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Private LTE: Making the enterprise future-ready

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The Besen Group

What will the enterprise and industrial networks of the future look like? Wi-Fi and distributed-antenna-system-based cellular coverage are certain to stick around, but there's another option looking increasingly viable. The private LTE market is expected to see significant growth in the next few years, as a mature LTE ecosystem makes LTE an attractive network technology choice for enterprises in a wide-ranging number of verticals.

Private LTE is, simply, the ability to operate a standards-based Long Term Evolution network in licensed or unlicensed spectrum as a private network with local control which serves specific users or devices, as opposed to commercial networks which typically serve both consumer and enterprise users. Private LTE networks could be operated either by enterprises themselves; by neutral-host network operators or aggregators; or even by traditional MNOs in a network-as-a-service context.

Source: ExteNet

CBRS-ready equipment deployed by ExteNet for WISP Peak Wireless.

"Private LTE networks are jumping ahead of the current market confusion about wireless connectivity and … re-defining how value is created from devices and data," Harbor Research said in a 2017 white paper about trends in the private LTE space. "It treats user concerns—from reliability and service quality, to security and compliance—as challenges that can be addressed by a single, scalable wireless networking solution that leverages LTE's technology and ecosystem benefits."

Alex Besen, founder and CEO of The Besen Group said that he expects to see initial interest across segments including hospitality, oil and gas, mining, energy, government, military, education, manufacturing and public safety.

This report takes stock of the status of the private LTE market and the technology options for enterprise and industrial networks; market drivers pushing the development of private LTE; and some of the challenges and considerations for private LTE network deployment.

Market predictions for private LTE

"LTE is increasingly being viewed as an all-inclusive critical communications platform for the delivery of multiple mission-critical services ranging from PTT group communications to real-time video surveillance," said SNS Telecom & IT in a report analyzing the private LTE and 5G opportunities over the next few years. "Organizations across the critical communications industry – from public safety agencies to railway operators – are making sizable investments in private LTE and 5G-ready networks." SNS predicts that the market will reach $2.5 billion by the end of this year and more than $5 billion in annual spending by the end of 2021.

Harbor Research sees particular opportunity in private LTE for mining (predicting $5.5 billion in private LTE system revenues by 2023) and shipping ports ($2.4 billion by 2023). Harbor Research estimates that there are more than 14.5 million sites around the world

Here are some private LTE use cases that are being explored

Mining. Mining operations face a number of challenges when it comes to connectivity, because they often operate in remote areas with little to no cellular coverage and have complicated network needs — such as being able to expand its network technologies options and possibly allow roaming onto commercial cellular networks.Ericsson and Canadian network engineering company Ambra Solutions recently provided a private LTE solution for connectivity at the Agnico Eagle gold mining site, LaRonde in Abitibi, Quebec. The system, completed in late 2017, enables connectivity at a depth of three kilometers underground.

Networks for shipping warehouses and hubs. United Parcel Service, which operates 900 MHz private land-mobile radio at its hub facilities, said in comments to the Federal Communications Commission last year that it supports a proposal to realign narrowband 900 MHz spectrum to allow broadband uses, including private LTE, in order to expand its technology options.Although UPS said there was no guarantee that it would end up going with private LTE if the option was available, the company was generally supportive of the concept because it would expand its network technology options — and introduced the possibility of roaming onto commercial networks.

Fixed wireless access. Private LTE as a FWA technology is the focus of a number of trials of the Citizens Broadband Radio Service shared spectrum. During a keynote at ConnectX 2018. During a discussion at ConnectX, Mike Hart, CTO of Vivint Internet and SVP Engineering for Vivint Smart Home and Federated Wireless CEO Iyad Tarazi discussed Vivint's tests of CBRS technology to provide private LTE FWA that complements Vivint's smart home offerings. Meanwhile, network infrastructure provider ExteNet has been testing CBRS for two years, and its projects include deploying a CBRS-ready FWA network for Paladin Wireless, a wireless internet service provider in northeastern Georgia; and for Peak Internet, a Colorado WISP serving Colorado Springs and Pike's Peak. Both of those networks were deployed using 3.65 GHz spectrum, which WISPs already use, with the ability to do a software-only upgrade to CBRS 3.5 GHz in the future.

Utilities. According to a Navigant Research white paper, modern utilities sometimes manage up to a dozen different networks. Private LTE has the potential to simplify utilities' communications networks across their geographic footprints, while increasing the available capacity and available bandwidth for human or IoT application usage.In a case study published in UTC Journal, a publication of the Utilities Technology Council, utility company Duke Energy, which operates in the Carolinas, Florida, Ohio, Indiana and Kentucky, ultimately concluded that in addition to its distribution and transmission grid and traffic from its customer-facing and utility generation operations, it effectively had a "third grid": its communications infrastructure.When Duke took the time to develop a comprehensive communications network strategy, one of its conclusions was that "it is time to plan the transition to next-generation cellular technology."

where private LTE networks could potentially be deployed, from military bases and warehouses to hospitals, industrial and manufacturing sites to mines.

IHS Markit forecasts that the critical communications broadband LTE market -- which includes private LTE for mission-critical enterprise communications as well as public safety LTE -- will grow at a compound annual growth rate of 20% until 2020 and reach $2.6 billion in revenues at that point.

