WIA Wireless Infrastructure Association

Private Wireless Network Perspectives

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Disclaimer

This white paper is meant to be an educational tool and does not reflect Wireless Infrastructure Association policy.

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Introduction

Private wireless networks represent an emerging opportunity for the wireless infrastructure industry because they expand the addressable market for hardware, software, and services. Providers of wireless infrastructure can now engage with new potential customers, including public institutions, manufacturers, utilities, healthcare providers and event venues.

Several of these industries are already familiar territory for companies that build, host or operate distributed antenna systems. But private wireless should allow vendors to dive deeper into these verticals.

"There is a cost component for DAS that becomes challenging after a certain tier of venues, and so I think that's where we should probably focus," said American Tower Engineering Director Amit Shah, explaining his company's approach to private networks during a panel at Connect (X) in May 2022.

In order to capitalize on this opportunity, infrastructure providers need to present solutions that can support the larger digital transformations that so many companies are undertaking. Private wireless networks will rarely address every problem a company needs to solve, but they can provide the secure, reliable, high-speed connectivity necessary to support an increasing number of enterprise applications.

More and more of these applications reside in the cloud, and by combining private networks with edge computing, companies can access cloud-based applications faster. As public cloud providers extend their services to the network edge, they are also eyeing the private wireless market.

Hyperscalers Enter The Market

AWS announced a private wireless solution late in 2021, saying it can deliver all the elements needed to stand up a proprietary cellular network on shared spectrum. The cloud giant said its private networks are already at work in its own warehouses and are also being used by Dish Network and Koch Industries. In August 2022, AWS made its solution available to the wider market.

Microsoft and Google also are muscling into the private cellular network arena. Microsoft has acquired AT&T software-defined networking expertise and is in the process of moving many parts of the operator's core network to its cloud. The software giant also purchased virtualized networking specialist Affirmed and softswitch expert Metaswitch.

Google was the last of the big three hyperscalers to enter the market, and it did so with a roster of partners from across the industry. Crown Castle, Betacom, Boingo, Celona and Kajeet are all helping Google offer private wireless solutions based on the Google Distributed Cloud Edge.

Although it did not announce a priviate network solution until 2022, Google has been a player in the market for much longer since it offers a Spectrum Access System to enable enterprises and other organizations to access shared spectrum.

The Enterprise Opportunity

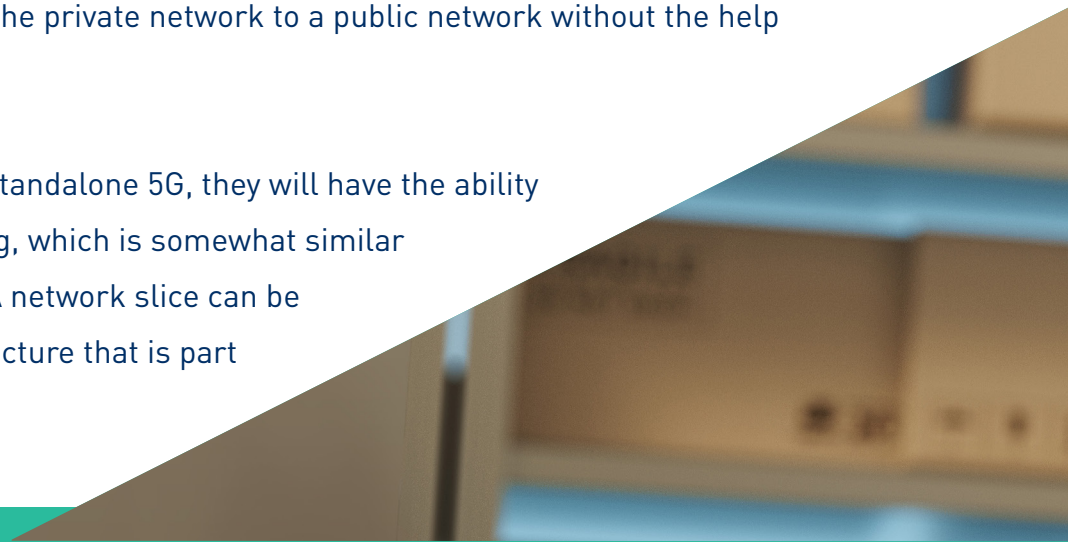
Enterprises are adding new capabilities at the network edge, like artificial intelligence for data processing and virtual reality for training, which is prompting many of them to investigate private wireless. This paper highlights some of the use cases early private networks are supporting.

