spectrum give the enterprise access to spectrum assets it can use to deploy private or neutral host networks and support internal applications. Control over the real estate where the enterprise is located is fundamental for the enterprise to take advantage of this opportunity and to protect its investment in private networks.

With licensed spectrum, the license provides investment protection (i.e., nobody else, other than the licensee, can use the licensed spectrum). Licensees can easily negotiate deals to deploy the infrastructure, because these deals are a revenue opportunity for tower companies, cities and other entities that have control over the real estate. With CBRS, control over the real estate gives the enterprise a good grip on the 3.5 GHz band, because the enterprise can decide who can install equipment within its premises. The grip is stronger than that with Wi-Fi: anybody can switch on a Wi-Fi access point within an enterprise location, but only

registered users can turn on CBRS. And the enterprise decides who to grant this privilege to –it may deny it even to PAL licensees. While the enterprise has no incentive to deny access to mobile operators wishing to install licensed equipment within its premises, it may choose not to allow PAL to keep a tight control over the CBRS band.

Many enterprises, especially venue owners, take a similar approach in the 5 GHz band, declining third-party permission to install their own, independent Wi-Fi networks within their premises, to retain control over the entire band and avoid having to deal with interference.

The enterprise can decide whether and how to collaborate with PAL owners, and in many cases it will make sense to do so. But the enterprise, by virtue of controlling the real estate, will be able to carve for itself reliable access to CBRS spectrum – e.g., the enterprise will continue to be able use its network infrastructure after PALs have been allocated and contention for CBRS use grows with new PAL deployments.

Of course, licensed spectrum will continue to be crucial for wide-area coverage and high-speed mobility support, and mobile operators will continue to build and operate large, high-capacity public networks, as they do today. However, these networks will coexist with smaller, distributed private and neutral host networks that will likely be, but do not have to be, integrated with the mobile operators' networks.

The CBRS connectivity fabric has a deeper reach in the enterprise

In the previous sections, we talked about the benefits that CBRS brings to the enterprise. But how will the enterprise take advantage of these benefits? What can CBRS do for the enterprise?

A frequent answer to this question is to offer a list of use cases and verticals (see tables on the right and on the next page) that illustrate how the capabilities of the technology meet the enterprise's needs. Not surprisingly, the list of use cases is long: pretty much any IoT, IIoT or other enterprise applications can run on CBRS. Some exceptions are mission-critical safety services that need a dedicated channel, and applications that rely on wide-area network coverage (e.g., fleet management). With LTE and eventually 5G, CBRS can support any application that has tight latency, capacity, mobility, reliability and security requirements, in both indoor and outdoor locations.

Target enterprise verticals
Agriculture
Financial
Healthcare (e.g., hospitals, home care)
Hospitality (e.g., hotels)
Manufacturing
Military
Mining, oil
Office buildings, corporate campuses
Public agencies
Public venues (e.g. stadiums, entertainment venues)
Retail (e.g., malls, shops)
Supply chain, distribution (e.g., warehouses, ports)
Transportation
Transportation venues (e.g., airports, train stations)
Utilities, power generation and distribution

The extensive list of use cases illustrates the flexibility of CBRS to meet the enterprise's expectations and is necessary to justify the adoption of CBRS in the enterprise. But it is the creation of a deep, wide connectivity fabric, in which multiple applications and services coexist side by side, that ultimately closes the business case for CBRS. In some instances, a single application may be sufficient to generate a positive ROI. But in most environments, the coexistence of multiple applications and services greatly increases both the usefulness and the financial attractiveness of

CBRS, and it is crucial to the business case.

A CBRS network can simultaneously host applications making some opposite types of demands: URLL applications such as robotics or vehicle remote control, which require the highest priority and reliability but often only limited capacity, alongside video monitoring or video communications applications that require more bandwidth but are less sensitive to latency. Voice services can be supported as well, for both stationary and mobile users. Guest access can be provisioned on a best effort basis.

LTE and 5G have advanced traffic management capabilities to ensure that these applications coexist on the same network, and that the allocation of network resources is properly balanced across applications. In this example, URLLC traffic has the highest priority, and guest access the lowest – and the network schedules transmission to maximize throughput given these constraints.

Because in most cases the traffic requirements of applications are highly variable through time, the ability to manage traffic at the application level increases the utilization of network resources and the efficiency of the network – strengthening the business case by lowering the per-bit costs.

The variability of requirements across applications makes traffic management more effective because it increases the scope for optimization of the network. If, for instance, all applications were based on video and had the same priority, the opportunities for traffic management to optimize network utilization would be limited, because all traffic would have to be treated in the same way. Adding URLLC and best-efforts traffic adds a variability in the traffic flows – eventually, network slices – that can be used to optimize transmission.

Use case examples
Asset monitoring and tracking
Automated manufacturing
Autonomous vehicles
Building monitoring and control
Diagnostics, predictive maintenance
Employee access control (e.g., using biometrics or face recognition)
Environment control with sensors
Fire, fault, outage detection
Location-based services
Logistics
Marketing and advertisement
On premises AVG, tracking, routing, navigation
Patient monitoring (healthcare)
Remote control of devices, equipment
Robotic control
Staff communications
Video security and surveillance
Voice, including PBX replacement and voice applications on wearables
VR/AR and 360° or 4K video for staff training and communications, marketing, sales, and entertainment of guests and visitors.

CBRS creates a dynamic wireless environment

Not only traffic management has to happen at the application level – and network slicing and edge going to play a major role in this – it also has to be dynamic, real-time and automated. Artificial intelligence and machine learning will further contribute to the effectiveness of traffic management, and closed-loop learning and automation will further refine network optimization.

The ability of wireless networks to optimize transmission dynamically based on resource availability and demand fits well with an increasingly dynamic environment in the enterprise, where processes have to continuously change to adapt to changes in market demand, products, resource availability and so on.

The need to accommodate change is indeed one of the main reasons to move from wireline to wireless communications in many verticals. For instance, in industrial environments, frequent changes in the production line make wireline connectivity cumbersome for remote automated control or for robotic applications. CBRS is ready for commercial deployments at a time when enterprises in many verticals are ready to move from wireline to wireless, and it allows them to do so without losing the control, performance and reliability that wireline connectivity offers, and gaining the flexibility and adaptability of a wireless network.

7. Takeaways

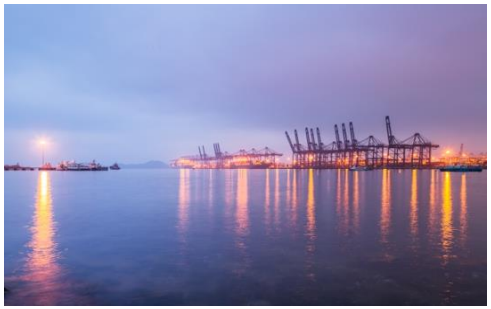
CBRS introduces a new way to manage spectrum that is dynamically tied to those who need it and are ready to use it.

CBRS expands and deepens the role of wireless in the enterprise: it enables a pervasive connectivity fabric that permeates multiple processes, applications and services, and that is necessary to support increasingly dynamic environments in all verticals.

In the enterprise, CBRS supports a long list of use cases in diverse verticals. But CBRS benefits goes beyond this: it enables the concurrent deployment of applications and services with different requirements. This is a crucial foundation for a robust business case.

With the growth of unlicensed and shared spectrum allocations, the enterprise will have more control over spectrum access and, if it so chooses, over the wireless infrastructure, because of its control over the real estate – and hence its ability to decide who can install the equipment to use unlicensed and shared spectrum within its premises.

CBRS creates a bigger, more active role for the enterprise in shaping wireless. No longer just a user of wireless infrastructure, with private and neutral host networks, the enterprise has the opportunity to become a major stakeholder in the wireless ecosystem.






Conversations

Westell | Simple and easy-to-deploy CBRS networks for the enterprise

A conversation with Mark Kerschner, AVP, GM In-Building Wireless, and Mike Brownson, Director of In-Building Wireless, Business Development, Westell

CBRS is based on LTE, a technology developed for mobile operators that have complex networks and need to manage large footprints and a large number of subscribers.

For the enterprise to adopt CBRS, much of this complexity has to go away, while the performance benefits of the technology are retained.

In this conversation, Mark Kerschner, AVP, GM In-Building Wireless, and Mike Brownson, Director of In-Building Wireless, Business Development, at Westell talked about what the enterprise needs from CBRS, and Westell's approach to make CBRS simple to deploy, manage, and use.

Monica Paolini: What does Westell do in the CBRS space? And what do you personally do?

Mark Kerschner: I'm working with a great team at Westell that is pulling together the pieces that will make CBRS deployments easy for our customers.

Westell offers an end-to-end customer solution with CBRS in a private LTE network format. Our solution provides access points (Citizen Broadband Radio Service Devices, or CBSDs) with a Spectrum Access System (SAS) interface for the customer, to be deployed throughout the customer premises. It provides an Evolved Packet Core (EPC), a radio access network (RAN) controller, an Element Management System (EMS), and then user equipment (UE) for the customer to interface to that network.

Our main focus in this area is to make this solution as easy as possible for our customer to deploy and to reap the benefits of utilizing a private LTE network.

Monica: Is your solution for indoor or outdoor coverage?

Mark: Initially, our solution is focused on the indoor space. However, we will also work towards outdoor solutions as a fast follower onto our indoor solution.

At this point in time, our solution is aimed at enterprise customers in hospitality, transportation, healthcare, and manufacturing. We are also focusing on anything that has to deal with low-latency IoT devices.

Monica: LTE is much more complex than Wi-Fi, a technology that the enterprise is more familiar with. How can you make it easy for the enterprise to deploy CBRS, which is based on LTE?

Mark: CBRS is a far more complex solution than Wi-Fi. The CBRS solution includes a SAS and an EPC. The CBSDs have a RAN controller and an EMS. The integration and provisioning can be very daunting for the enterprise. Westell understands this challenge for a traditional enterprise. Our goal is to take that complexity away and make the implementation as easy as possible.

To make it easy, we're developing unique intellectual property that simplifies customers' experience by enabling them to own and deploy a CBRS network with basic IT skills. Our CBSDs have an auto-provisioning feature that will make the deployment and management of CBRS networks easier.

Monica: How can auto provisioning facilitate the deployment of CBRS networks in the enterprise?

Mark: From an enterprise perspective, you turn on your CBSD – the counterpart of a Wi-Fi access point – and it automatically provisions itself. It has the ability to automatically connect back into the network and recognize and be aware of its neighbors.

We are developing a solution that our customers can use to operate a CBRS network without

knowing much about the technology. If they want to learn more about it, we will educate them. But our solution is transparent to them out of the box.

We do all the upfront homework of interfacing a CBRS network with the SAS. We can bring an EPC-in-a-box solution, if this is what the customer needs. Then we can add a white-glove service for integration, if needed.

Monica: What is special about your solution?

Mark: Our unique intellectual property takes away all difficulties of the SAS, the EPC and the RAN controller. Our customers can just tell us: "Hey, I need to have a private LTE network in my enterprise space. This is the space I need to cover. These are the devices and applications that I need to support."

The enterprise does not need deep LTE expertise from its IT personnel. Westell can bring the knowledge and expertise that enables an easy-to-deploy CBRS network. We can help enterprises manage and support the solution.

Monica: What deployment models do you think will work best for the enterprise?

Mark: Westell is looking at three different models.

The first one is a customer-owned and customer-operated model where the enterprise has everything on site. The customer takes control over the network, and runs it and manages it.

In the second model, Westell hosts the RAN controller and the EPC. The enterprise customer owns and manages the CBSDs on site. It would be a shared approach, where we work on the core side. The customer owns the hardware – CBSDs and UEs.

The third model is a service in which we host and manage the complete solution as a service.

We feel that these three models give our customers the flexibility to deploy a network that fits their financial capabilities, and to pick and choose the network structure that works best for them.

Monica: How is the third model different from a neutral-host model?

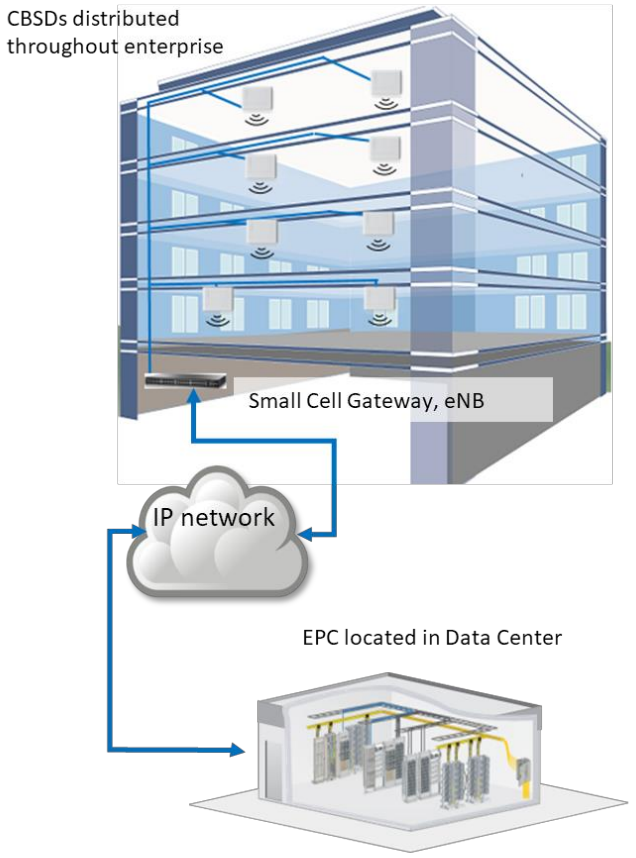
Mark: Neutral host is a solution for hosting multiple carriers and multiple services in a venue or enterprise. What we offer to the enterprise is to operate a CBRS network that is contained within the enterprise.