"For critical communications users today, it is clearer than ever that LTE is the de facto broadband standard, with the option of private LTE networks a reality," said Jesus Gonzalez, market analyst for critical communications at IHS Markit. The research firm concluded that "initial deployments of private cellular networks have been small in scale and varied across several sectors" and that there is "evidence of systems deployments across China, the Middle East, the United States, Western Europe, and Australia, among others. ... The Middle East and Africa region has had the fastest short-term growth rate of installed base of private LTE users, but the Asia Pacific region will

continue to have the greatest share of the world private LTE users installed base in the upcoming years."

"I think it's a real market," said Greg Collins, founder and principal analyst of Exact Ventures. "I think it's starting out very focused on a few, critical applications -- things like mining, ports and other applications --places where traditionally, it's been very hard to get good coverage.

"Where a lot of the efforts are going now, is expanding the market outside of those initial use cases, where the efficiencies are very measurable. I think that's where we are now," Collins said.

Source: 123RF Stock Photo

The Port of Los Angeles.

Enterprise network options evolve

Enterprise and industrial companies basically have three options when it comes to wireless connectivity. They can deploy an enterprise Wi-Fi network in unlicensed spectrum. They can rely on the coverage is available from the commercial cellular carriers, and depending on the size and location of the business, may be able to get the outdoor carrier network supplemented by a distributed antenna system, small cell or licensed signal booster. Or they can turn to private networks, which have been around in various forms (mostly supporting two-way radio/narrowband voice) for decades, utilizing either licensed or unlicensed spectrum.

Enterprise Wi-Fi isn't going anywhere. Going by the aforementioned market predictions, the private LTE market is expected to be worth somewhere between $2.6-$5 billion by 2021. Compare that to the current enterprise WLAN market, which IDC pegged at $5.7 billion in revenues for the full year of 2017. The enterprise WLAN market is growing at nearly 6% for the year on a global basis and is seeing double-digit growth rates outside the U.S.

Wi-Fi as a technology continues to evolve as well, with the new 802.11ax standard emerging to support greater density of devices to address capacity needs (particularly important for Wi-Fi support of IoT), as well as the new security features of WPA3, which was just recently introduced for certification. Wi-Fi also has the advantage of being a familiar technology to IT teams; and having low-cost chips and devices, which comes along with bring a mature technology that utilizes unlicensed spectrum.

There is a broad Wi-Fi ecosystem of vendors and system integrators. Wi-Fi Alliance expects about 3 billion Wi-Fi equipped devices to ship this year, and the technology has an installed base approaching 10 billion devices.

Despite its continuing success, however, there are limitations to the capabilities of Wi-Fi. "From a technical perspective, there are some pros and cons between Wi-Fi and cellular," said Alex Chua, director of product management and business development at testing company Keysight Technologies. While Wi-Fi has the advantage of ubiquity, he said, there are a number of features of LTE that make it a potentially attractive choice for enterprises. "They will have a greater amount of control and level of customization that they are able to do on their own private LTE networks, for very specific applications they need to support," he said, citing uses such as connecting high-value equipment within a factory. "The operator or owner of the private LTE network has control over the data communication on their own network. It's not going through external wireless operators. [They] have the basic ability to customize and configure the prioritization needs of each of the nodes within the network and decide if a certain set of equipment requires lower latency that other equipment in the environment."

In a Qualcomm white paper on private 4G networks, Heavy Reading analyst Gabriel Brown cited a number of advantages to LTE: its range and link budget; spectral efficiency and capacity; configurable quality of service; mobility/seamless handovers; ability to be deployed in a variety of spectrum bands, from unlicensed to shared to single-license-holder; SIM-based security and a roadmap for extensive features (many of which haven't yet been deployed in commercial networks but have been standardized) and a roadmap to future cellular technologies including 5G.

"Wi-Fi is doing okay. Wi-Fi will always be around, especially in the public environments," said Borghei, co-founder and EVP operations for network infrastructure provider Vertical Bridge. "But I think once people taste the benefits of operations, security, [and] reliability **...** of a private LTE network or private 5G NR network, then they will be less inclined to rely on public Wi-Fi."

As far as enterprises relying on commercial cellular networks, there are two types of issues:

Source: 123RF Stock Photo

control and coverage. Businesses may be all right with their employees relying on cellular for voice calls, but often desire more control of and tailored security for data traffic than a commercial cellular network offers. Getting a cellular subscription for every device that a business wants to connect (especially as IoT adoption revs up) can also be cost-prohibitive and complicated to manage. Meanwhile, as the majority of cellular usage has moved inside, extending coverage becomes more challenging and expensive. Building materials (such as low-emissivity glass or cinder block) may mean that the radio frequency environment is quite challenging, especially deep inside a building. For example, Borghei said that Vertical Bridge has seen an increase in infrastructure needs from institutions such as college campuses reaching out for both coverage and capacity solutions: they need to equip tucked-away classrooms for increasingly bandwidth-heavy usage by students and professors.