"It starts to unlock some really creative use cases to help us drive efficiency and productivity in our factories," said John Deere Industry 4.0 lead Kiel Ronning, who was also a speaker at Connect (X). John Deere acquired its own spectrum to use for private networks, but many of the companies discussed in this paper are using shared spectrum without a license.

Spectrum sharing is a prime example of the way policy and technology are coming together to create new ways for enterprises to leverage wireless connectivity. This paper outlines several of the technology and policy shifts that are converging to set the stage for an expansion of investment in private wireless networks.

Some companies interested in deploying a private network will turn to their mobile service providers first. All four of the leading U.S. mobile network operators are sizing up the private network opportunity, and some are already making bullish revenue projections. But with spectrum available to enterprise users today, some customers may bypass MNOs altogether. The tools are in place to allow a company to stand up its own network, but devices will not be able to move from the private network to a public network without the help of an MNO.

As MNOs implement standalone 5G, they will have the ability to offer network slicing, which is somewhat similar to a private network. A network slice can be thought of as infrastructure that is part



of a public network and is assigned to a specific customer or use case, while a private network will have its own infrastructure, including a dedicated core. So compared to users of a slicing solution, private network customers generally will have more control of, and more responsibility for, their wireless networks.

Unlike network slicing, private networks do not need 5G. In fact, LTE is expected to dominate private network deployments throughout this decade. While LTE private networks often are deployed primarily for coverage, 5G is more likely to be chosen by users that want to enable capabilities like artificial intelligence at on-premise servers, or other applications that require the low latencies of 5G.

Together, LTE and 5G private networks probably represent a multibillion-dollar opportunity over time, but the size of the market is a subject of debate. This paper compares market projections from several leading analyst firms, as well as from the U.S. mobile network operators.

The Stage Is Set For Private Network Expansion

Mobile network operators have been building private wireless networks for their customers for years, but investment in this technology has recently increased across the wireless industry. Technology and policy have converged to make private networks more attractive for a wide range of industry and public-sector organizations.

Cloud service providers are moving compute and storage resources to the network edge, meaning that manufacturers, retailers, financial institutions and others can process data closer to locations at which it is generated. Meanwhile 5G networks are enabling high speeds and low latencies that can deliver applications in real-time when combined with edge compute resources.

The semiconductor industry is investing billions in artificial intelligence, and servers running powerful AI chipsets can process trillions of operations per second, enabling robots and autonomous guided vehicles to assist humans in factories, hospitals and warehouses. Private 5G networks give these organizations a secure, reliable way to move data to and from edge servers running AI.

5G also enables network slicing, or the ability to dynamically allocate mobile network resources to bespoke use cases. So private network operators have the capability not only to boost quality of service with dedicated infrastructure and software, but also to allocate those resources as needed to prioritize different applications and devices at various times.

While multiple technology advances are driving demand for private networks, policy developments also are creating new opportunities for enterprises and public-sector entities to deploy these solutions. Governments around the world are making spectrum available to

buyers that will offer connectivity to their own stakeholders, rather than selling mobile subscriptions to third parties. In some cases, users can access this spectrum without a license, making the economic model comparable to Wi-Fi.

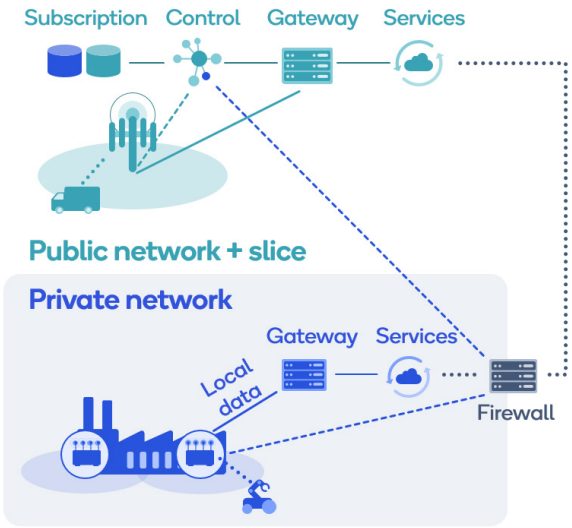
Federal funding for broadband is another policy development driving demand for private networks. CBRS networks have been built to help bridge the digital divide in Utah, Arizona, New York, Nevada, Texas, California and several other states.