The industry is still waiting on the cellular operators and the FCC to determine how to share a CBRS network with the general public. In the meantime, an enterprise that wants to have a private LTE network in the CBRS spectrum can do so today.

Our hosted model can evolve to include neutral-host capabilities to help enterprises manage their private networks and open them to carriers.

Mike Brownson: A lot of people are talking about using the CBRS band – or OnGo, the new brand name for CBRS – as a neutral-host platform.

The neutral host is the holy grail, but many things need to happen before that becomes a reality. In the meantime, we're waiting for CBRS, Band-48 handsets. We're also waiting for the FCC and cellular operators to define how we're going to have a single RAN as a multi-carrier platform.



In-building wireless infrastructure with CBRS *Source: Westell*

In the meantime, we have some very compelling business applications for the enterprise.

For instance, today, voice in the enterprise is tied to the PBX, and not to the cellular carrier network. CBRS can carry voice traffic and be tied into the enterprise PBX. This allows your handset to be both your mobile phone and an extension off the

corporate PBX when in the CBRS coverage area.

The enterprise can also use CBRS to do massive IoT. And there are enterprise applications for widely adopted devices such as smartphones.

Monica: How does the ecosystem need to develop to meet the needs of the enterprise?

Mike: We need to make sure we have the devices.

Right now, the FCC and SAS providers are working together to test their systems and get SAS approval. The devices – such as those that Westell is developing – are the only network elements that need to be FCC certified along with the SAS interface. The SAS domain proxy needs to be tested too.

We're working through all the certification processes. We expect them to be done in early 2019.

The other thing we're waiting for is, of course, the end-user devices. Sierra Wireless was the first UE manufacturer to receive FCC device certification, in November 2018.

There are many devices that are CBRS-ready, and are going through FCC approval. We're going to see a literal tsunami of OnGo devices in 2019. We know of devices under development that will convert OnGo to USB, Ethernet, serial ports, Bluetooth and Wi-Fi, as a fill-in measure until the devices incorporate OnGo.

Monica: When is Westell going to launch OnGo devices?

Mike: We expect to be shipping our first OnGo access points and core components in the first quarter of 2019. In the second quarter we should have our intelligent remote, the RMX4000, CBRS capable.

The device can take analog, digital, Ethernet, and Wi-Fi in a variety of interfaces, and convert that to 4G cellular over a public network or over a private CBRS network.

Monica: How difficult is it to add support for CBRS in a device?

Mike: Handset manufacturers have already done most of the hard work. For example, many handsets used in Asia already operate in Band 42 and Band 43, which overlap Band 48, the band used in the US. All these bands operate in nearly the same frequency in the TDD domain. It should be pretty simple for UE suppliers to modify their devices for CBRS. The industry anticipates that a majority of handset manufacturers will launch their OnGo smartphones in 2019.

Monica: Why should an enterprise look at CBRS for private networks?

Mike: The capabilities of CBRS/OnGo have never been available to a private enterprise. The enterprise has ubiquitous Wi-Fi and, currently, Wi-Fi is faster than CBRS. Private LTE shines in other areas. For instance, it has much lower and predictable latency. For industrial IoT applications, CBRS can provide incredibly low latency, approaching 5G latency requirements.

LTE and CBRS support high levels of mobility, or inter-cell handoffs, which other existing technologies in unlicensed bands cannot provide. Because LTE offers optimized handoffs, we can have very active data sessions with a tablet-mounted machine, such as a forklift that roams through an auto plant. LTE has a clear advantage in doing inter-cell handoffs, and the EPC controls and manages these handoffs. It knows when to hand off a device to an adjacent cell, and there's no loss of data integrity or increase in latency.

Westell CBSD for indoor CBRS networks *Source: Westell*

Monica: How does CBRS manage traffic across users?

Mike: The built-in scheduler in LTE ensures that all LTE user devices get some bandwidth. You can even prioritize certain devices, so they get more bandwidth. A popular LTE site such as a stadium may have hundreds of users on a sector on a particular LTE channel. They all get bandwidth. You can configure the amount of bandwidth they get. Wi-Fi can't claim that. There's no scheduler mechanism built into the current Wi-Fi standards.

Monica: How does CBRS handle security?

Mike: Security is very important for manufacturing,

financial and healthcare verticals. For instance, regulations, data and device security are paramount to meet HIPAA regulation.

With LTE UEs being SIM based, there's a level of authentication that is far more secure than Wi-Fi. Additionally, we incorporate IPsec security into our link from the CBSD to the gateway. This gives the enterprise a very secure interconnection among all network devices, from the CBSD and the RAN controller, to the EPC.

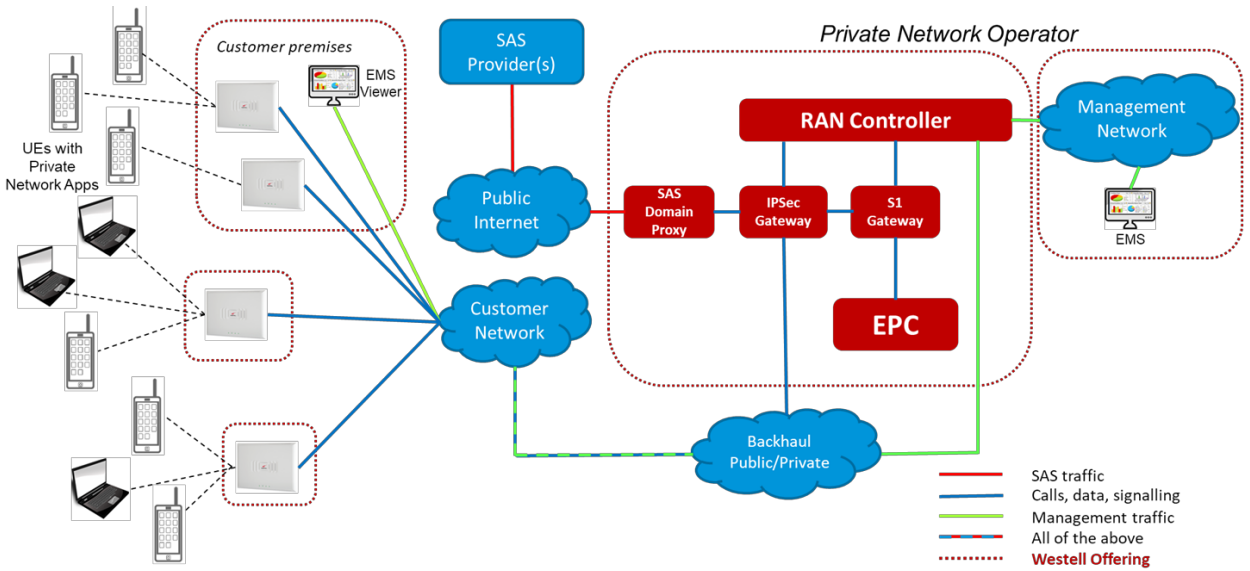
Monica: What kinds of verticals are likely to find CBRS most compelling?

Mike: By looking at LTE's advantages of roaming, enhanced security, low latency, and capacity sharing, we can identify the applications in which LTE will be most beneficial. There's a huge number of applications. It's tough to point out exclusively any one of them.

Consider the current functionality of your smartphone. Now imagine that you have a variety of apps specially designed to increase information flow, performance and the efficiency of your staff when they are on premise.

Private LTE systems have been deployed elsewhere in the world, so we do have some actual use cases. They have often been connected to the company PBX so the UEs can operate as an extension of the company PBX. We've seen applications for video, as well. Picture a technician on an offshore oil rig being connected via a live video link to the equipment expert onshore providing live guidance on a repair.

Private LTE is also attractive in the hospitality, healthcare, manufacturing and transportation verticals. Let's use an example in the hospitality industry.



Architecture for a CBRS private network *Source: Westell*

Currently housecleaners get a paper list of who's checking out, and when a room is cleaned they use the bedside phone to report to the housekeeping manager. That's pretty old school. Now imagine a smartphone app that provides a list of rooms to be cleaned and which guests have arranged for late checkout and which guests have checked out early. Through the app, the housekeepers can tell what rooms to clean next and, once a room is clean, notify management through the app to release that room for the next guest. This would increase efficiency and, quite possibly, guest satisfaction.

In the healthcare market, there is a plethora of devices that need wireless connectivity. In addition, you have specific medical applications, such as telemedicine or nurse calls, that run on a CBRS-enabled smartphone. Using micro-location detection within an indoor LTE network, you can precisely locate the position of things and people. Micro-location detection helps in finding gear and people.

Manufacturing is another vertical that has a lot of potential for CBRS and IoT. Manufacturers need communication to mobile devices to reach people in the field and on the client floor, but they also need M2M communications to control machines on the factory floor.

We're also looking at transportation hubs. There have been a couple of preliminary deployments in transportation hubs and airports. An international seaport recently studied ways to provide ubiquitous voice and data coverage throughout the port. The study determined it would require 11,000 Wi-Fi access points or 15 private LTE base stations. Now they can track containers, monitor cranes and loading vehicles, send instructions to

data terminals for use by the equipment operators, and keep track of everything within the port. This has increased efficiency and reduced errors substantially.

We also have the enterprise space, where a private LTE system can be cross-connected to the PBX and a private CBRS network becomes an extension of the desk phones. You can also use the network for internal messaging, and for workflow and project management applications.

Everything you can do with your smartphone and enterprise-specific applications, you can do in a private CBRS LTE network, without having to rely on a carrier's signal penetration into a plant or an office. Having your own private LTE system ensures security: the data can stay entirely in house. It also assures low latency and wall-to-wall connectivity within the building without having to rely on an expensive and complicated cellular DAS solution.

Monica Paolini: Will dual SIM help the enterprise share CBRS-enabled devices such as smartphones both for private network applications and for personal cellular access?

Mike: Absolutely. Many of the handset manufacturers have already announced dual-SIM phones. As the manufacturers incorporate the CBRS band into future releases, individuals will be able to have the same smartphone for both business and personal use. Dual SIM is going to help us progress from purely private LTE devices, to handsets with two phone-number IDs on two carriers that can be used both in private and public networks. Dual-SIM handsets will operate on regular outdoor carrier networks; however, as the user enters the coverage area of a private LTE network, the other SIM is programmed to connect to the private LTE network.

With a private LTE solution installed in the enterprise, my smartphone becomes an extension of my desk phone and replicates all the functionality and features of my desk phone. Now I'm no longer tied to my desk, and customers don't need to guess whether to call my desk phone or my cell phone. The same phone also works as a regular cell phone, with all of the applications that are available over the public network.

Monica: How can the enterprise manage the connectivity between dual-SIM devices attached to the local CBRS network and the carrier network?

Mike: Over time the industry will work out how to deal with dual SIM within a neutral-host platform, but that's going to take time. The roadmap toward neutral-host solutions is not totally clear. This is primarily a business issue with the cell phone carriers.

However, we're currently having conversations with partners that are close to making this a reality. Through interconnect and roaming agreements, a neutral-host solution may be closer than most think.

Monica: How do you see the development of the CBRS market as we move to 5G?

Mike: 5G is still somewhat nebulous as to what it is and how it will materialize. In 5G, the data rate and latency are the qualifiers. We see the CBRS band as being a component of 5G. Tier-one carriers wishing to augment their bandwidth can deploy 5G in the CBRS band. In the private network space, we're definitely keeping an eye on the evolution of 5G. We believe that the CBRS band will be a component of 5G.

The FCC is looking at using hundreds of MHz of spectrum in the 6 GHz range for unlicensed or lightly licensed use. 5G is going to require a lot of spectrum. When available, the 6 GHz band may use a spectrum sharing technology that is similar to the one used by CBRS and OnGo. We see a roadmap for private enterprise to 5G, where we can have higher orders of MIMO and bandwidth aggregation over multiple frequency bands.

In a private LTE system, we're already deploying more of the components at the edge, where you have the RAN controller and the EPC on premise, and this gives us more control over latency. In 5G, you have high data bandwidths as well as very low latency. But I think we're close to achieving 5G latency already.

Monica: We can do a lot before we have 5G.

Mike: I think that's a great way to put it. The enterprise shouldn't wait for 5G. It'll take years before 5G is available for private use, and the roadmap for 5G can incorporate components of Westell's CBRS solution installed today.

About Westell

Westell is a leading provider of high-performance network infrastructure solutions focused on innovation and differentiation at the edge of communication networks where end users connect. The Company's comprehensive set of products and solutions enable service providers and network operators to improve performance and reduce operating expenses. With millions of products successfully deployed worldwide, Westell is a trusted partner for transforming networks into high quality, reliable systems. For more information, please visit westell.com.

About Mark Kerschner

Mark joined Westell in 2016 in the In-Building Wireless Business Unit and is currently the AVP/GM of the IBW Business Unit. Mark brings to Westell more than 20 years of experience in the Wireless and Telecommunications industry. Before joining Westell, Mark held a variety of business development and product management positions within CommScope (Formerly ADC/TE Connectivity) including Senior Proposal Engineer, Product Manager for Copper Connectivity Products, and Senior Product Manager for Outdoor and In-Building Distributed Antenna Solutions. In his last role, he was responsible for product development initiatives, market management and lifecycle management for CommScope's wireless products and business expansion into global markets. Mark holds a Bachelor of Arts degree in Business Management from St. John's University and a Master of Science in Telecommunications from St. Mary's University.