Enterprises in high-value venues such as malls, high-profile office buildings or transportation hubs often benefit from DAS installations, but carriers' willingness to fund things like major neutral-host DAS has waned in recent years -- and most enterprise buildings don't have DAS due to costs. However, Borghei offered some hope on that front: within the last year or so, he said there has been renewed interest by carriers in wireless coverage of mid-sized venues of 600,000-square feet or less.

"We knew that time would come, and it has come," he sid. "We've seen more requests from carriers to augment their hetnet architectures, and it's not just the big venues."

Even if commercial carriers substantially expand their indoor coverage, however, there's still another factor: the majority of their high-value customers are consumers, and their networks have been built accordingly.

Enterprise connectivity "is not necessarily one size fits all," said Stephane Bandayan, director of solutions for carrier wireless at iBwave. "Unlike the consumer market, where carriers have been used to providing basically the same flavor of connectivity, here you are really talking about very different types of connectivity depending on the vertical that you want to address."

Due to their customers' usage patterns, for example, carriers have focused on downlink speeds; but an industrial network might need low-latency uplink connectivity for equipment control.

"These kind of general-purpose networks, they're not very good at addressing these industrial uplink data scenarios, said Stephen Litjens, board chair of the MulteFire Alliance and GM of digital automation at Nokia. "That's why you need a special, purpose-built network."

Jeff Miller, SVP and GM of RF Solutions for testing and antenna company PCTel, which recently launched antenna models supporting the Citizens Broadband Radio Service shared spectrum, said that he expects the low-hanging fruit for private LTE networks to be IoT-focused industrial solutions, rather than enterprise connectivity: closed networks in warehouses and distribution centers, for instance, where quality of service and robust bandwidth are needed to support high densities of IoT devices, but voice service may not be needed.

Besen expects that private LTE will be used both to support people and IoT devices. He estimated that about 60% of private LTE usage would be by IoT devices and

40% by subscribers.

Carriers are rolling out their own IoT networks, to be sure, and those -- along with low-power, wide-area network competitors such as LoRa and SigFox -- will address some IoT use cases and enable commercial carriers to serve vertical markets better. 5G, once it emerges, is likely to help support data-heavy, low latency use cases -- and private LTE offers a migration path to 5G NR, noted Paul Challoner, VP of network product solutions at Ericsson.

Scott Nelson, chief product offer and VP of product at Digi International (which will have CBRS-ready products in its IoT line-up this year), sees three motivations for enterprises to consider private LTE: privacy/trust; availability of private LTE as-a-service when current coverage is lacking; and interoperability of equipment and devices.

Private networks have been around for decades, but they have often been limited to narrowband voice capabilities/two-way radios. To operate a private network, a company has to either have purchased a spectrum license or made arrangements to get access to licensed spectrum; or deal with the vagaries of unlicensed options. Spectrum scarcity and cost has been an inhibition on this front, but many verticals are also getting to a tipping point where they simply need broadband data capabilities for current operations and future needs.

Utilities are one such vertical. They already typically operate their own private networks, which can cover multiple states and may consist of multiple technologies due to growth by acquisition. According to a Navigant Research white paper, modern utilities sometimes manage up to a dozen different networks. Private LTE has the potential to simplify utilities' communications networks across their geographic footprints, while increasing the available capacity and available bandwidth for human or IoT application usage.

Utilities also are facing the fact that as the use of solar, wind and other renewable power sources increases, the utility grid is becoming a two-way street instead of one-way transmission. They need to adapt to a more-distributed grid and want to leverage IoT to navigate these changes -- which means many more devices on their networks. Navigant expects the number of connected devices on utility networks to increase by at least an order of magnitude, and for the volume of data from each device to also increase — while at the same time, other, non-utility devices in unlicensed spectrum are projected to jump by more than 400%, making unlicensed options an unappealing option for such critical networks. Navigant said that the combination of those two pressures is helping to drive the utility industry's interest in private LTE networks.

In a 2017 case study published in UTC Journal, Duke Energy (which operates in the Carolinas, Florida, Ohio, Indiana and Kentucky), conducted a network assessment and concluded that in addition to its distribution and transmission grid and traffic from its customer-facing and utility generation operations, it effectively had a "third grid": its communications infrastructure. When Duke took the time to develop a comprehensive communications network strategy, one of its conclusions was that "it is time to plan the transition to next-generation cellular technology."

The biggest appeal of private LTE may come down to the fact that it opens up a new choice that businesses didn't have before.

Recent developments in private LTE

As private LTE gathers steam, here is a selection of recent related news:

Nokia launched its Flexi Zone MulteFire Multiband Pico BTS in January at Mobile World Congress, which it claimed was the world's first MulteFire small cell. Also at MWC 2018, the MulteFire Alliance introduced its MulteFire Release 1.1, which expanded the technology from the broadband uses covered in its first specification release, to narrowband internet of things capabilities.

The Wireless Innovation Forum, which provides the technical specifications for CBRS, completed the foundation work on the specs in February.

The CBRS Alliance introduced a brand -- OnGo -- and a certification program for CBRS devices in May. CTIA will administer the OnGo certification program, and the first six certified testing labs were named earlier this month.

The city of San Francisco has been operating a CBRS trial this summer with two sites, working with partners including Nokia to test the technology's ability to support smart city use cases.