What Makes A Network Private?

A private wireless network is one that segregates traffic from the public macro network in a given location, thereby offering higher levels of control, reliability and security. Users have the ability to dedicate network resources to specific devices or use cases, in order to ensure quality of service for mission-critical applications.

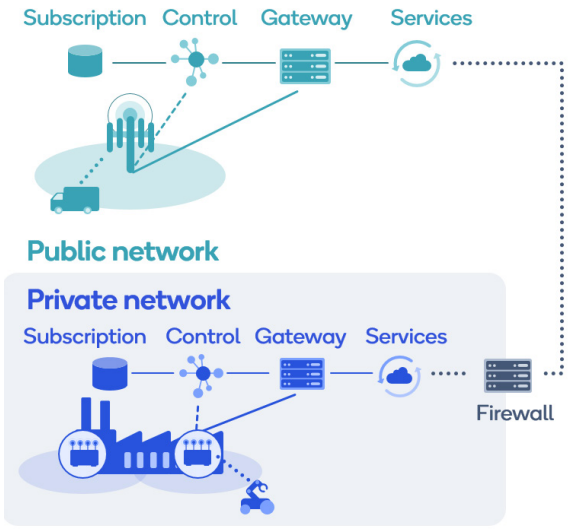
To accomplish this, private networks will use a dedicated mobile core. This may be located near the network's radio/antenna units, in a carrier's central office, or somewhere in between.

Mobile network operators can use their licensed spectrum to create a private network in a customer



Integrated Private Network

Source: Qualcomm



Independent Private Network

location, or they can use publicly available unlicensed spectrum. If an MNO enables roaming onto the public network, individuals and devices connected to a private network can stay connected even when they leave its boundaries. In some cases, they may have access to proprietary enterprise applications supported by the private network.

Devices connected to a private network can be authenticated via a SIM or eSIM. Alternatively, they can connect to gateways via Wi-Fi or Ethernet, and the gateways can use a SIM to connect to the private network.

Ritesh Mukherjee is senior VP and GM for enterprise networks at Inseego, a maker of LTE and 5G gateways. He said the market for these devices in private network settings is in its early stages. "Adoption has been slow due to the complexity of the technology, high initial costs, and slow down due to the pandemic," said Mukherjee. He continued,

"We expect the spending on private LTE/5G CPEs and routers to be around 5% of the expenditure on public LTE and 5G routers in the next five years. Our initial deployments in private LTE/5G have been in manufacturing and factory automation."

Mukherjee added, "We expect Industry 4.0, healthcare, hospitality, and first-responder applications to drive the subsequent use cases."

What Spectrum Is Available For Private Networks?

Spectrum availability for private networks varies from one country to another. Fortunately, a number of nations have made mid-band spectrum between 3.4 GHz and 3.8 GHz available to private enterprise users, creating a larger potential market for makers of IoT devices that may want to add cellular modems in anticipation of enterprises deploying private networks.

Spectrum For Private/Local Uses - A Global Movement

Source: Hewlett Packard Enterprise

In the U.S., the primary band available for private networks is Band 48, Citizens Broadband Radio Service (CBRS). This mid-band spectrum (3.55 GHz - 3.7 GHz) has good bandwidth and propagation characteristics, although transmission range is somewhat limited by the power limits the FCC has placed on commercial CBRS radios, which are called Citizens Broadband Service Devices or CBSDs.

The lower part of the CBRS band (3.55 GHz - 3.65 GHz) is shared by three sets of users: the U.S. military, commercial license holders, and unlicensed users. Incumbent military users (primarily the U.S. Navy) have top priority, followed by winners of Priority Access Licenses (PALs) auctioned by the Federal Communications Commission in 2019, and then users accessing the spectrum for free through General Authorized Access (GAA).