About Mike Brownson

Mike Brownson is an industry veteran with over 45 years in the wireless industry. Throughout his career he's been involved in a wide variety of wireless technologies including two-way radio, cellular, microwave, unlicensed broadband wireless and most recently has invested the past ten years dedicated to Distributed Antenna Systems for public safety and cellular enhancement. Currently, as Director of Business Development at Westell, a manufacturer of wireless solutions, Mike leads the company's efforts to promote, educate and inform on all aspects of in-building wireless solutions. He also works with the Electronics Technicians Association in their in-building wireless education and certification program, holds numerous industry certifications and is on the Standards Technical Committee for UL-2524.

Nokia | Reliability to drive adoption of CBRS private networks in the enterprise

A conversation between Stephane Daeuble, Head of Private Marketing in Wireless Vertical Solutions, Nokia, and Monica Paolini, Senza Fili

As we enter the fourth industrial revolution and the role of wireless connectivity expands in the enterprise, reliability becomes a crucial attribute of networks, alongside capacity, latency and security. CBRS can provide the reliability the enterprise needs in the 3.5 GHz shared band in the US. This gives enterprises the opportunity to deploy private networks to run IoT and other applications and services.

Stephane Daeuble, Head of Private Marketing in Wireless Vertical Solutions at Nokia, told us about how Nokia decided to focus on private networks and CBRS, and how reliability has become paramount.

Monica Paolini: Stephane, Nokia has been quite active on the CBRS front. What is your take on the technology?

Stephane Daeuble: CBRS has been part of our strategy for almost two years. We believe there is significant potential for the enterprise to use wireless technologies that operators used in the past and that we use every day on a mobile phone.

We believe that technologies such as 4G and 5G have the scope to bring as much change to the enterprise in the future as the mobile phone did in the last 20 years. A number of enterprise segments require reliable wireless connectivity as part of their processes.

About five years ago, one of our customers in the mining industry approached us because it was facing issues in extending connectivity, for both workers and machines, throughout the mines, with the existing Wi-Fi.

After the installation for this customer, we realized that the coverage and capacity of LTE had a potential for growth for that client. Ever since then, we have felt there was a potential, and now we put a significant focus on bringing the quality of those 3GPP networks into many industry verticals.

Monica: The timing is important here. Five years ago, we didn't have the technology tools we have today. CBRS is one of them.

There is much more interest in having private LTE networks today than five years ago when you started to work on this. What drove the increased interest in private LTE in the enterprise?

Stephane: There're a couple of factors.

The first is the realization of need in this market. Nokia and other vendors in this industry have to adapt their solutions to meet the specific requirements of private networks.

Here, when you are talking about even a very large enterprise, the scale is not the same scale as for a country-wide network, whether in the US, Russia or elsewhere. Clearly, from a scale point of view, things had to change.

The evolution of our solutions towards the cloud and the virtualization of functions means that now we have a solution in our portfolio that can be scaled down to the smaller-sized networks which the typical enterprise will require.

The second factor is that with CBRS and other technologies such as MulteFire, many enterprises will get their private networks or 5G networks using an operated public network, slicing the public networks of the operator for the enterprise needs. At the same time, there are many enterprises which, for a number of reasons, want full control of their destiny and the performance of their networks. These organizations require spectrum for deployment of such technology.

In terms of the technology, CBRS is a trailblazer. It allows enterprise customers to deploy their own technology and networks in their own campuses, and to have full control of their destiny.

A third factor is the ecosystem. When we consider different industries – such as merchants, mining, harbors, or even factories – it's not just connectivity, but a whole new technology. You need devices that enable you to connect to this range of technology.

This is where CBRS adoption will really take time. Although in the telecom world, innovation and product change are as fast as in IT, in industrial

markets some of the adoption of robots is a little bit slower. It will take time to get the ecosystem we need to support this technology.

Despite the technological evolution and advancements in the last five years, we need further significant technological development to ensure all different machines, devices and sensors can talk the same language.

Monica: The ecosystem is very important. The ecosystem for enterprise-specific applications is going to be wider than the ecosystem for our traditional cellular networks.

From a spectrum perspective, how is CBRS helping the enterprise? What does CBRS do for the enterprise that LTE or, eventually, 5G in licensed bands doesn't do?

Stephane: There is a big difference. In the US, CBRS brings the capability for enterprises to effectively register for an amount of spectrum that is specific to their campuses.

If you manage a factory or a harbor on the West Coast, you will be able to register for a specific amount of spectrum dedicated to your site. It means that you'll be able to deploy your networks and be guaranteed a certain quality of service, because different enterprises won't be reusing the same registered spectrum.

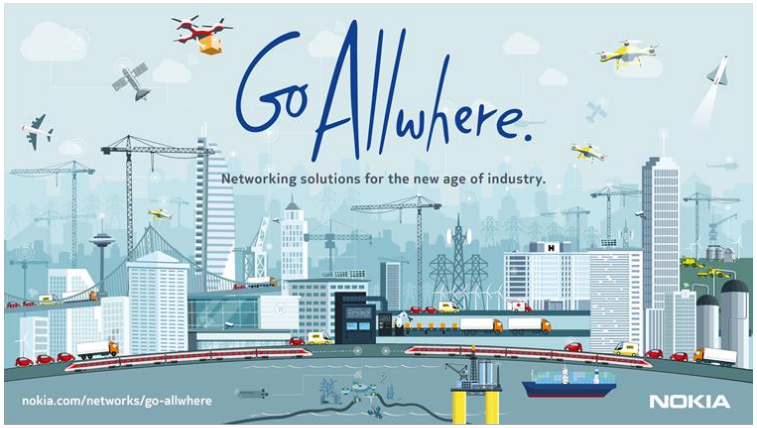
A guarantee of a certain level of quality is the typical issue with Wi-Fi. Because the Wi-Fi spectrum is free, everybody can use that spectrum. CBRS gives you a certain quality of service, because you are allocated that spectrum for your campus.

Monica: CBRS is only in the US. What are we going to learn from CBRS in the US? What impact will CBRS have on the rest of the world?

Stephane: CBRS started the trend of using spectrum for vertical use cases. The US, the FCC did well in creating a framework that allows the enterprise to reuse or share spectrum assets.

MulteFire is another initiative in which Nokia participates and that was launched at about the same time as CBRS. MulteFire takes LTE into the Wi-Fi spectrum, bringing LTE capabilities into the unlicensed spectrum for enterprise users.

A couple of other countries have also taken the lead on making spectrum available for vertical applications. Finland is one market that already has auctioned some spectrum for verticals in the 2.6 GHz TDD LTE band. In Finland, a lot of enterprises are now deploying LTE in this band.



Nokia's Go Allwhere vision *Source: Nokia*

Other countries, such as Germany and France, are looking to auction part of their 3.5 GHz band for vertical access. At the same time, telecom regulators have been very open to leasing or lending spectrum to verticals.

A final piece in the CBRS puzzle is the CSPs. We feel that the CSPs still have an important role to play. Quite a few CSPs are realizing the opportunity and the value that LTE brings for industrial customers. CSPs are increasingly willing to work with customers and lend them part of their spectrum for enterprise use cases in their campuses.

Monica: Nokia has been putting a lot of emphasis on the transition to the fourth industrial revolution, with Future X and the expanding role of enterprise in wireless. What is Nokia doing differently from the past to address the growing enterprise market?

Stephane: We believe that the digital transformation is the cornerstone of the fourth industrial revolution. To empower people, you need to connect a lot of things, such as sensors, devices and machines.

Today, there is Wi-Fi in many enterprises. That's useful for day-to-day business communications, such as in Outlook, email or meetings. Wi-Fi is perfectly fine, even for VoIP.

We are talking about the wireless technology that brings together the best DNA from both Ethernet and Wi-Fi. Wireless technologies and IoT are the key enablers of the fourth industrial revolution, because they bring connectivity to the enterprise with business-critical reliability.

Let me make this clear: CBRS is not going to replace Wi-Fi. It will be an additional layer that enables the enterprise in various campuses to support their most important processes. These processes may require connecting people, machines, vehicles, robots or

anything else. Connectivity in these processes requires a certain level of reliability, and this is why reliability is so critical.

And that's why we feel Nokia has a key role to play. We have been studying the industry verticals for a long time. We've got over 1,000 business-critical networks in the world today. The next step is to bring reliability to enterprise wireless networks to leverage what IoT brings and to automate industrial processes by digitalization. This is what our Go Allwhere vision is about.

Needs vary across segments, but there is a common drive towards more digitalization, more flexibility, and more responsiveness to customers. These general megatrends are taking us into the fourth industrial revolution, and wireless technologies can improve the business efficiency of enterprise customers.

Monica: When will the enterprise start to deploy CBRS? And which verticals will be the first to launch?

Stephane: Today, heavy industries are not very advanced in automating processes. Mining, harbors, airports, and many other heavy industries fall within the same ambit. They all need reliable connectivity to run their applications. They may have moving things in their campus – forklifts, trucks and other vehicles. These industries and segments have some of the greatest prospects today.

We also see significant interest from manufacturers in almost all industries – for instance, from the car industry or the electronics industry. Most industrial manufacturers have already automated their processes, but they're looking for more flexible wireless technology to expand automation.

For instance, a car manufacturing plant may produce one to three models. Production lines are bolted to the floor, and so they are extremely difficult to change. But with wireless technology, the manufacturers have more flexibility, and can rapidly move the production line from one place to another and reshuffle the production line based on demand.

Monica: Is security a differentiating factor for CBRS?

Stephane: CBRS networks require security strategies that constantly measure the security posture and risk level. It is a real-time assessment that needs new methods, such as machine learning to detect anomaly behavior; contextual analytics to correlate all log files and events for the early identification of security threats; and automation to respond fast, before the attack occurs in the network. The security strategy for modern networks is evolving from a technology issue into a business issue, because of companies doing business in the cloud, employees acting mainly outside of the secured perimeter wall, and third parties having access to confidential data as part of a business relationship. So, making security a differentiator in a business requires aligning security strategies with business strategies.

Requirements for industrial private networks *Source: Nokia*

Monica: Many requirements for enterprise IoT or other services are tough to meet. And enterprises want to have more control over their networks and keep most of the processing local to their premises. Is edge computing becoming a requirement for private networks – as well as an advantage for technologies such as CBRS that go hand-in-hand with MEC and, more generally, edge computing?

Stephane: MEC and CBRS do go hand-in-hand. MEC is now also part of the 5G standard and has proven its value.

The first benefit from MEC is low latency. Many

processes require a very low-latency response. With an on-site, local edge-computing server, you can run applications directly on the site, and this guarantees you a low latency.

Second, the MEC infrastructure gives you a lot of processing power, which enables you to run many applications, especially ones that use video and need a large amount of processing.

Security is the third way MEC benefits the enterprise. With local breakout, the enterprise can keep specific data within its premises for security or other reasons, and allow the rest of the data to flow outside. MEC also plays a role in confidentiality of the data.

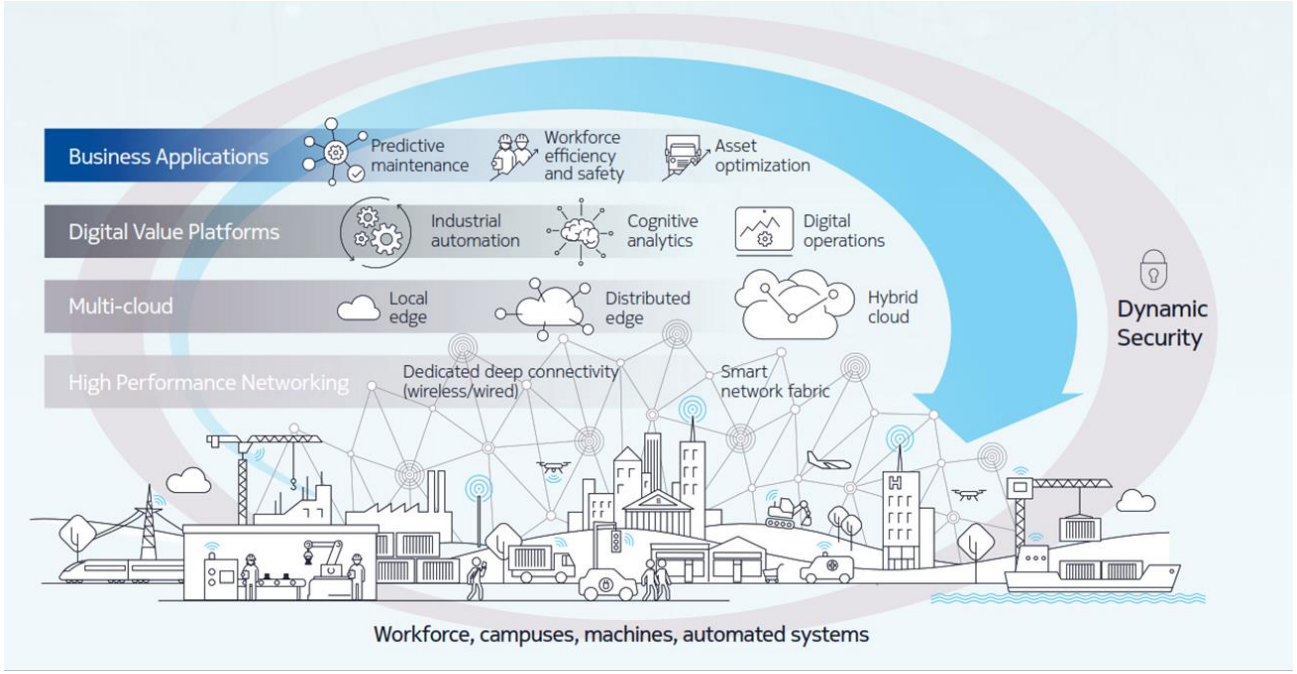
Monica: It's a really crucial time for CBRS as we're getting close to actual deployments. What is Nokia doing specifically in the CBRS area?