Verizon has been testing CBRS on its live network, with a test site in Florida that included both indoor and outdoor equipment. Ericsson provided its Radio DOT system for indoor and Radio 2208 for outdoor for the test, which aggregated 50 MHz of CBRS spectrum with some of Verizon's licensed 700 MHz spectrum and produced peak speeds of 790 Mbps. The test utilized Federated Wireless' Spectrum Access System and a test device with Qualcomm's Snapdragon 845 chipset. Verizon said that outdoor small cells to augment network capacity will be its first use case for the technology. Verizon expects to have CBRS-enabled devices available by the end of 2018.

In May, DAS provider Zinwave said that it will be supporting a number of OnGo private LTE pilot networks with Fortune 100 customers.

"We believe that private LTE networks will be part of the ecosystem of our wireless space for various reasons: control, reliability, security, creating a mission-critical private network," said said Borghei of Vertical Bridge. He added that as industrial manufacturers increasingly rely on IoT and artificial intelligence, it creates a need for very secure, low-latency, high-throughput networks -- and private LTE can fill that niche.

"How it will develop and how quickly and how big it will be - I don't have that crystal ball," Borghei said with a chuckle. "But I think it will be a niche in the space."

Options for private LTE

One of the main drivers for interest in private LTE, especially in the U.S., is the availability of new spectrum and technologies. The main options domestically are the Citizens Broadband Radio Service spectrum at 3.5 GHz and MulteFire, which enables LTE to operate in unlicensed spectrum at 5 GHz. With up to 150 MHz of CBRS

Source: ExteNet

CBRS 3.5 GHz MIMO equipment installed by ExteNet.

spectrum available and up to 500 MHz available in the U.S. at 5 GHz, the spectrum bands can support a variety of use cases.

Besen said that CBRS has the most market momentum currently, with an ecosystem in the works that is set to launch later this year, pending final actions from the Federal Communications Commission on approvals for supporting systems and licensing rules.

The maturity of the ecosystem means that LTE can be cost-effectively deployed, according to experts -- if inexpensive spectrum is available, as in the case of CBRS' unlicensed allocation (80 MHz). According to Mobile Experts, CBRS small cells can be deployed at $.30 per square foot, as opposed DAS at $3 per square foot (although CBRS can also be deployed via a DAS, and some vendors have already announced support).

"I think the key is to demonstrate the ROI on the CBRS technology for private LTE networks, so that [enterprises] feel comfortable to invest in the technology," said Besen. "This is new technology. They have a hard time understanding the difference between Wi-Fi versus CBRS or [other] private LTE. That's why I think the key thing is to look at it from an economic perspective."

Eric L'Heureux, CEO of Canadian private LTE network company Ambra Solutions, said that his company can deploy carrier-grade, mission-critical private LTE networks for about half the cost of enterprise Wi-Fi. For companies which were relying on two-way radios and Wi-Fi (or no connectivity at all in harsh and remote environments, such as underground mines), L'Heureux said that private LTE networks offer a unified voice and data network with a single infrastructure that can support a variety of users and utilize different spectrum above- and below-ground with seamless handovers. (Ambra owns spectrum at 1900 MHz, 850 MHz and Band 41 at 2.5 GHz to support private LTE deployments, and makes roaming or spectrum-sharing arrangements with other network operators in areas outside its footprint, L'Heureux explained.)

"For the end customer, the payback is pretty quick," L'Heureux said. He said that the most frequent issue his customers run into once their networks are operating, is the number of requests for real-time monitoring and sensors that their networks can now support.

"The challenge they are facing is, there are so many options that are possible with LTE," he said.

Source: ExteNet

ExteNet's NOC for monitoring deployments in licensed and unlicensed bands.

Private LTE networks are also free to implement 3GPP features that have been standardized but that commercial carriers may have passed on, such as mission-critical push-to-talk, voice and data and others. L'Heureux said that Ambra's customers use cell broadcast for alerting personnel on-site of events such as blasting, or for rapid evacuations.

Meanwhile, in a study looking at the cost benefits of MulteFire, Randall Schwartz, founder and principal analyst for Wireless 20/20, found that for a MulteFire deployment for a port with a high density of IoT devices, the private LTE scenario would require around 257 small cells, while Schwartz estimated that an 802.11ac Wi-Fi network of similar capacity would need more than 1,000 access points.

"Although some of the MulteFire controllers are more expensive than those needed for Wi-Fi, and the units themselves are more expensive, the cost savings in the initial deployment adds up to more than 40% over a Wi-Fi deployment," Schwartz found.

Private LTE also leverages two other trends that are converging in the enterprise: virtualization/ software-defined networking, and mobile edge computing. For security reasons and to support low-latency applications, private LTE is expected to be deployed with small-scale virtual cores at the network edge. Those edge devices then need to be managed to ensure that enterprises are receiving the stability and performance that they're paying for.

Collins noted that 5G is starting to be talked about in similar ways -- that latency-sensitive applications could have a finer degree of control in LTE, and that network slicing and mobile edge computing as well as cloud radio capabilities might even lead to opportunities for collaborative networking between service providers and enterprises.

"We see some of these other, larger trends coming into play with enterprise LTE," Collins said.