The five companies that spent the most on PAL licenses in 2019 were Verizon, Dish Network, Comcast, Charter and Cox. All of these companies now offer wireless service to consumers, and at least three of them (Verizon, Charter and Cox) have said they will use their CBRS licenses to support these mobile broadband services. Dish and Comcast ultimately may do the same, but both these companies have discussed using the spectrum for private networks, and Comcast has an actual deployment at Wells Fargo Center, a stadium in its hometown of Philadelphia.

Within the 3.55 GHz - 3.65 GHz band, some spectrum remains available for GAA use, meaning no license is required. In addition, the entire 3.65 GHz - 3.7 GHz band is available for GAA. A number of U.S. companies and school districts have set up private network trials using GAA spectrum.

Licensed and unlicensed users of Band 48 are required to subscribe to Spectrum Access Systems (SAS) to ensure the spectrum is shared effectively. This means they need to connect their base stations or network management systems to cloud-based servers that are constantly receiving information from a nationwide network of sensors, located primarily near the oceans, which inform the SAS if the spectrum is available. CBRS base stations ping the SAS every few minutes and continuously receive permission to transmit. If they don't receive this permission, they are expected to move to a different band or power down. The SAS prioritizes the military above PAL holders, and PAL holders above GAA users.

Federated Wireless, Google, Amdocs, Sony and Key Bridge Wireless have been certified by the FCC to operate SAS. CommScope also received certification but said in May 2022 it had shut down its SAS. CommScope[1] and Google jointly operate an environmental sensing capability (ESC) network to deliver data to Google's SAS as well as to others.

Band 48 is not the only spectrum available to U.S. enterprises and public-sector entities for private networks. The FCC in 2020 approved the use of the 900 MHz band for broadband, and the biggest license holder in this band, Anterix, started leasing spectrum to entities that want to establish private networks. As of July 2022, three utilities had executed agreements to use the Anterix spectrum: Ameren, Evergy, and San Diego Gas & Electric, which is also using CBRS.

More than a dozen other entities have received experimental licenses from the FCC to investigate use of the 900 MHz spectrum: Ericsson, Motorola Solutions, Southern Linc, Burns and McDonnell, Tampa Electric Company, Avangrid, Western Kentucky Rural Electric Cooperative Corporation, Dominion Energy, Texas State University, Xcel Energy, New York Power Authority (NYPA), Exelon and the National Renewable Energy Laboratory (NREL), which is working to validate the performance of 900 MHz private LTE for utility use cases.

The 600 MHz band also has generated interest from U.S. organizations that want to deploy private wireless networks. NYPA is trialing a private network in 600 MHz spectrum leased from Omega Wireless, using equipment supplied by Nokia. And T-Mobile has asked the FCC for permission to lease 600 MHz spectrum to Shawntech Communications, which wants to use the spectrum to build private networks in prisons.

A number of U.S. educational institutions hold Educational Broadband Service (EBS) spectrum in the 2.5 GHz band, and many previously have leased the spectrum to public carriers. In 2019, the FCC told schools they can sell the

spectrum, or use it for activities that are not strictly educational. The COVID-19 pandemic prompted several districts to explore the possibility of using their EBS spectrum to support private networks.

Private networks also can be deployed using public carrier spectrum. The largest private network in the U.S. is FirstNet, which uses AT&T's 700 MHz spectrum. AT&T, Verizon, and T-Mobile are all making bandwidth available to enterprise customers that want dedicated networks. The trend is expected to accelerate as 5G standalone cores enable carriers to dynamically dedicate network resources to enterprise applications known as network slicing. Carriers say mobile edge compute is also driving demand for private networks.

"Private networks are the gateway to mobile edge compute, which can deliver game-changing customer outcomes, including revenue growth, new customer experience and cost savings," said Verizon CEO Hans Vestberg, during the company's Q2 2022 earnings call.

Verizon recently announced private network deployments with BlackRock at the asset management firm's new Manhattan headquarters, and with Virginia International Terminals to build a private network at a Port of Virginia container terminal.

Sizing The Market

A number of analyst firms and service providers have estimated the current and future size of the market for private wireless networks. Forecasts are all over the map, partly because various firms define the market differently. The revenue generated from sales of network equipment dedicated exclusively to private wireless networks likely will be just a fraction of the revenue created by the entire ecosystem. When one considers spending on design and installation of private networks, software licensing, and ongoing payments made for managed network services, the projections of market size swell considerably.