Stephane: It was about three years ago that we launched the world's first CBRS small cells. We have both indoor and outdoor solutions. Our solutions rely on our award-winning small cell series, called Flexi Zone. They are very capable small cells that have what we call macro parity and macro capacity.

We also have an indoor pico and an outdoor solution for CBRS. The pico cell has the same capacity as a macro BTS, despite the fact it's only three liters – and it can support a large number of simultaneous users, which can be either machines or people.

Small cells enabled us from the beginning to try CBRS technology. We typically have roughly 30 to 50 ongoing trials around CBRS at any time.

Availability of CBRS equipment enabled us to work with partners. CBRS requires the ability to sense the use of the spectrum in the 3.5 GHz band by the incumbents – e.g., by radar users or wireless ISPs in some rural places – to ensure they have priority



Nokia's FutureX for Industries vision *Source: Nokia*

access to the band.

We did a lot of work with the SAS providers to test spectrum sensing and access coordination. We were involved up front in integration and IoT testing with partners and the device manufacturers. As a result, we have many ongoing trials. At this point in time, the only thing we're waiting for is the finalization of the plan by the FCC to make these private networks commercial.

Like for all the other private LTE contracts, we are covering a wide range of industry verticals, especially in logistics, manufacturing, airports. We are also working with wireless ISPs in rural areas that are looking into using a wireless technology to connect areas that are still unconnected.

Initial CBRS deployments will be in these industry verticals. Once CBRS is ready to go into day-to-day mobile phones, CBRS will also be used for indoor connectivity, for example, in public or enterprise venues. Operators already invest in indoor, dedicated small cells or DAS solutions for the larger venues or larger customers. But typically, for the smaller or medium-size indoor spaces, the business case is challenging.

However, once phones support CBRS, a neutral host operating a CBRS network in a hotel will be able to deploy its own CBRS network within the premises for the hotel's operational needs and to keep hotel

guests connected.

CBRS also brings further innovation, because it can interconnect the private LTE networks to CSP networks. After a commercial agreement with CSPs is in place, CBRS network services can be opened up to the subscribers of that CSP.

Subscribers from an operator in the US can walk into that hotel and seamlessly connect to the hotel network, thinking they are still on the operator's network. This will significantly help the business model for indoor connectivity, which is critical for 5G.

Monica: Availability of mobile devices – primarily smartphones – is essential to getting enterprises on board, deploying CBRS within their premises, and expanding their networks beyond what they need for IoT. What are your expectations for device availability?

Stephane: Operators will have a big role in CBRS. They will use CBRS to boost the performance of their networks, and they will need mobile devices in the hands of their subscribers. In the US there is a big pool of operators that have announced that they will use CBRS.

We are waiting for the PAL option that will accelerate CSPs' deployments. It will drive the integration of CBRS technology into the traditional UE chipsets for phones.

In the meantime, there are many machines that you can simply add to an IoT gateway. You can make an old machine, truck, or vehicle talk to CBRS networks by using something that's not much bigger than a phone.

On top of the wireless CSPs, we will also see the hotel and venue indoor model in an early phase. But we need to ensure that a large percentage of the population has CBRS phones, so they can connect and benefit from CBRS neutral-host indoor coverage.

Monica: CBRS is not the only solution that enterprises can use for LTE-based networks outside cellular licensed bands. What are the options available?

Stephane: Operators are also using 5 GHz spectrum with LAA. LAA is a 3GPP technology that enables operators to exploit the unlicensed spectrum that Wi-Fi also uses to boost the performance of their 4G networks. We've seen some of the promising results in the field, and some carriers in the US are deploying LAA.

With CBRS commercial availability, operators will deploy CBRS as well. The 3.5 GHz spectrum for CBRS will have a big role to play in the US because, as the FCC indicated, it will be a key band for 5G deployment.

Monica: How will these technologies coexist?

Stephane: There is still work ongoing in this area, with significant discussions among 3GPP, the MulteFire Alliance and the CBRS Alliance to make sure these technologies will coexist and be fair to each other.

Monica: What should we expect from Nokia over the next few years?

Stephane: We are already seeing fast growth in private LTE across the globe. The US market, because of CBRS, has been at the forefront in this growth. We've seen a significant amount of activity and interest in that market.

The enterprise market has great growth potential. We've seen significant growth in volumes of deployments of our small cell, in line with various market forecasts. While 5G will drive small-cell deployments, the opportunity around enterprise is absolutely huge.

Just consider some recent census figures. In the world, there are 10.7 million factories, which is a huge number when you consider that each factory could have its own LTE network.

One of our industrial clients is planning to launch LTE-connected screwdrivers for a factory. Why use LTE on a screwdriver on a lightener? With an LTE private network, you can upload the right profile to all screwdrivers throughout the factory. Every single screw or bolt that you tighten will have the right setting.

As soon as they have LTE-connected tools, these 10.7 million factories will need to deploy private LTE, CBRS or MulteFire networks. Potentially, the market is huge.

Global IoT is supposed to be a trillion-dollar market, and CBRS will make a big contribution in that market. With CBRS, the US is taking a driving position in the private LTE space.

Monica: The number of enterprises and the number of things that can be usefully connected is set to grow quickly. But it not just the number of things to grow, it is the value of connectivity that will grow, as well, because enterprises will discover new applications and services to host on their networks.

Stephane: In almost every single deployment, there's an initial application driver that the enterprise is keen on establishing. Once enterprises have a network, they realize they can do so much more with it. In the mining project I mentioned before, the initial requirement was just to provide connectivity to people in the mine. Once they had the connectivity, they realized they could use the connectivity for

remote drilling, putting explosives inside the mine, video surveillance: "Well, I can do remote drilling, and I don't need someone to do it for me anymore. I just connect something to my machine and I can just drill."

And then: "While drilling, we can put the explosive inside. Why should we have somebody there? I can just do that remotely."

They also installed video cameras around the mine to see what was happening, and improved their operational awareness.

Mobility was next: "Well, maybe I can also connect my trucks, and they can become autonomous." They go and collect gravel from one place and bring it back up.

Then finally: "What about the workers? Maybe I can now have a wearable that monitors their fatigue and their tiredness. And if there's an accident, I know straight away, helping with the safety as well."

This is complex, but in line with our experience at Nokia's factories where we started trying IoT networks. The initial driving application was about humidity sensors. We needed to implement several hundred humidity sensors throughout the factory to improve the quality of the SMT, the mounting of components on PCBs. We had the choice to either wire the 300 sensors or use a wireless technology. We first used Wi-Fi but that collapsed. Subsequently, we used our own technology.

We are also using private LTE for AGV with robots that bring parts from one part of the factory to the next and to connect all our test machines. Every time we change production, the test machine can just move around, and we don't have to reconnect it. There are plenty of use cases that we are now discovering.

In the same way, we learn and bring our experience in every industrial segment in which we work. Both IoT and CBRS have plenty of applications. But reliable wireless connectivity is absolutely important.

About Nokia

Nokia is shaping the technologies at the heart of our connected world, to transform the human experience. Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers, with the industry's most complete, end-to-end portfolio of products, services and licensing. We adhere to the highest ethical business standards as we create technology with social purpose, quality and integrity. Nokia is enabling the infrastructure for 5G and the Internet of Things to transform the human experience.

Digital technologies are changing our world. Nokia is driving innovation and the future of technology to power this digital age and transform how people live, work and communicate. www.nokia.com

About Stephane Daeuble

Stephane is head of Private Marketing in Wireless Vertical Solutions at Nokia. He is responsible for the marketing program to show how Nokia solutions can help industries, enterprises and the public sector to benefits from wireless technologies such as Private LTE, MulteFire, CBRS, 5G and IoT. He aims to increase the efficiency of their business operations and to help them embrace the 4th industrial revolution. Stephane is a self-professed IT geek and gadget guy and has been an active industry advocate in various different roles. He is based in Paris and speaks Czech, English, French and Spanish. You can connect with him on stephane.daeuble@nokia.com

Federated Wireless | The benefits of coordinated spectrum access in CBRS private networks

A conversation between Iyad Tarazi, President and CEO, Federated Wireless, and Monica Paolini, Senza Fili

The most fundamental requirement of spectrum sharing is that all the legitimate users have fair access to the spectrum resources, according to their priority level. In CBRS there are three levels: incumbent users, PAL users (with license) and GAA users (registered, but no license). Access to the CBRS spectrum has to be coordinated to give appropriate access to all authorized users.

I talked to Iyad Tarazi, President and CEO at Federated Wireless, about the benefits of coordination in spectrum use and how the enterprise can seamlessly and easily deal with spectrum coordination.

Monica Paolini: Iyad, can you tell us what Federated Wireless does?

Iyad Tarazi: Federated Wireless is a software company. We have built an enablement tool to allocate and manage spectrum in the new 3.5 GHz band for a shared-spectrum private LTE model.

Monica: What's your perspective on sharing spectrum in the enterprise?

Iyad: Shared spectrum promises to bring another step forward in quality and capacity for enterprise connectivity solutions. Today, most enterprises use Wi-Fi. It is usually quite good, but there's not enough spectrum, and this causes overuse and unpredictability of the coverage.

Spectrum sharing allows you to take spectrum that's open, and use it to deploy economic and scalable 4G and 5G solutions. You end up with better coverage, better capacity and better security. Spectrum-sharing private connectivity solutions are highly valuable to enterprises.

Monica: What's the difference between shared and unlicensed spectrum?

Iyad: Unlicensed spectrum, especially in the Wi-Fi space, is uncoordinated. Anybody that wants to use the spectrum can buy a piece of equipment, turn it on, and fight for the space within unlicensed spectrum. As more users start sharing the unlicensed band, they sacrifice coverage and speed.

In a shared-spectrum model, a central cloud system coordinates spectrum access. Shared-spectrum equipment has to consult with the coordination system before using the shared band. The coordination system has very sophisticated algorithms to figure out the optimal use of the spectrum for everyone, and then allocate the spectrum to maximize use and performance. A coordination system provides greater capacity and quality than everybody would get out of the same spectrum without coordination.

Monica: What degree of performance improvement should an enterprise expect with CBRS over Wi-Fi?

Iyad: There've been many trials and live deployments with equipment that uses shared spectrum in 3.5 GHz. These tests have shown that systems using shared spectrum have three times more coverage and capacity than they would with unlicensed spectrum. The deployment of more pieces of equipment further increases the capacity and the speed.

Monica: Do we also have better security?

Iyad: CBRS has better security than Wi-Fi because of the way security is built for 4G systems. By design, security is integrated all the way into the chipset in an LTE network.

CBRS simplifies security for all applications, because it's riding on native security within the LTE stack or within the 5G stack. That makes it a lot simpler and more secure.

Monica: Coordination sounds complicated: you have to act in real time, as network and traffic conditions

change. Can you coordinate spectrum in a way that is effective and yet simple?

Iyad: We achieve coordination by tapping into the power of cloud computing and sensor technology. Cloud computing and sensing are two portions of our system. Our system is primarily software that sits in the Amazon cloud, applying algorithms and collecting data.

Every time an access point is turned on, we collect a range of parameters about location, antenna direction, and the type of equipment. These parameters are translated into an accurate model of where the spectrum is going to be used, what the traffic demand is, and what spectrum is available around it. We also get feedback from actual users. If they run into any unanticipated interference, a learning algorithm process gets feedback and adjusts the algorithms accordingly.

The ability to constantly run the algorithms, do the modeling, and collect the data from the access points in real time enables us to accurately read and coordinate the use of spectrum, delivering the value of spectrum sharing and coordination to the network.

Monica: We currently have two models. In the LTE licensed model there is a single user – typically the mobile operator – who owns the license and has exclusive access to the spectrum. In the Wi-Fi unlicensed model, everybody can use the spectrum – and we pretty much all do so.

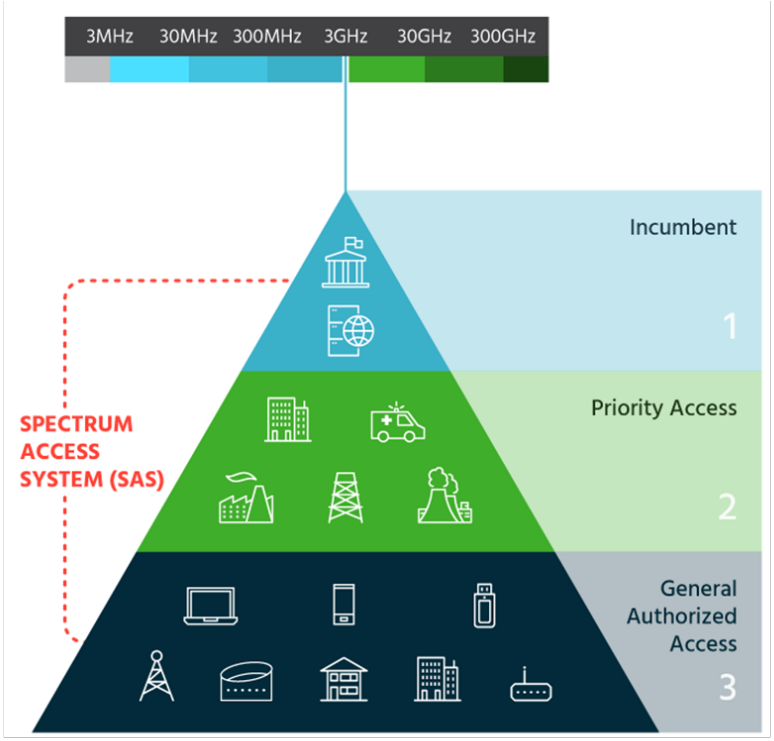
Shared spectrum gives us a third model. With shared spectrum you have different classes of users with different access privileges and, hence, access has to be coordinated to make sure every user gets what it is entitled to. And there is a great scope to optimize coordination.