"We've talked a lot about the fact that networks are going to migrate toward the edge," said Chris Stark, Nokia's head of business development and chair of the CBRS Alliance. "It has a lot to do with the move toward 5G and low latency, and just some of the physics involved in the data transmission, and the need to have edge cloud and data centers. We're seeing enterprises, and operators in enterprise-like situations, as a really good entry toward the idea of moving more to the edge." So where are the business opportunities in private LTE and who stands to benefit from this new enterprise network option?

Although some enterprises will want to operate their private LTE networks themselves, that's a challenging proposition for existing IT teams: cellular is a different animal, and most companies won't necessarily want to source in-house expertise for designing, deploying, provisioning and maintaining these networks and devices.

Joel Lindholm, VP of LTE business for Ruckus Networks and co-chair of the CBRS Alliance's in-building working group, said that since Ruckus' business is split 70/30 between enterprises and operators, it speaks to both sides. Ruckus is using CBRS -- shared spectrum with a three-tiered framework -- as its first foray into LTE equipment and will have both standalone private LTE and private LTE as an augmentation option for its Wi-Fi access points. He said that in the case of CBRS, there is both a market for offload from cellular networks

and for enterprise -- which doesn't want an operator version of LTE, he said, but "a version of LTE that can be packaged and used, and just consumed by an enterprise." Lindholm added that "there's really a larger need than we probably even expected inside the enterprise.

Most observers expect private LTE to take shape in network-as-a-service form -- one that the commercial cellular operators may very well extend as they take advantage of their own expertise in cellular technology, and their desire to serve different verticals with new IoT-based services.

"Mobile operators are becoming ever more creative in their strategies to gain a foothold in the private LTE and 5G network ecosystem – ranging from operated-branded critical communications LTE platforms to the BYON (Build Your Own Network) business model where mobile operators provide access to their licensed spectrum so organizations can establish their own private LTE networks in their active footprint," said SNS Telecom & IT. "Vertical-domain specialists are leveraging partnerships with established wireless network infrastructure OEMs – such as Ericsson, Nokia, Huawei and Samsung – to offer end-to-end private LTE and 5G-ready network solutions."

Private LTE is also seen as a definite opportunity for neutral-host providers with a history of cellular expertise. ExteNet, for example, has been testing CBRS under special temporary authority from the Federal Communications Commission for two years. Infrastructure provider CommScope developed its own Spectrum Access System and Environmental Sensing Capability system, which together enable dynamic CBRS spectrum sharing; it recently completed successful interoperability testing with Ericsson.

Besen said that companies which offer Evolved Packet Cores will have a particular advantage in the market in terms of offering services enabled by private LTE.

"The EPC is the key component," he said. "They will have to offer it into different business models as a managed service that can be by dollars per small cell or per subscriber," he said. He also envisioned the possibility of private LTE mobile virtual network operators who stitch together multiple networks and work out roaming and billing relationships with the four national carriers.

Speaking of carriers, private LTE is expected to offer them new opportunities as well. In the case of CBRS, operators will likely use the band like typical cellular spectrum for offload purposes -- but they could also leverage private LTE to tailor their enterprise offerings.

"I think operators should have an interest, insofar as they have large corporate customers and this can just be another type of service that they provide to them -- integration types of services that may be complementary to other things they purchase from the operator," Collins said. "Operators have backhaul solutions that may be part of this overall solution. Operators should not necessarily see this as one-for-one competition, but rather, 'we can play an important role in this trend also.'"

Besen sees private LTE as a natural convergence of IT and telecom networks.

"A whole new set of players are going to emerge from the shared spectrum," he said. He thinks cable operators in particular could have an advantage in the market -- Comcast has already launched an MVNO on Verizon's network and Charter Communications plans to

do the same thing shortly. Having network and billing relationships with an operator gives them a leg up on the OSS/BSS relationships that they would need in order to offer private LTE, he noted.

"For me, this is a little bit like the edge computing space right now," Borghei of Vertical Bridge said. "There are a lot of folks talking about the concept, everybody is doing a little bit of trialing, but [they are] playing it very close to their chests. They don't want to reveal too much of their strategy and their competitive edge. But I think once the auction is over with and people know how the licenses are going to be owned and administered, you're going to see a real push to get some of the networks live."

The FCC factor

There are still a few regulatory issues that have to be resolved before CBRS can get underway. CBRS has three tiers of access: protected incumbents such as naval radar systems; Priority Access Licenses, which as the name suggests, will have prioritized access to the spectrum while incumbent protection is maintained; and General Authorized Access, which is considered unlicensed spectrum (CommScope describes GAA devices as "lightly licensed"; they still have to be approved and registered with SAS administrators). The Spectrum Access System administrators are still awaiting final authorization from the Federal Communications Commission -- companies including CommScope, Google, Federated Wireless and others which have developed SASes to support the three-tiered spectrum sharing system and allocate channels to ensure priority access and incumbent protection. In addition, the Environmental Sensing Capabilities which are based on coastal sensor networks to detect the presence of naval radar incumbents, still need final certification as well.