At Dish Network's analyst day in May, COO Stephen Bye predicted the global private wireless network market eventually could be valued at more than $30 billion. Executives at other wireless carriers have been less willing to put a number on the market size, but they do characterize it as promising.

During T-Mobile's Q2 earnings call, CEO Mike Sievert declined to project the size of the market, telling analyst Craig Moffett of MoffettNathanson, "We're hesitant to take an early business like this and forecast it forward for you when it's in its infancy." Verizon CEO Hans Vestberg said on his company's Q2 earnings call the carrier sees "more and more customers" investigating private networks but acknowledged a slower economy could cause some short-term changes in the market's growth trajectory.

The analysts at IDC have projected the global market for private LTE/5G wireless infrastructure at $1.7 billion and could grow to $8.3 billion by 2026. Analyst Patrick Filkins noted applications in the industrial sector are placing new demands on enterprise networks, adding "many organizations are expected to invest in private 5G over the coming years as advances are made in 5G standards, general spectrum availability, and device readiness."

A less aggressive outlook for the market comes from Dell'Oro Group, which

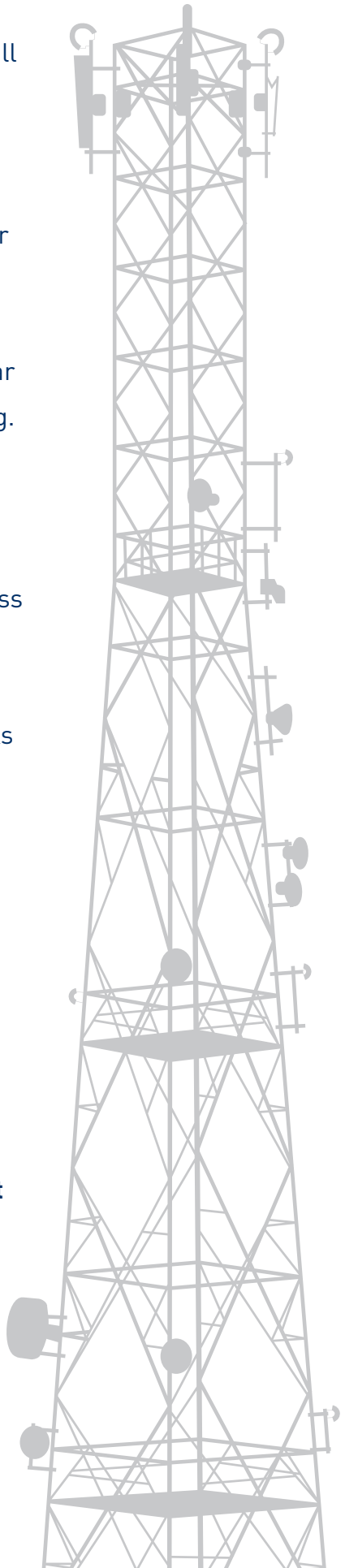
forecasts between $800 million and $1 billion of LTE and 5G small cells dedicated to private wireless will be sold in 2026. Analyst Stefan Pongratz said the firm revised its forecast downward after finding the market's current value is lower than the analyst team expected it to be. Pongratz estimates the value of RAN gear purchased for private networks in 2022 at roughly $500 million.

Pongratz acknowledged that his forecast for private wireless gear is just a drop in the bucket in the context of overall RAN spending. The private wireless RAN market "will be a fraction of the total opportunity," Pongratz told WIA.

Analyst firm Mobile Experts breaks the market for private wireless RAN equipment into two categories: heavy industries such as utilities that will deploy private networks for reliable coverage of large areas, and enterprises that deploy private cellular networks as a supplement to Wi-Fi, or even a replacement. The firm estimates enterprises will spend roughly $300 million on private wireless RAN equipment this year, less than a tenth of the $5 billion they will spend on Wi-Fi. By 2026, the enterprise private cellular market is projected by Mobile Experts to be $1.6 billion, exclusive of heavy industries, which the firm had not yet created a forecast for as of August 2022.