How can an enterprise benefit from that?

Iyad: Equipment manufacturers such as Ericsson, Ruckus and Nokia use our API-centric architecture. For an enterprise, our technology sits behind these equipment makers, which are exposed to our APIs. We provide these equipment manufacturers with spectrum allocation and other services that in turn they use to support enterprise deployments. The enterprise will buy the equipment and deploy it, and when they turn it on, spectrum coordination will work out of the box. That's all they have to do.

Monica: The enterprise doesn't need to have a direct connection with you to benefit from coordination and comply with the regulatory requirements?

Iyad: The enterprise does not need to have a direct relationship with Federated to use CBRS. We're a B2B service company. We enable other partners who go directly to the enterprise. These could be OEMs who are in the equipment space, technology partners, managed service providers, sophisticated technology integrators, and IT teams. We also support wireless carriers and cable companies, and it would be one of these partners who would interact with the enterprise directly.



SAS management of CBRS's three tiers of users *Source: Federated Wireless*

Monica: Enterprises are interested in having a technology like LTE on the premises. But the licensed LTE complexity is daunting for them. How can you make LTE easier for private networks in the enterprise?

Iyad: Most of our technology partners are working to develop integrated private LTE solutions that are frictionless and that will come as one solution to the enterprise. They've integrated the Federated Wireless Spectrum Controller into their solutions, and they are adding other capabilities, such as the ability to have dashboards, manage performance, and integrate with IoT ecosystems or edge computing products. The majority of enterprise customers will choose more integrated and entwined solutions that will simplify their 4G and 5G networks.

Monica: Enterprise networks don't need the same core functionality as mobile operators do. How can they shrink the core and retain only the capabilities that they need?

Iyad: Most enterprise CBRS networks will not look like an operator network. The core capability for 4G is going to be directly integrated with the radio solution or will come as a cloud service. It is very unlikely that an enterprise will to have to worry about deploying its own mobile core solution.

Monica: This is crucial, to approximate the simplicity of a Wi-Fi network. Although, a high-quality Wi-Fi network is not that simple to set up, either.

Federated has been doing a lot of work with both operators and enterprises. Can you tell us what you are working on for enterprises?

Iyad: We've been one of the pioneers of this whole ecosystem. All we do is shared spectrum and CBRS. We've been at it for more than five years. We've invested $75 million and will invest some more. We have conducted over 50 technology trials in different markets.

We've built operational support teams and programs to enable multiple business models. For example, we created a partner program and have pre-integrated the equipment of more than 20 OEMs directly with our SAS.

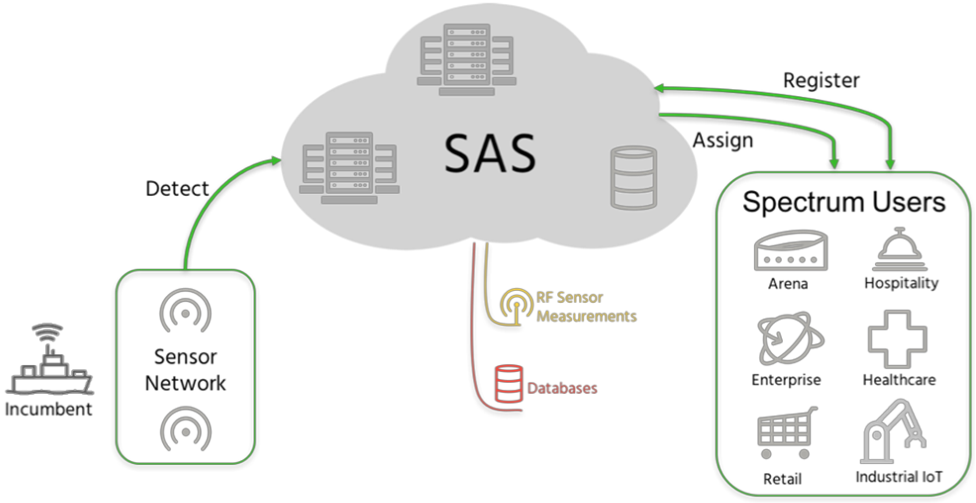
We have created online training and support tools for trouble management. We manage the nationwide network through a NOC. We will continue to do more by integrating additional open source, IoT and application enablement, edge compute and other capabilities to expand the scope of the solutions that enterprises can easily tap into.

Our partners will then bring these solutions to enterprises.

Monica: What opportunities do you see out there?

Iyad: There are many opportunities. We are working, for instance, to enable an airport to have a private LTE network with CBRS that is as simple to manage as a Wi-Fi hotspot.

We're working with a couple of universities to put together IoT solutions over CBRS that integrate with their existing Wi-Fi systems.



The role of the SAS in coordinating spectrum access *Source: Federated Wireless*

In Virginia, we're working with a city on smart-city sharing solutions that can be used to build new IoT applications. We're also working on fixed wireless systems for stadiums, hospitals, multiple-dwelling units and underserved communities.

Together with our partners, we are developing solutions for about 16,000 locations.

Monica: Which verticals or use cases do you think will be the most promising?

Iyad: I can mention two enterprise use-case groups that are gaining momentum right now.

The first is digitization and automation, and that comes in multiple flavors. It could be a smart factory, a smart building or a smart mall. This includes deployment of either cognitive or machine learning applications that extend all the way from the cloud into edge-compute private LTE deployments. I expect this will grow in popularity and become a dominant set of use cases.

Another set of use cases revolves around deployment at big venues and locations that handle thousands of people. They need private networks in order to offload some of their Wi-Fi traffic – e.g., use CBRS for their internal applications and keep their Wi-Fi for their customers. For instance, they may choose to shift all internal coordination and security cameras from Wi-Fi to a private LTE network.

Monica: Is the enterprise willing to invest its own funds for private LTE networks and to operate them on their own?

Iyad: We see a significant pull from the enterprise space for private LTE networks. It's driven by the belief that connectivity is mission-critical, especially in a large company.

This is part of their digitization efforts and their integrated solutions. The enterprise wants to be able to build private 4G and 5G solutions that don't

require a constant carrier connection unless they desire. These private networks must have a low-cost structure that approximates enterprise Wi-Fi, but run on pristine spectrum that's making the network faster, simpler and more reliable.

Monica: CBRS is creating a new, more streamlined and less complex framework for private networks. It's coming at a time when enterprises need and are willing to pay for private networks.

Iyad: There's a need and demand in the enterprise to continue to build more connectivity solutions and enable more automation.

The timing is good. We have new spectrum, and a massive, standards-based equipment and technology ecosystem that drives equipment costs down. It's also driving a significant number of players who want to take this solution into the enterprise.

CBRS private networks are also a good fit for cognitive and cloud applications that are being developed on big cloud systems, and which are looking to move into the enterprise and to the edge of the network.

The combination of all these things is creating the perfect opportunity for enterprises to take advantage of this new technology and new capability.

Monica: Typically, enterprises already have Wi-Fi, and they want to expand their wireless assets to 4G and eventually 5G with CBRS. How will these technologies coexist?

Iyad: Every technology will have different locations and different use cases. I haven't yet seen a location or a business that doesn't try to optimize and take advantage of all the connectivity solutions they can get their hands on.

Wi-Fi already has a very big ecosystem with many devices, from laptops to chipsets. The Wi-Fi ecosystem will continue to grow after 4G and 5G private networks are available, because these networks will support more reliable and predictable applications that will sit on top of Wi-Fi or be integrated with Wi-Fi. This will enable automation, new capabilities and new use cases. 5G solutions from the carrier networks will be a complement, and provide more consistent connectivity across multiple locations and a bigger geography.

Key CBRS market segments *Source: Federated Wireless*

Eventually, these technologies will coexist– sometimes in the same device and sometimes in the same solution across multiple devices.

Monica: When do you expect CBRS to move to 5G?

Iyad: The latest FCC rulings have made the necessary adjustments to use 5G in the CBRS spectrum.

The timing of 5G is more related to equipment and handset availability than the spectrum. 5G on CBRS will show up at the same time 5G begins to show up in the rest of the spectrum sets. Just like in public networks, 4G and 5G will coexist for a long time to come. This will look no different.

Monica: In the US, the FCC is expected to open the 6 GHz band to shared licensed and unlicensed access. Is this going to be an opportunity to expand the CBRS spectrum coordination framework to a new band?

Iyad: 6 GHz is a large band in excess of 1,000 MHz It has multiple users in it today. They are sharing it in an inefficient way, compared to CBRS. There's definitely an opportunity to change the rules and open up more of the spectrum in a CBRS-like model. It may not be exactly like CBRS, but that process has started. The FCC has opened the door. Industry coalitions are working to make it possible. Most likely it will not be just 4G and 5G, but Wi-Fi as well. There is a lot of interest in this area, and we're certainly very focused on it.

In the US, there are two or three other spectrum bands that people are examining. Some bands are in

the millimeter wave and others are just adjacent to CBRS.

The CBRS model is portable across multiple spectrum sets and multiple countries. Since shared spectrum solutions are software-driven, a degree of customization is possible for every spectrum band to maximize its use while protecting incumbents in the band.

Outside of the US, serious trials are being conducted in the UK, and we expect additional countries to follow.

Monica: What's going on in the UK?

Iyad: We have been active in the UK now for about 18 months. We've done a demo for a couple of the different agencies, including military teams, on 2.3 GHz. We're expanding that work to do agricultural trials and field trials in the 2.3 GHz band.

We're also working on additional 5G spectrum bands for a proof of concept for infrastructure sharing in 5G spectrum in the UK. There's serious support for it, and there's certainly a lot of work that has to be done.

Monica: Because of underutilization of many bands, the idea of coordinating spectrum access is really powerful – especially for IoT and enterprise applications.

In the longer term, is there something else you are looking at?

Iyad: We are a B2B enablement platform. Our job is to optimize and maximize the utilization of spectrum bands so that spectrum, a rare resource, can serve the maximum number of businesses, consumers and use cases. We're a neutral party, and we just want to enable broad ecosystems and open models. Our customers recognize our neutrality, and partner with us to solve their customers' problems in innovative ways. It's a great place to be.

About Federated Wireless

Federated Wireless is leading the wireless industry through the shared spectrum revolution, eliminating the decades-old problem of spectrum scarcity. The Company offers the industry's only end-to-end spectrum controller, enabling government and commercial users to securely share the same spectrum band. Headquartered in Arlington, Virginia, Federated Wireless is removing the multi-billion dollar price tag associated with spectrum access, allowing for the creation of new wireless carriers and business models. www.federatedwireless.com.

About Iyad Tarazi

Iyad Tarazi, President and CEO at Federated Wireless, is a known thought leader in spectrum and telecom technology and has led massive transformations and pioneered new technologies in spectrum, machine learning, 4G, small cells, and cloud software development. Iyad joined Federated Wireless as CEO in August 2014, at that point an early stage startup with significant intellectual property in spectrum management. Iyad is leading the commercialization of the technology, tapping the emerging $1B+ market in shared spectrum.

Ericsson | CBRS will boost small cells and infrastructure sharing in the US

A conversation between Marko Babovic, Head of Product Line Street and Indoor, Product Area Networks, Ericsson, and Monica Paolini, Senza Fili

CBRS opens a new way to think about, deploy and use small cells, and to push for infrastructure sharing in a market like the US, where operators prefer to retain end-to-end exclusive ownership of their networks, with the exception of DAS neutral-host deployments.

This is good news for enterprises and venue owners. Small cells in CBRS shared-infrastructure deployments will reduce costs and improve cellular coverage on their premises.

Marko Babovic, Head of Product Line Street and Indoor, Product Area Networks at Ericsson, shared his perspective on the impact of CBRS on the enterprise market and how it will encourage growth in in-building small-cell networks in the US.

Monica Paolini: Marko, first can you tell us what your role at Ericsson is?

Marko Babovic: I am responsible for the solutions we build for indoor and outdoor small cell systems based on the same RAN technology suite we use in many other products.

Monica: Ericsson has been working with operators for a long time. Are you working on small cell solutions for the enterprise too?

Marko: Our customers are big and small vendors and carriers. For years and decades, our customers have been trusting us and asking us to provide various solutions. We are working with them on CBRS, too, to meet their needs. But we are also working with the enterprises, system integrators and new players in the field, both through our customer operators and directly.

Monica: What is the difference between small cells that use CBRS and small cells that operate in licensed spectrum?

Marko: There is not much difference. We reuse the technology that we have applied in macro networks for indoor and small cells, and we have added CBRS functionality for radio access networks. The difference is in frequency. We apply a different frequency on the radio, which is one component of our solution. What is new in CBRS is how this frequency is managed. The decision on who has access to this frequency is made by a Spectrum Access System (SAS) that is outside the network. This is different from how we manage spectrum in our current networks.

Monica: Who do you think will deploy CBRS in the US?