The FCC also has yet to issue a final decision on a notice of proposed rulemaking that would change the geographic size and the length of the term of the Priority Access Licenses, the second tier of the three-tiered CBRS framework. The original rules called for selling PALs on the scale of census tracts, of which there are about 70,400 in the U.S.; and licenses of three-year terms with one three-year extension. (There are seven PAL slots for each geographic area.) Multiple PAL blocks of 10 MHz each can also be aggregated, up to 40 MHz of spectrum.

But the national carriers advocated in favor of larger geographic areas -- partial economic areas, which divide the country into about 440 sections -- and longer license terms with unlimited renewals. Other companies, including Google, wireless internet service providers and private industrial users, asked the FF to keep geographic licenses small and affordable for new players. Most industry observers expect the FCC to come to a compromise on geographic size, with a combination of larger license areas in metropolitan areas and smaller ones in rural areas. The FCC is also expected to extend the license terms and renewal options.

According to WInnForum's anticipated timeline for CBRS development, the group doesn't expect FCC-approved supporting systems and certified devices to be available for GAA use until the fourth quarter of 2018 at the earliest.

The FCC also has yet to rule on the request to realign parts of the 900 MHz band in order to support broadband operations, which was requested by pdvWireless, the

primary spectrum holder in the band. (See sidebar.)

However, the industry is trying to get as much done as it can as it waits for the final pieces from the FCC -- and in some cases, that means deploying CBRS-ready networks. Infrastructure provider ExteNet has been testing CBRS for two years, and its projects include deploying a CBRS-ready FWA network for Paladin Wireless, a wireless internet service provider in northeastern Georgia; and for Peak Internet, a Colorado WISP serving Colorado Springs and Pike's Peak. Both of those networks were deployed using 3.65 GHz spectrum, which WISPs already use, with the ability to do a software-only upgrade to CBRS 3.5 GHz in the future.

Deployment considerations

In some ways, private LTE will be very similar to traditional LTE systems, according to Miller of PCTel: spectrum will still need to be cleared and tested for interference sources; RF environments surveyed and mapped for network planning and new networks tested for performance, troubleshooting and optimization. There may be a need or desire for probes with CBRS deployment, he added, for insights into the dynamic spectrum environment.

But when it comes to deployment of private LTE systems, one thing is clear: the groups who are backing the technology are trying to take lessons learned from Wi-Fi's success in the enterprise and make the infrastructure as "Wi-Fi-like" as possible. But there are certainly some challenges that will take some time to shake out.

"These networks have to be much easier to install and deploy -- something that an IT department is capable of and maybe Wi-Fi-like," said Alex Chua, director of product management and business development at Keysight Technologies. "Companies are working on tools and infrastructure to enable that," he added.

Keysight is involved with both the MulteFire and CBRS alliances, and Chua said that private networks of all types will need to be tested, from small offices spaces to large enterprises and factories.

CBRS Alliance chair Chris Stark said that his organization has made ease of deployment a key area of focus -- and scalability matters, but in a different way than in traditional cellular networks.

"I think in terms of flexibility of deployment and ease of deployment, there is a lot of effort going into trying to ensure that LTE itself scales down," Stark said. "One of the things about LTE that clearly we've seen in the U.S. is that it scales up, because you've got so many cell sites across the U.S. and you have so many users on it. The top end is something that's just there. **...** What you will see, and I think it's fair to say that is an issue some of our members are working on, is that we can scale it right down and make it very viable in terms of a low number of APs that get deployed and a low number of users. There are a lot of folks working on that, so in fact CBRS can cover even small deployments, of one or two APs and a low number of users, or even just straight enterprise IoT users."

Art King, director of enterprise at SpiderCloud Wireless (now owned by Corning) described the basic enterprise deployment process as a "labor sandwich" of the three types of people involved: the bottom slice is the cellular network designer who does the radio frequency design for the network; the person who physically places and plugs in the equipment, often a member of

the IT staff; and another cellular expert who will commission the system and verify its performance of the system (typically with walk-testing).

That may sound simple, but it's likely to be more cellular expertise than enterprises have -- so private LTE needs to be either simple enough that enterprise IT teams can deploy and operate it, or with a robust ecosystem of companies willing to take on the role of operating these networks for enterprises. Private LTE is expected to be a bit of both.

King said that one of the issues Corning ran into as it developed its CBRS solution was that when it looked for an EPC partner, vendor conversations were stuck in a traditional cellular network mindset: many blade servers for registering millions of devices to an EPC. It ended up partnering with Druid Software, which already served the private enterprise network space, because the company understood business' network needs and could offer single virtual machines and list prices for customers.

Test companies are already preparing their product lines to support CBRS testing; MulteFire, since it operates in unlicensed 5G spectrum, will benefit from the fact that LTE License-Assisted Access aggregation of 5 GHz spectrum is already being rolled out by some mobile network operators.

Although theoretically, virtualized network cores for private LTE can be operated in the cloud, companies that are actually deploying these systems say that option isn't what they're seeing enterprises ask for.

"Most of the customers we're seeing are so concerned about security that they want to keep things on-premise," said King. Having a cloud-based EPC can also mean variable responsiveness, he added, which is undesirable for time-sensitive control traffic.

Infrastructure company ExteNet sees private LTE as a good fit for building owners who are interested in leveraging IoT for smart systems, digital signage and security use cases like body cameras for security guards. While landlords could use Wi-Fi, they are often operating buildings full of enterprise Wi-Fi networks.