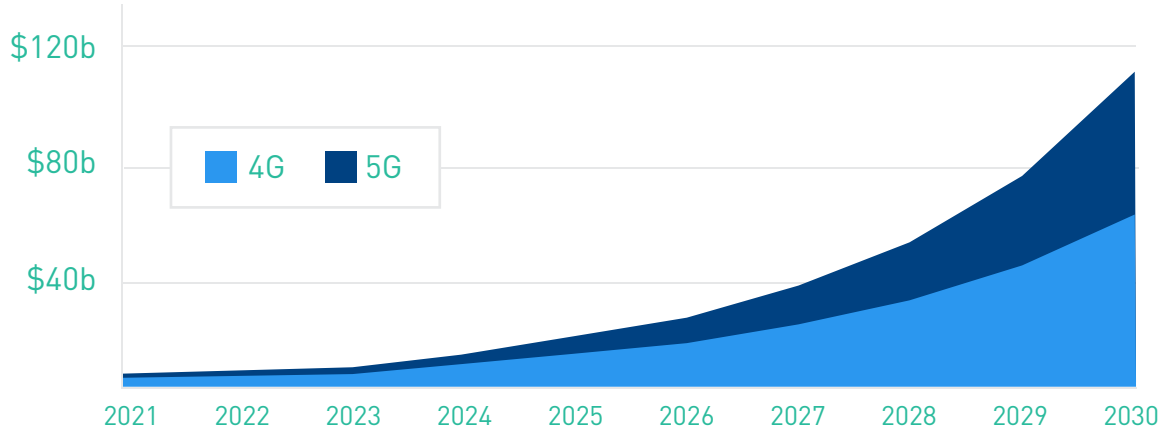
LTE is projected to dominate the private network landscape for several years to come. ABI Research expects 4G to still account for more than half of all private network deployments in 2030.

ABI forecasts professional services will account for 43% of a $109 billion private networks market in 2030. Senior analyst Leo Gergs expects enterprises to seek assistance with the integration of the wireless technologies available to them[2].



Private Network Revenue By Technology

World Markets: 2021 to 2030



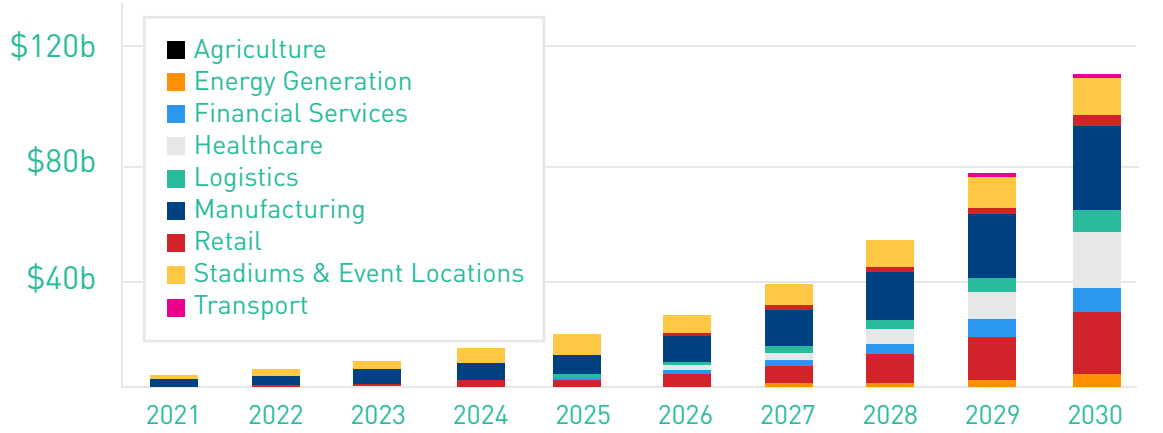
Source: ABI Research

"Enterprises have a plethora of connectivity technologies at hand – look at Wi-Fi, Bluetooth, Zigbee for example," said Gergs. "Expecting private cellular to emerge and knock off all these technologies at once will forever remain a sweet telco dream. The telco industry needs to wake up to reality and understand that this is not going to happen."

ABI has also projected a breakdown of private network deployments by industry, with manufacturing claiming the biggest share.