Marko: The deployment will really start from the operators and carriers. At Ericsson, for example, we work very tightly with Verizon to meet their needs. Verizon wants to increase the capacity of its outdoor and indoor systems, but keeping the spectrum acquisition costs down.

New players are also going to play an important role in the development of CBRS. There are many of them, and they are very creative, but most of them are still in an exploratory phase. They are trying to understand, what does it take to run a network? What does it mean to have a radio access network with 3GPP? How can they handle it? These new players are a second group of potential users of CBRS.

The third category of potential users includes operators that see CBRS as a neutral host technology that allows them to share their solutions without the need to share their frequency with third parties. Therefore, CBRS will allow a better system and solution in the future.

Monica: Let's talk about use cases. The most basic use case is smartphone and laptop access. Are there other use cases for CBRS that you are seeing right now?

Marko: We divide CBRS use cases into two categories: what is driving CBRS at first today and the

exploratory ones for the next few years, and. Normal mobile broadband services that demand higher capacity drive the first category. For the second category, the options are unlimited, and many use cases exist for IoT and private LTE, for instance. The demand for them is there, the technology is there. We have solutions that can satisfy most of the CBRS use cases. The question is, how will the business models work? Who drives them? How fast will they appear?

Monica: Do you think the initial CBRS deployment will be aimed at specific vertical applications in IoT, or it is going to be more for data access or broadband access?

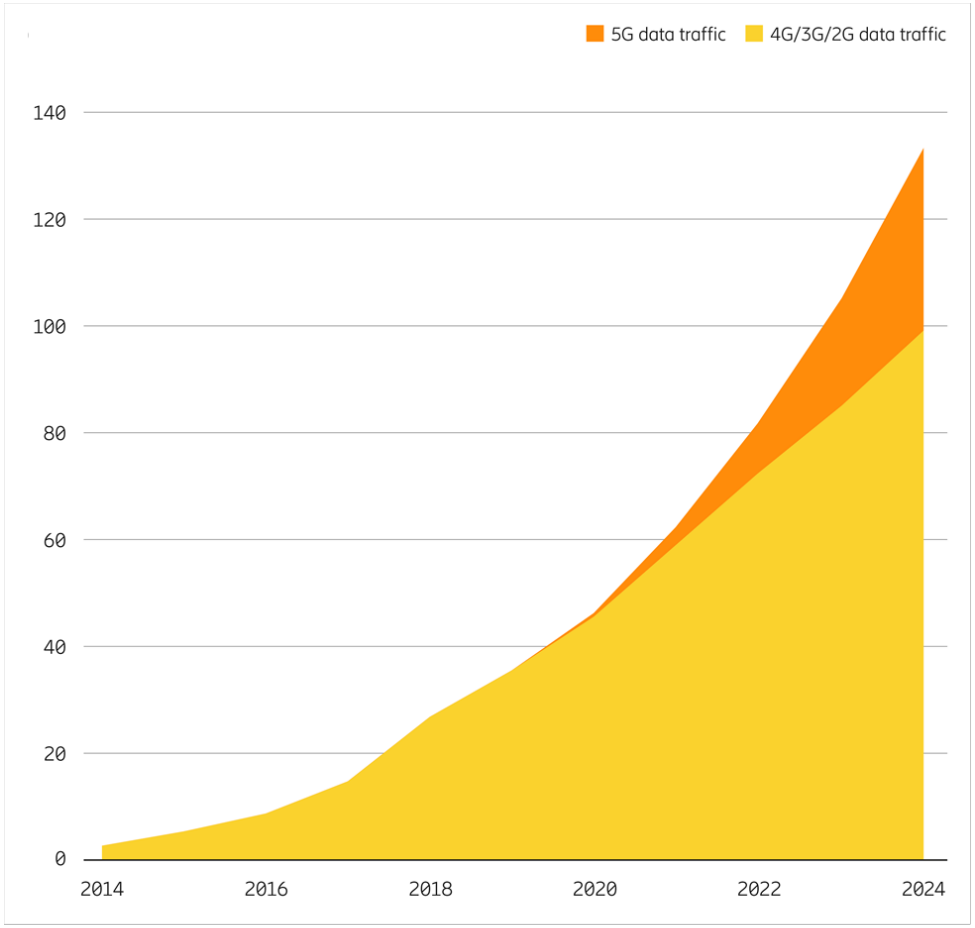
Marko: I think the latter. Mobile broadband is the primary use case, and there the capacity increase is an obvious priority. Other use cases such as IoT are going to help develop a new type of behavior of end users or machines, and they are also going to drive deployment. However, these other use cases are still in an exploratory phase.

Enterprises are another use case in this exploratory phase. They may not be happy with their current 3GPP coverage or cellular mobile broadband, and they may drive the use cases not for only increasing capacity, but for expanding coverage without waiting for the big carriers to provide it. They are looking at doing this either on their own or with the help of smaller carriers.

Monica: Enterprises have many options. How will they choose among technologies such as Wi-Fi, CBRS, MulteFire, and LTE with LAA?

Marko: Few people can answer this question. We believe that 3GPP technology provides better performance and better capacity than Wi-Fi, for example. Of course, Wi-Fi performance and capacity will improve with 802.11ax, the new Wi-Fi version. But what is essential for 3GPP is the seamless management of the system. This is very valuable for an enterprise, building owner or tower company. A second exclusive advantage of 3GPP is its robustness and security.

In the future, the enterprise choices will be based on the combination of these two factors. There will be Wi-Fi, 3GPP and other technologies, as well. But 3GPP will always come with the advantage of having excellent security, and we are living in times in which security is very important. We see a lot of breaches, and the breaches are going to continue. Security will be even more important than before.



Global mobile data traffic (EB per month) *Source: Ericsson Mobility Report*

Because of the robustness of the system and the easy and seamless management of the whole network, 3GPP will exist everywhere.

Monica: Do you think that different enterprises such as hospitals, colleges, and venue owners will deploy CBRS?

Marko: We are still in the early phase of building business models around CBRS technology and regulations. There will be options for enterprises that are not happy with their cellular coverage, assuming there is good enough terminal penetration with the CBRS-capable phones. Large enterprises may decide to build their own systems. But what does it mean for them to own such a system? And some of them will even decide to build such a system with the same

components the big operators have.

Some enterprises, especially smaller ones, will choose to go down a similar path, but without building their own system. These enterprises will search for new players such as system integrators and tower companies.

New players will emerge, along with another wave of smaller carriers, and will specifically address the enterprise needs. A new ecosystem will evolve, but it is very hard to say which one will evolve first and how fast.

Monica: If enterprises deploy their own networks independently or with a neutral host, what type of relationship will they have with mobile operators?

Marko: The easiest business model is a roaming agreement. If an enterprise builds a network alone or with the help of a new player, it can set up a roaming agreement. A neutral host can offer roaming agreements to carriers, and the carriers may decide to go with it or not.

Monica: What does your solution offer to the enterprise?

Marko: We are reusing everything that we are doing for big macro 4G and 5G systems, but what we do differently is the last mile, the last path, the radio.

Our solution is the CBRS Dot, which supports 2x40 MHz and can serve 2,000 users and 600 Mbps per access point. It has a very compressed form factor.

There is nothing specific about the CBRS Dot, compared to our other Dots, except for the frequency. One very specific advantage over other solutions is that Dots are super easy to install. This makes it easy for an enterprise to design and build its own CBRS system, and, in the future, we want to make it even easier.

For example, when you put these Dots in the ceiling, you can move them left or right several meters without affecting the performance. The performance is robust. Design is absolutely easy, and there is no need for optimization after that. This excellent plug-and-play with low opex will be essential for those who want to build a CBRS system.

Ericsson Radio Dot *Source: Ericsson Mobility Report*

We also have outdoor solutions that are light and can be held in your hands. They consist of a small cell with a micro radio which provides the maximum power that we can use in the US with CBRS in outdoor environments.

Monica: In terms of size, the indoor unit can be smaller than a Wi-Fi access point. From an enterprise point of view, how is the installation of a Dot different from the installation of a Wi-Fi access point?

Marko: The design is pretty much the same; however, the installation is different. The choice of solution may be more restricted than for Wi-Fi. We have a number of vendors in Wi-Fi, but in 3GPP the situation is different. Not many vendors can provide a system that is small and comparable to Wi-Fi.

But the real difference between Wi-Fi and 3GPP is in operations. The operation of 3GPP cells is seamless: they are handled by someone else, who may be a carrier, a power company, or someone else. For Wi-Fi installations, enterprises normally have an IT technician, and the CIO of an enterprise is responsible for managing networks that range from simple to complex. For an enterprise, there is much more work to do with Wi-Fi than with 3GPP.

Monica: What do you use for the backhaul in a Dot installation?

Marko: We use a CAT cable to a central place in the building where we have some additional equipment. After that we use a backhaul to connect to the core network. This is a typical solution. The backhaul can either be internet-grade untrusted backhaul or it can be carrier-provided. Both options are there.

Monica: Some enterprises may have a DAS system already. For those enterprises, what is the advantage of moving from DAS to CBRS or, more generally, to small cells?

Marko: I always loved DAS, because it is a fantastic system, built years ago. It has worked very well for many years, and it provides a unique neutral architecture that enables neutral-host business and deployment models. However, DAS has limitations that make it not future- proof. With 5G, we add another layer – e.g., 2x2 or 4x4 MIMO, beamforming – that is difficult to accommodate in a DAS. We have designed our own system, the Dot, to address these limitations.

What is the relevance of DAS today? What will happen with DAS? DAS is still relevant because it provides multi-operator access. DAS will still be relevant for years in situations that do not require much capacity or coverage.

But it is possible to have a multi-operator solution without DAS. The Dot is a multi-operator solution. You may have multiple Dots in the ceiling from different operators sharing the infrastructure. Or you can have one Dot serving several operators with different vendors beneath. These options are all attractive from a TCO point of view, especially in the US, but they require some kind of coordination among operators during design and deployment.

CBRS will offer something different. CBRS will offer something that is not so popular today with operators using licensed bands: the multi-operator RAN (MORAN) and the multi-operator core network (MOCN) options, where you basically have one radio access network coupled simultaneously to the core networks of different operators or carriers. This solution is attractive in some geographies – in parts of Canada and Europe, for instance – but not in the US. CBRS will reopen that book, and it will restart the discussions about sharing the networks.

If you compare the TCO of the coverage solutions for multiple operators with CBRS, MOCN and MORAN, it will become clear that DAS will not have any place there. Infrastructure sharing with CBRS, MOCN and MORAN will be much simpler, much faster, and much cheaper than DAS.

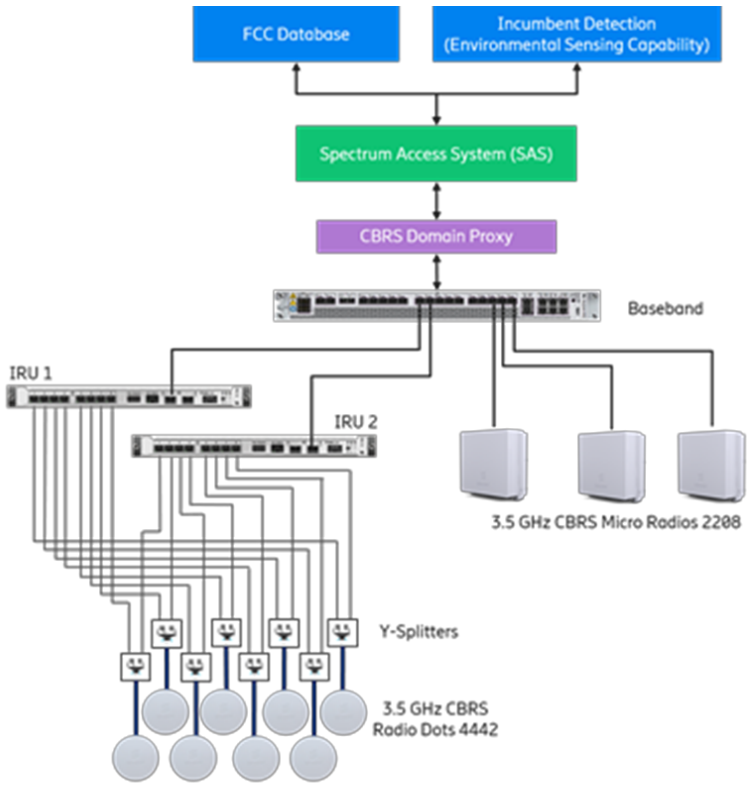
Monica: In the US, spectrum sharing or infrastructure sharing is more difficult than in other markets, and hopefully CBRS would change that. But operators are often worried that if they share network access, they cannot control the user experience. How do you address that issue?

Marko: This is the key question. I have met many operators, and often I hear expressions such as "I will share my baseband over my dead body." If you are a carrier, you are responsible for performance to the end user, and you have to have control mechanisms all the way.

But even DAS today does not give operators full control, because the link from the head to the antenna is not controlled by the operator. This makes it difficult for them to accept this system.

The Dot can be operated by two completely independent operators who access the network half-and-half. For example, the dual-band Dot is electrically split half-and-half between the two operators. The operators will not see each other – from their O&M systems all the way to antenna – and they will have full control up to the very last piece of the antenna. This is the most important part to address with indoor small cell systems.

CBRS allows MORAN and MOCN options. As a vendor, we have to provide even better slicing of domains for different operators. Within the baseband, we have to provide them guarantees that this part will not see the other part. We have to support their O&M all the way to the Dots. That will be our task to fulfill, and we are ready for it.