"The last thing you want to do is interfere with your tenants," said Tormod Larsen, VP and CTO of ExteNet. He added that private LTE is more likely to appeal to building owners, rather than individual enterprise tenants, because of the investment involved.

ExteNet has supported CBRS-ready deployments of private LTE for wireless internet service providers as well as conducting its own testing, and is offering private LTE as-a-service. It operates packet core monitoring for its private LTE customers, so the company has seen first-hand the provisioning needs and operational demands associated with the technology.

Larsen said that the biggest challenge is "less about deployment and more about operations. **...** The deployment piece is actually pretty straightforward." He compared it to other technologies that ExteNet has expertise in, like small cell and DAS deployments: at the physical layer, private LTE isn't much different, requiring a transmitting node and connectivity and power to that transmitting unit. The operational needs, though, are quite a bit different. ExteNet, which typically has served carrier customers, is now in a carrier-like operating position, right down to providing things like customer service for its private LTE network clients.

"How do you operate [the network] and make sure that these customers are actually getting the benefit that they're paying for? That's where it's more of a challenge, and a bigger gap between the Wi-Fi mentality and the private LTE," Larsen said.

He also said that there are some details of deployment realities that could get very complicated for situations where private LTE networks might have roaming arrangements with commercial carriers: how will those networks handle the Communications Assistance for Law Enforcement Act, which requires that network data be available for law enforcement subpoenas? What about e911 requirements? He also noted that while Wi-Fi "provisioning" more or less consists of entering a password or MAC address, SIM cards have more extensive provisioning needs.

Eric L'Heureux of Ambra Solutions said that his company installs a network core at each site it serves, and provides end-to-end network services. For ease of device provisioning, the company is already using eSIM technology. It will also bring a cell on wheels to a customer site to allow end users to try out devices, as well as to help in radio network planning. For ease of device provisioning, the company is already using eSIM technology for Cat M1 devices that its enterprise customers are deploying.

The device front has seen an interesting shift as CBRS has gotten closer to reality. In its early days, when it was seen mostly as a way for businesses to launch their own networks, there was fretting about whether device OEMs would be willing to make smartphones with CBRS support. With the interest of national MNOs who plan to use CBRS to supplement their existing LTE networks, that is no longer such a concern. And most people expect that private LTE for the enterprise will be used for more IoT devices than people.

"We really see these private LTE networks being more IoT," said Larsen.

L'Heureux said that since his company serves commonly used spectrum bands, it isn't the quantity of devices that are an issue -- it's ruggedness, for the harsh environments of oil and gas and mining deployments; and support for specific LTE features, since Ambra is deploying standardized LTE features that the commercial carriers typically haven't chosen to roll out.

"The biggest work we have to do is integration work with the end customer -- the way we connect LTE at each location, we need to build all those cores and RANs, and they all have their own security policies. **...** We're really delivering full, complete solutions to the end customer." All of Ambra's systems are designed with dual cores, dual RANs and dual backhaul systems, and at least eight hours of battery backup due to their mission-critical nature.

He added that private network vendors have traditionally been locked into a single vendor for network and devices -- but the interoperability of the LTE ecosystem gives them new choices in devices and network equipment from multiple vendors that will all work together.

Key takeaways:

• With the maturity of the LTE ecosystem, enterprises in a number of verticals are seeking to take advantage of LTE technologies and features. Private LTE enables them to do so and could be offered in a number of ways, either network-as-a-service by carriers or third-party providers, or with the enterprise

bringing cellular expertise in-house.

• Private LTE can be considered a middle-ground between enterprise-class Wi-Fi and relying on commercial cellular networks. The market is expected to grow, but will still be dwarfed by enterprise Wi-Fi for the foreseeable future. The two primary options in the U.S. are CBRS and MulteFire, although there are other options such as obtaining spectrum access through a licensed spectrum holder.

• Use cases for private LTE often center around supporting increased IoT adoption within verticals from ports to utilities to office buildings. Evolution of that model is expected as the technology goes through successive waves of adoption and development.

• With spectrum access crucial to private LTE enablement, a few regulatory issues remain before the CBRS ecosystem and other private LTE network options are fully enabled.

How pdvWireless hopes to shape the private LTE space

The most commonly talked-about spectrum for private LTE use is the still-in-process CBRS band at 3.5 GHz, or the unlicensed spectrum at 5 GHz most commonly used by Wi-Fi. But there is another option in front of the Federal Communications Commission: the reshaping of spectrum at 900 MHz that currently supports narrowband uses for private networks such as utilities, municipal transportation, railroads, airlines and other enterprise and industrial critical communications.

"We think of private networks as being new, but if you look at utilities, they're operating a lot of different private networks for quite some time," said Rob Schwartz, president and COO of pdvWireless, adding that those can range from Land Mobile Radio voice networks to Supervisory Control and Data Acquisition (SCADA) systems. "Utilities often operate in places where there isn't ideal coverage, or for specific use cases, and with the exponential growth in connected devices, this creates the need for broadband Private LTE."