Private Network Revenue By Vertical

World Markets: 2021 to 2030



Source: ABI Research

Cost And Complexity

Controlling private network costs is of critical importance to enterprises, and their evaluation of these costs will in some cases depend on their perspective. For those comparing private cellular networks to Wi-Fi, the costs may seem high but the performance also is likely to look better. For those comparing an owned and operated private network to a managed service offered by a public carrier, the upfront cost may seem steep, but ongoing operational expenses could be less. Other organizations, such as mines, oil fields, or school districts, may compare the cost of private wireless to a fiber deployment and determine that wireless is the most cost-effective way to get the connectivity they need.

But cost is of course just part of the equation. Most of the organizations that could benefit from a private wireless network do not have the expertise to select, integrate, and operate the infrastructure they need. Here customers will rely heavily on vendors, network operators, and systems integrators. Companies in all parts of the wireless industry have an important role to play in educating new customers and helping them understand and deploy private wireless networks.

Use Cases For Private Networks

Organizations invest in private cellular networks for at least three distinct reasons: to support critical applications, to reduce costs, and to address new markets and customers.

Critical applications supported by private networks include public safety, defense, healthcare, education and power generation, among others.

Cost savings that potentially can be delivered by private networks include reduced operating expenses that result from no longer paying monthly service fees to a carrier for each connected device, as well as avoiding a potential one-time cost associated with data breaches, which can be minimized when all data stays on-premise. For manufacturers, private networks are expected to cut costs by reducing the amount of time it takes to reconfigure a factory floor, since wired connections can be replaced with wireless. And large enterprises of all types can use private networks to support smart-building applications that reduce their carbon footprints and cut their energy bills[3].

Another driver of investment in private networks is new revenue opportunities. Farmers that use drone-mounted wireless cameras for crop inspection are seeing higher yields, and private networks enable them to capture and process the data fast enough to take action. In San Diego's Petco Park, a private wireless network in one part of the stadium supports staff members as they process food and beverage orders on tablets, potentially enabling the venue to sell more concessions as people can move more quickly through the lines.

Large enterprises across industries are evaluating private networks in the context of digital transformation initiatives that will involve multiple technologies. Telco operators, cloud providers and systems integrators all can provide a path to market for companies in the wireless infrastructure industry that want to take advantage of the private network opportunity.

The leading mobile network operators are eyeing the private network market carefully. AT&T CEO John Stankey told attendees at the May 2022 J.P. Morgan Global Technology, Media & Communications Conference that he sees private networks as a way to engage corporate customers in new relationships, and that these eventually could lead to device-based recurring revenue streams. AT&T helps enterprises figure out whether private networking is relevant to their business needs, Stankey said. He said the operator can advise companies, make spectrum available, and manage its deployment.

Dish Chairman Charlie Ergen also spoke to investors about private networks recently and outlined a different path to market. Dish does not have the breadth or depth of enterprise relationships AT&T has, and Ergen said his company will partner with Cisco, Amazon, Dell and others, giving these vendors a way to add private networks to their portfolios when they work with enterprise customers[4].

Verizon CEO Hans Vestberg recently described his company as "the world leader in mobile edge compute and private 5G networks" and said this market is a sweet spot for Verizon.

T-Mobile also has been laying the groundwork for private network and mobile edge compute engagements with customers, and CEO Mike Sievert recently told investors "We're a lot further along in this space and in thinking around it and execution around it than you would probably surmise from our press releases."

Private Networks and Critical Applications

The largest private network in U.S. was conceived in the aftermath of the 9/11 terrorist attacks, as the U.S. government recognized the need for a dedicated public-safety network. AT&T secured the right to operate a nationwide public-safety network in the 700 MHz spectrum band through a competitive bidding process and is not required to use the spectrum exclusively for FirstNet. Like CBRS, the 700 MHz band is shared by commercial and public-safety users, and because FirstNet has a dedicated core, it is a private network for first responders. Their communications can pre-empt those of AT&T's other subscribers who may be using the band.

The U.S. military has committed $600 million to 5G deployments in licensed, unlicensed and shared spectrum[5]. A significant portion of these funds will be spent on private networks. For example, the Marines are investing more than $100 million in a private 5G network at their global logistics center in Albany, Georgia.