Ericsson Radio Dot and Micro CBRS solution *Source: Ericsson*

Monica: In the US, small cells have been around a long time; however, the deployment of small cells and indoor infrastructure has been slower than what we initially expected, and much slower than in China. Do you think CBRS will change that?

Marko: This is one of the million-dollar questions: How will indoor small cells accelerate in the US? Will CBRS contribute to that increase in the adoption of small cells?

CBRS will contribute, allowing many actors to start thinking about indoor small cells in a different way. But CBRS will be just one of the tools to accelerate that.

In the US, we have a deep in-build and strong ecosystem of DAS suppliers. We have vendors, local engineers, suppliers, carriers that are all fitting in one ecosystem that works very well. That ecosystem is preventing us from focusing on small cells. This is not the case in China – it is a different story there, and that is why there are many more small cells there.

CBRS will help, but I don't think this will be the biggest accelerator for indoor small cells in the US. It will contribute, but it will not be the biggest accelerator.

Monica: What will be the biggest accelerator in the US then?

Marko: One of the biggest contributors will be 5G. DAS is a good system that has been working for years, but it is difficult to upgrade. Every upgrade is a nightmare. But with systems like the Dot, which have forward compatibility, you don't need to think about whether or not you will have a 5G possibility if you invest today. You don't have to think about that because moving to 5G is just a software upgrade. The real story for going to 5G is only possible with indoor small cells, and therefore, DAS will be kept on a flat level for 4G basic coverage only. The 5G introduction will be the mover of indoor small cells in the US.

About Ericsson

Ericsson is one of the leading providers of Information and Communication Technology (ICT) to service providers, with about 40% of the world's mobile traffic carried through our networks. We enable the full value of connectivity by creating game-changing technology and services that are easy to use, adopt and scale, making our customers successful in a fully connected world. For more than 140 years, our ideas, technology and people have changed the world: real turning points that have transformed lives, industries and society as a whole.

About Marko Babovic

Marko Babovic is Head of Product Line Street and Indoor, Business Area Networks, at Ericsson AB - a world leader in communications technology and services. With more than 110,000 professionals and customers in 180 countries, Ericsson combines global scale with technology and services leadership Ericsson supports networks that connect more than 2.5 billion subscribers. Within Ericsson's Business Area Networks, Babovic is responsible for establishing and accelerating Indoor and Small Cells solutions as a part of the company vision towards a fully networked society.

Babovic has extensive experience within the telecom industry through various roles – from Cell Planning and Optimization and RAN System Design to leading roles within Research and Development as well as Product Management of 3GPP Radio Products and Solutions. Born in Serbia, he graduated from the University of Belgrade with both Bachelor and Master of Science degrees in Telecommunications. At the same University, Babovic also worked as assistant professor during the early stages of his career, before joining Mobtel Serbia. In 2001, he joined Ericsson AB.

CBRS Alliance | A smooth path to private networks and neutral host models with CBRS and OnGo

A conversation between Dave Wright, President, CBRS Alliance, and Monica Paolini, Senza Fili

CBRS comes at a time when the enterprise increasingly needs private networks and sees the benefits of neutral host models. Enterprises and venue owners are willing to invest in private networks they control, but they need both reliability and simplicity.

In this conversation with Dave Wright, President of the CBRS Alliance, we talked about how CBRS can meet the reliability and simplicity requirements of the enterprise, and how CBRS can accelerate the deployment of private networks and neutral host models, which can finally give us the in-building coverage that we need.

Monica Paolini: To get started, could you tell the readers what the CBRS Alliance does to promote the adoption of CBRS?

Dave Wright: At the CBRS Alliance, we're looking at LTE and next-generation cellular services in the CBRS band in the US. We came together approximately two years ago. We had six founding members who started the organization in August 2016. Over the course of the last two years, we have grown to 115 members, which include mobile operators, cable operators, chipset vendors, cellular infrastructure vendors, enterprise wireless LAN vendors, and a whole cast of other ecosystem players.

One of our roles is to develop technical specifications. We don't want to recreate the wheel, and we work on areas that 3GPP or the WInnForum – an organization we work very closely with – have not touched.

Interoperability is another big focus for the Alliance. We want to create an ecosystem in which the equipment elements from multiple vendors work together seamlessly.

The Wi-Fi industry has flourished because clients and infrastructure devices are all certified by the Wi-Fi Alliance. We're looking to recreate that same type of environment with CBRS. OnGo is our certification and branding program. We also create awareness of the opportunities in the market.

On the marketing side, one of our major activities is around establishing the business case and requirements for different applications of OnGo. These requirements are fed into our Technical Working Group, which develops specifications to support these use cases.

Recently, we started a Deployment and Operations Working Group that looks specifically at some of the unique aspects of deploying an OnGo network in a private LTE or a neutral host application.

Monica: Recently, the CBRS Alliance launched OnGo. What is the difference between OnGo and CBRS?

Dave: CBRS is a spectrum access framework put in place by the FCC. Strictly speaking, CBRS is not the 3.5 GHz to 3.7 GHz band, it's the framework. The CBRS framework has a three-tiered sharing structure comprising incumbents, priority access license (PAL) users, and general authorized access (GAA) users. CBRS describes a sharing structure and the spectrum access paradigm that we're utilizing.

OnGo is the brand that we've adopted for the technology that operates in this shared spectrum framework. OnGo signifies interoperability. The idea is that you will be able to purchase RAN infrastructure equipment that is OnGo-certified by the Alliance, and will know, without a doubt, that the equipment is going to interoperate with the Spectrum Access System (SAS), which is the coordinator of the RF environment, and with any other ancillary services, such as coexistence managers. If the components are OnGo-certified, you'll know that they will work well together, and you would not have to do your own interoperability testing.

We're bringing the simplicity of the Wi-Fi model to cellular technologies. I think that's really pertinent to

the enterprise.

Monica: Wireless is taking on a larger role in how the enterprise works, and both enterprises and venue owners are eager to deploy and control their networks. What role do you expect CBRS/OnGo to have in supporting this trend?

Dave: The enterprise is a broad market: within the enterprise, there are all sorts of sub-classifications.

At my regular employer, we deal with a large variety of enterprises on the Wi-Fi side, ranging from large-scale public venues and Fortune 500 to Fortune 5000 companies, to small and medium businesses and retail companies. We also work in specific vertical sectors such as healthcare, hospitality, and primary and secondary education. They all have some subtly different requirements and needs, but they're all grouped within the enterprise classification.

From the 100,000-foot view of the enterprise, there are some well-established trends. In the last two or three years, many companies have switched to a wireless-first or wireless-only office. They are moving away from the Cat 6 cabling to each desk or cubicle, and they are relying on wireless services for their employee communications within offices.

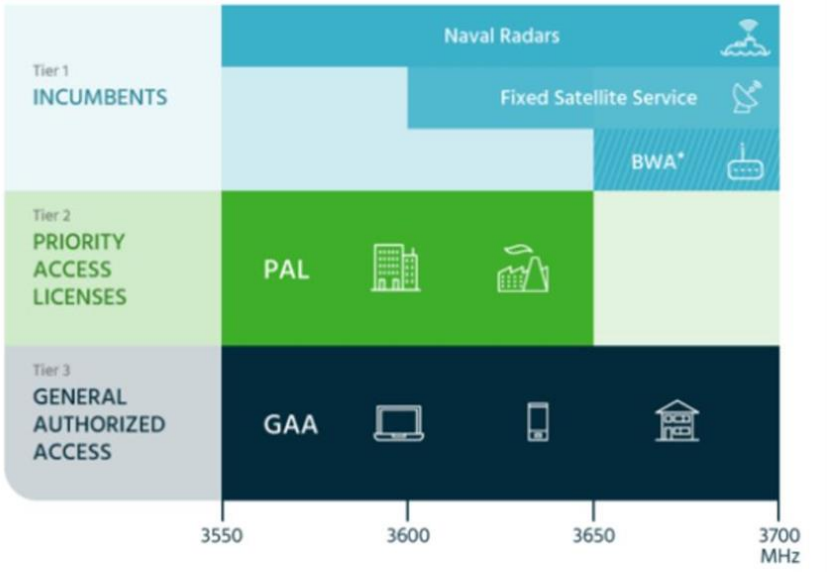
There are a lot of advantages to that approach. Obviously, it cuts down on the infrastructure and installation costs. Enterprises don't have to put in as many switch ports as they would for gigabit Ethernet wired connections.

Wireless also allows more flexibility within the workspace. Voice and data services provided over a wireless connection are very conducive to open workspaces and shared workspaces – the all-wireless workplace is a big trend now.

Monica: Everybody loves wireless, but the all-wireless enterprise faces some challenges, too.

Dave: Many business users have to use their mobile devices, whether that's personally-owned devices or corporate-supplied mobile devices, because often they no longer have a wired Ethernet connection. They have to use wireless to get connected.

Spectrum availability in the 2.4 GHz and the 5 GHz unlicensed bands is one of the major challenges in the wireless workplace. We are making great use of those unlicensed bands, for sure. But as the 802.11 Wi-Fi technology advances, to get gigabit Wi-Fi 6 rates we have to go to wider channels. To get a gigabit rate with Wi-Fi you need a channel at least 80 MHz wide.



CBRS spectrum available to incumbents, PAL users and GAA users *Source: CBRS Alliance*

In the 5 GHz spectrum, if you want to avoid the channels which require the Dynamic Frequency Selection (DFS) capabilities for radar detection, and if you happen to be near an airport or you've had issues with lack of DFS support in the clients that you need in your enterprise, you effectively have only two 80 MHz channels – one at the lower end of the band and the other at the upper end of the band. That's not a realistic deployment situation, because you can't cover a dense campus or public venue with two channels.

One of the big challenges people are facing in unlicensed 5 GHz spectrum is that they are often constrained to using the smaller channel sizes (e.g., 20 MHz).

That's where OnGo becomes a unique new opportunity. It has up to 150 MHz of spectrum that IT managers and CIOs can take advantage of. It's not subject to some of the vagaries that fully unlicensed spectrum has. You don't have to worry about people coming in and turning on hotspots on their smartphones, potentially interfering with a nicely laid out channel plan within an enterprise, hotel or conference center.

With OnGo, there are no mobile hotspots. Every CBSD, which is the CBRS small cell, has to be registered in a fixed location. The spectrum environment is much more predictable for enterprise

IT managers or CIOs.

OnGo becomes very attractive for mission-critical applications and anything that requires very high availability and low latency. OnGo is a quality layer that you can add on top of Wi-Fi. We certainly don't think Wi-Fi is going to be supplanted by OnGo. OnGo is very complementary to Wi-Fi and adds a new capability for the enterprise.

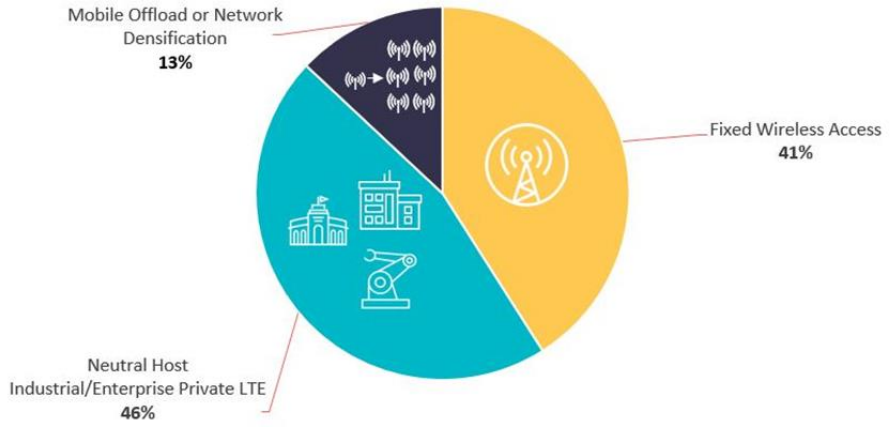
Monica: With the growth of IoT, we are not talking just about basic connectivity. A lot of applications have different requirements, such as latency, security, or reliability. From an enterprise point of view, Wi-Fi is well-understood and relatively easy to use. Some Wi-Fi networks can be complex, but the enterprise has been using Wi-Fi for two decades. Can CBRS/OnGo provide the same ease of use, even though it is based on LTE, which is a more complex technology than Wi-Fi?

Dave: OnGo solutions for the enterprise will be very close in simplicity to Wi-Fi solutions.

I agree with your point about the complexity of traditional cellular technologies, and even LTE. But LTE is more simplified than 3G, which was much more simplified than 2G. Data-focused and IP-focused cellular technologies are less complex. Yet it's a fully different paradigm from what most enterprise IT managers are used to with Wi-Fi. They're not used to thinking about EPC services and components, or about the function of an MME or an HSS.

The good news is that many members of the CBRS Alliance are very focused on the enterprise markets. They have a lot of history in the enterprise markets and are very well-established, leading companies in the enterprise and carrier Wi-Fi markets. They're now bringing OnGo solutions to the market, with the needs and requirements of the enterprise wireless LAN administrator in mind. This is the kind of deployment and management paradigm we're looking for.

The good news is that there's been a paradigm shift toward cloud management even on the Wi-Fi side. More and more of the management plane and the control plane is residing in the cloud. A lot of LTE services, and specifically EPC services, will be attracted to the cloud.



Initial commercial deployments by use case, based on sample data from a SAS Admin Proposal *Source: CBRS Alliance*

That's not to say you couldn't have a local breakout capability for data. It's very important that enterprise data shouldn't have to go up to the cloud or back to a mobile core before it comes back to the corporate data center.