Back in the days of Nextel, Sprint used holdings in the 896-901/935-940 MHz to operate its iDEN network. In 2014, that Nextel spectrum was acquired by pdvWireless, which is headed up by a number of former Nextel executives, including Nextel's co-founders. Although there are other licensees in the band, pdvWireless says that it is the largest holder with a nationwide footprint of licenses in the spectrum, owning about 60% of the channels with a nationwide footprint and an average of 240 channels (out of 399) in most major metro markets. Schwartz said that pdvWireless' spectrum holdings represent one of the few opportunities for companies that require private broadband networks on sub-1 GHz spectrum.

"If you're one of those enterprises that needs spectrum for cost-effective coverage, there really aren't any other options," he said. "We're going to be the enabler to allow them to build and operate a broadband network."

In late 2014, pdvWireless made a proposition to the FCC: 900 MHz should be realigned to allow a Private Enterprise Broadband allocation, and the spectrum subdivided in order to support both narrowband and broadband operations (such as LTE).

"The rules governing the 900 MHz band have not been updated in any meaningful technical or operational sense for more than 30 years," pdvWireless said in one of its FCC filings. "The spectrum remains assigned in 12.5 kHz bandwidth increments, affording limited opportunity to aggregate channels for wideband operation. Outside the major urban areas, much of it has never been placed into operation."

"Today, the most advanced communications networks are usually part of public networks offered by wireless common carriers," pdvWireless said. "These networks are quite capable, but they are built to the specifications of the wireless carriers, not the unique specifications of individual businesses that use 900 MHz

pdvWireless (cont'd)

networks. Utilities, for example, may require better backup and greater survivability during emergencies than common carrier networks. As examples, during recent hurricanes, utility narrowband networks were more likely to remain operational than wireless carrier broadband networks. These private networks would be even more valuable with broadband capabilities."

The FCC responded by taking comment on a number of possibilities for making more efficient use of the 900 MHz spectrum: allow greater aggregation of licenses so that broadband operations could be achieved; realign the band, perhaps as pdvWireless suggested for both broadband and narrowband use; and generally, how to make more efficient use of the spectrum.

PdvWireless has gathered a number of backers for its proposal, although current licensees have made clear that they don't want interference from new LTE operations in the band to interfere with their current narrowband critical communications infrastructure.

United Parcel Service, for instance, which operates 900 MHz private land-mobile radio at its hub facilities, said in comments to the FCC that it generally supported the PEBB proposal in order to expand its technology options.

"The entrance of a 900 MHz PEBB licensee will provide a much-needed enterprise-grade provider in the marketplace for commercial LTE services, where current providers are understandably more focused on the typical consumer's needs," UPS said. "UPS is a heavy user of commercial LTE services throughout many parts of our business, but for mission-critical communications at many of our larger facilities, no existing LTE service provider to date has been willing or able to guarantee contractually the service levels we require. As a result, private trunked radio systems are the only option available today for meeting this critical business need."

In its most recent filing with the FCC in May, pdvWireless urged the commission to move forward with a Notice of Proposed Rulemaking on changes to the band -- but there's no guarantee that the FCC will do so. PdvWireless has focused its operations on narrowband dispatch systems, and as of its most recent quarterly call, Schwartz told investors that the proliferation and sophistication of OTT PTT applications on carrier LTE networks mean that the narrowband dispatch business wasn't sufficiently supported by the market. Pdv cut 20% of its workforce and reported a net loss for the quarter of $8.8 million, which was less than its loss of $14 million during the same period in the previous year.

In the meantime, the company is focused on trials, such providing spectrum support for a drone trial led by Rockwell Collins to demonstrate the ability to serve as "utility infrastructure for preventive and restorative maintenance," and a large project with utility company Ameren. Ameren was granted a two-year experimental license for a private LTE pilot network in Illinois and Missouri and according to pdv, is "currently preparing to launch their multi-state pilot program this calendar year."

So what would be the relationship of 900 MHz to CBRS? PdvWireless says they would be complementary.

"Pdv's 900 MHz provides superior coverage and penetration characteristics of a sub-1 GHz spectrum band with existing off-the-shelf LTE technology and devices that [allow] for a foundation of cost-effective coverage for private wireless sytems," Schwarz said on the company's quarterly call. "We believe higher spectrum bands like CBRS ... can provide incremental local capacity on a licensed or unlicensed basis where and if needed, and we look forward to potentially proving out this use case in future pilots."

PdvWireless also argued that if the FCC decides to go with a CBRS framework based on larger geographic license areas than enterprises want -- which seems likely -- that the 900 MHz spectrum would provide another opportunity for enterprises to get access to small geographic portions of broadband spectrum.

"If the Commission ... adopts a CBRS licensing framework that lacks reasonable small geographic-area licensing, such action would deny industrial and critical infrastructure entities meaningful access to the 3.5 GHz band and could undermine U.S. national and homeland security by denying them the ability to deploy [industrial IoT] applications and services that improve the resiliency of their operations," pdvWireless said in comments to the FCC. "The 3.5 GHz band ... will fill a vital role in addressing fixed, localized IIoT needs where expansive capacity is required, but it cannot provide the propagation and mobility advantages offered by the 900 MHz PEBB option. Together, these bands can play essential, complementary roles in addressing [private enterprise]/[critical infrastructure industry] broadband requirements."

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