There are local breakout capabilities in most of the architectures I have seen from the enterprise OEMs. The simplicity from a management perspective will be there.

A number of vendors are looking at common cloud management platforms. A single pane of glass would allow you to manage both your enterprise Wi-Fi assets and enterprise OnGo assets. It will have the robustness and the reliability characteristics of LTE, but not the complexity that's been traditionally associated with it.

Monica: From an enterprise point of view, you can have your private network without having the massive core that mobile operators need because they operate wide-area, public networks.

But what cellular competencies does an enterprise need to run a CBRS/OnGo network?

Dave: There will be a range of deployment models within the enterprise. Some very large, sophisticated enterprises may want the very granular control that can be attained by having an on-site EPC or an internal EPC. The Fortune 20-type companies, large manufacturers, may already have some private cellular, and so they could leverage that. The majority of enterprises will likely end up implementing a cloud-hosted type of service. This also goes well with the SAS service model. To operate within the CBRS band, you're going to need an arrangement with a SAS provider.

The infrastructure will send a request to the SAS and

say, "I'm at this location. I'm operating at the general authorized tier or the priority access tier. Here is the amount of spectrum I would like to use." The SAS will then look at your specific environment and assign a spectrum grant.

It is then easy to back-end an enterprise cloud management control platform with the SAS services. That's just one more cloud system that is sitting behind your enterprise OnGo infrastructure. The cloud paradigm for OnGo management control will become quite popular in my opinion.

Monica: Enterprise CBRS/OnGo networks will enable many use cases. Which enterprise verticals will find OnGo to be a good fit?

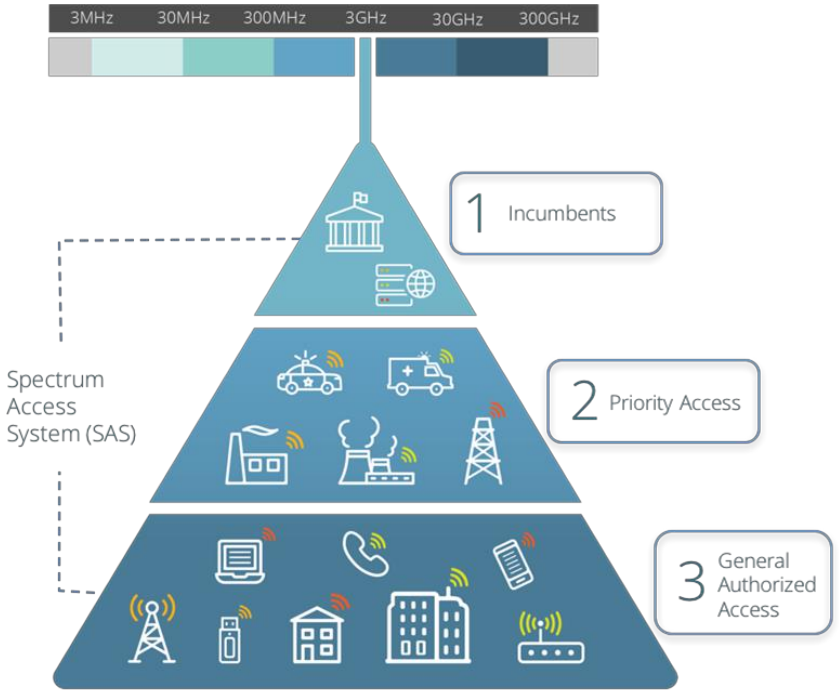
Dave: The hospitality industry has been extremely interested in the opportunities around OnGo.

Many hoteliers are looking for enhanced wireless solutions. They're looking for better internal communications for their staff. For instance, there's a big push within the hospitality industry to have a panic button capability for staff. Unfortunately, that has become a big requirement for the industry.

There is also considerable need to provide better IoT building management systems across commercial properties of all types, which could be everything from HVAC systems, to security cameras that monitor the buildings, to control systems for entertainment, lighting or door locks – all of these are going wireless.

Some of that is going to happen over Wi-Fi and some of it's going to happen over other short-range unlicensed IoT-specific air links. OnGo is another tool in the toolkit for the hotelier for the private LTE use cases.

Hoteliers also are looking to provide better communications capabilities for the guests at the property. Guests judge a hotel on the basis of their Wi-Fi experience. What is not as often reported, but is just as important, is the ability to make a voice call within the property. If you go to a property and you have an important business call or personal call to make and you have no reception within the facility, or if you are at a conference at a hotel and you don't have coverage in the facility, that negatively impacts return business for the property.



CBRS three-tier framework *Source: CBRS Alliance*

Hotels are also looking to provide better cellular coverage for the tier-1 MNOs. The larger properties' conference centers may have used DAS in the past. But the economics of DAS, the complexities around installing DAS, and also the coordination requirements of working with each of the mobile operators to get their spectrum deployed on the DAS mean that DAS makes sense only for the largest properties.

In smaller and medium-sized hotel properties and venues, DAS just doesn't make economic sense. We think OnGo is the perfect solution for those venues and has the right economics for that market.

Monica: Are there indoor environments where DAS has an advantage over CBRS/OnGo?

Dave: There've been other solutions to provide in-building cellular. DAS is one. It's been pretty successful in very large venues, especially public venues such as a large football stadium. The economics may justify DAS in a facility that's over 200,000 sq ft, where you get a large number of people transiting through. But when you push down a little bit into a Fortune 5000 property, especially when you get into commercial business offices and multi-tenant dwelling units, DAS just doesn't make financial sense. OnGo is the key to opening up the indoor market for medium-to-small enterprises.

Monica: What do you think about the healthcare

market? That's also an area where there are many applications – primarily for hospitals, but also for patients and guests.

Dave: Hospitals are also embracing wireless, and an amazing number of healthcare systems are now wirelessly connected. Hospitals have wireless connectivity not only for internet access for patients and their visitors, but also for critical systems such as telemetry systems that monitor vital signs. For all the same reasons that it's not good to be tethered in an office, it's also not good to be tethered in a hospital.

Hospitals are looking for predictable and reliable spectrum environments to service their needs. This isn't just mission-critical. These are potentially life-critical services that are being offered. The opportunities to deploy LTE, a highly reliable wireless technology, and in a highly predictable spectrum environment such as OnGo offers are very compelling to a health system CIO.

Monica: With CBRS/OnGo, the enterprise can choose to run its own show by building a private network and/or work with a neutral host to manage the relationships with carriers. How do you see these two models evolving?

Dave: The short-term opportunity for an enterprise is more on the private network side, geared to support internal communications. Enterprises know their needs, and that's more pressing in their minds. OnGo provides 150 MHz of clean spectrum that enterprises don't have access to today and that they can use for private LTE for internal enterprise-type communications, IoT services, building monitoring, mission-critical apps – all of these will probably lead deployments.

There is a good assortment of client devices coming to market that will support these types of private use cases, everything from Mi-Fi to USB-type dongles to enable enterprise-type traditional connectivity in the short term.

The longer-term opportunity around neutral host is amazing. We have been talking about providing better in-building cellular coverage for a long time.

Over the last few decades, people have been expecting different technologies and solutions to unlock this market. None of them have quite played out. The real obstacle was spectrum access – the fact that the enterprise wasn't free to deploy an infrastructure that it could use for its own internal communications. The enterprise needs spectrum it can access directly and also open up to the mobile operators' subscribers within their property.

OnGo enables that. OnGo becomes the nirvana that we've all been talking about for so long. Thanks to OnGo, instead of having to deploy separate infrastructure for each operator that relies upon their discrete licensed spectrum, the enterprise can deploy a common infrastructure with a common spectrum band.

In a neutral host model, mobile subscribers with a Band 48 handset – the 3GPP band for CBRS – can attach to the enterprise network. The handsets can see that the enterprise supports neutral host services and can query the network to find out which home operators are supported. The handsets can attach and be authenticated back to their home operator. Subscribers see that they are getting value from that home operator subscription. This provides a great quality of service. Mobile operators are going to be more comfortable with this model than with inter-radio access technology or inter-RAT models, because this is the same LTE-bearer they use in their macro network.

The enterprise or neutral host can feed mobile operators all the native KPIs and they can monitor the SLAs in a way that's familiar to them from their roaming relationships. It's a really compelling use case.

5G and the next generation of wireless presuppose a very dense network of small cells and in-building coverage. The traditional solutions have not unlocked the in-building market. CBRS and the technology solutions we're developing with OnGo will unlock that. We think it's setting the stage nicely for the next generation of wireless services.

Monica: With the commercial availability of CBRS/OnGo, can we expect to see the growth of in-building wireless we have been waiting for?

Dave: With 5G, there's a big focus on enterprise and industry, and serving these markets requires in-building presence.

The work we are doing is going to be quite valuable in the future. Whether it's sharing models like we're doing with CBRS or other spectrum access models, our work will enable the enterprise and the industrial players.

Many of the capabilities, the neutral host technologies, and the specifications that we've developed and are continuing to develop are applicable regardless of what the spectrum access paradigm is. This work is going to pay a lot of dividends going forward.

About CBRS Alliance

The CBRS Alliance believes that LTE-based solutions in the 3.5 GHz band, utilizing shared spectrum, can enable both in-building and outdoor coverage and capacity expansion at massive scale. To make this vision a reality, the 115+ member companies that make up CBRS Alliance – including founding companies Google, Qualcomm, Ruckus Networks, Intel, Federated Wireless, and Ericsson Inc. as well as the nation's largest mobile carriers – have collaborated to evangelize LTE-based OnGo technology, use cases, and business opportunities.

About Dave Wright

Dave Wright is the President of the CBRS Alliance, and the Director of Regulatory Affairs & Network Standards at Ruckus Networks, an ARRIS Company. Dave played an instrumental role in the formation of the CBRS Alliance, collaborating with other founding members to create a robust multi-stakeholder organization focused on the optimization of LTE services in the CBRS band. He served as the Alliance's first Secretary from its launch in August 2016 and was elected as the President of the Alliance in February 2018.

For his "day job", Dave leads Ruckus' policy and standards initiatives, ensuring the intersection of Ruckus' technology and product innovations with suitable regulatory environments and technical specifications. Dave is a champion of Open Spectrum, including both unlicensed and coordinated sharing regimes, while acknowledging the vital role that all spectrum management regimes play in our increasingly wireless world. Dave is a Cisco Certified Internetworking Expert (CCIE) Emeritus (#2062) as well as a Certified Wireless Network Administrator (CWNA).

Glossary

3GPP	Third Generation Partnership Project
AGV	Automated guided vehicle
API	Application programming interface
CBRS	Citizen Broadband Radio Services
CBSD	Citizen Broadband radio Service Device
CSP	Communication Service Provider
DAS	Distributed antenna system
DFS	Dynamic Frequency Selection
DPA	Dynamic Protected Area
EMS	Element Management System
EPC	Evolved Packet Core
ESC	Environmental Sensing Capability
EUD	End-user device
FCC	Federal Communication Commission
GAA	General Authorized Access
HIPAA	Health Insurance Portability and Accountability Act
HSS	Home Subscriber Server
HVAC	Heating, ventilation, and air conditioning
ICD	Initial Commercial Deployment
IIoT	Industrial IoT
IoT	Internet of things
KPI	Key performance indicator
LAA	Licensed-Assisted Access
LAN	Local area network
LTE	Long Term Evolution
M2M	Machine to machine
MDU	Multi-dwelling unit
MEC	Multi-access Edge Computing
MIMO	Multiple-input multiple-output
MME	Mobility Management Entity
MNO	Mobile network operator
MOCN	Multi Operator Core Network
MORAN	Multi Operator Radio Access Network
MSO	Multiple system operator
NOC	Network operations center
NTIA	National Telecommunications and Information Administration
O&M	Operations and maintenance
OEM	Original equipment manufacturer
PAL	Priority Access License
PBX	Private branch exchange
PCB	Printed circuit boards
RAN	Radio access network
RAT	Ratio access technology
RF	Radio frequency
SAS	Spectrum Access System
SIM	Subscriber Identity Module
SLA	Service level agreement
SMT	Surface-mount technology
TCO	Total cost of ownership
TDD	Time-division duplex
UE	User equipment
USB	Universal serial bus
WAN	Wide-area network
WInnForum	Wireless Innovation Forum
WISP	Wireless internet service provider

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About Senza Fili

Senza Fili provides advisory support on wireless technologies and services. At Senza Fili we have in-depth expertise in financial modeling, market forecasts and research, strategy, business plan support, and due diligence. Our client base is international and spans the entire value chain: clients include wireline, fixed wireless, and mobile operators, enterprises and other vertical players, vendors, system integrators, investors, regulators, and industry associations. We provide a bridge between technologies and services, helping our clients assess established and emerging technologies, use these technologies to support new or existing services, and build solid, profitable business models. Independent advice, a strong quantitative orientation, and an international perspective are the hallmarks of our work. For additional information, visit www.senzafiliconsulting.com, or contact us at info@senzafiliconsulting.com.

About Monica Paolini

Monica Paolini, PhD, founded Senza Fili in 2003. She is an expert in wireless technologies, and has helped clients worldwide to understand technology and customer requirements, evaluate business plan opportunities, market their services and products, and estimate the market size and revenue opportunity of new and established wireless technologies. She frequently gives presentations at conferences, and she has written many reports and articles on wireless technologies and services. She has a PhD in cognitive science from the University of California, San Diego (US), an MBA from the University of Oxford (UK), and a BA/MA in philosophy from the University of Bologna (Italy). You can contact Monica at monica.paolini@senzafiliconsulting.com.