Public safety is perhaps the most critical application for private networks, but it is by no means the only one. Utilities have used private networks for years and are expected to invest even more heavily in this technology going forward. "Faced with a tension between cost and convenience on one hand and reliability and security on the other, commercial networks geared to the consumer mass market will understandably strike that balance differently than will an electric utility for its critical grid communications," explained Ryan Gerbrandt, COO of Anterix. "Though they are notoriously deliberate in their decision-making, utilities are showing signs that their adoption of private networks — and 900

MHz private LTE and 5G specifically — could ramp up in the next few years."

Ericsson has been a strong proponent of private wireless networks for oil and gas producers, distributors and refiners. "With a private cellular network as the primary network, there can be increased operational simplicity and links to other technologies," wrote Viren Parikh, Ericsson's North American director for energy business development, in a March 2022 blog post. "For example, a cellular network could terminate a Wi-Fi access point, or even lead to an ethernet cable for applications requiring a wired connection (without running a cable through the entire facility)."

Healthcare is another vertical expected to invest heavily in private networks to support patient monitoring, asset tracking, edge compute applications, and internal communications.

Doctors and nurses are using their mobile phones to call one another, and are competing for bandwidth with all the visitors inside the hospital. Using the congested Wi-Fi inside hospitals is challenging for healthcare providers. St. Luke's Health System in Boise, Idaho, is investigating use of a CBRS network to connect iPads used by healthcare providers to translate for non-English speakers during patient intake. In Los Angeles, at the Ellison Center for Transformative Medicine, AT&T has built a private 5G network to transmit patient scans to on-premise servers that use artificial intelligence to analyze the images. All patient data can stay onsite and diagnoses arrive faster than if the data had to traverse the internet and get processed in a public cloud.

In the educational market, private networks are used to provide reliable connections for people as well as for next-generation technologies. Several universities have deployed private networks to support technology test beds, while others use them to provide basic connectivity. Purdue, Carnegie Mellon, and California State University Stanislaus are examples of academic institutions with private networks.

Tilson, SBA Communications, and Celona partnered with Purdue Research Foundation to deploy a private CBRS network at Purdue's Discovery Park District[6] to support remote learning, telehealth, and smart-city applications, and can provide a foundation for local companies that want to deploy their own private networks. Tilson deployed the fiber backbone as neutral host infrastructure, SBA supplied the SAS through Federated Wireless, and Celona is the CBSD vendor.

"With the rise of unlicensed cellular spectrum and private mobile networks, communities like the Discovery Park District now have the power to chart their own course in terms of what advanced services and applications can deliver to their members," said David Broecker, chief innovation and collaboration officer at Purdue Research Foundation. "From students getting home broadband for the first time to the industrial IoT, the sheer diversity of customers and application requirements demonstrates how CBRS-based technologies serve businesses, schools, industrial organizations and municipalities alike."

During the COVID-19 pandemic lockdowns, many school districts used CARES Act funding to finance private CBRS networks to connect students with teachers and assignments. School buildings or other public properties were often used as macro sites, and the antennas connected to CBRS gateway devices distributed to student homes. These devices typically function like mobile hotspots, connecting to end-user devices via Wi-Fi. School districts in Dallas, Fort Worth, and McAllen, Texas, as well as Murray City, Utah, and a number of California cities have operational CBRS private networks, among others.

Critical applications appear to be generating the most private network demand. Tilson, which has been deploying private networks for 10 years, sees the highest levels of activity from utilities, educational institutions, and government customers, including municipalities and defense. "Lightly licensed spectrum has been extremely beneficial to these markets," said Drew Ludwick, Director of Tilson's Network Operators Center. "Companies are taking full advantage of it."

Ludwick said Tilson's carrier customers are most interested in private networks for in-building coverage. "Our in-building program has seen a lot of interest in private networks from carriers," he said. "We think this could be a segment where carriers can efficiently bring more 5G inside in more places.

"Tilson is anticipating an increased demand of private networks for in-building in the manufacturing vertical specifically. This would support automation where applications require low latency, dynamic configurability, and increased security."

Private Networks And Commercial Real Estate

Commercial real estate developers have the opportunity to plan for private cellular networks when they build new structures, and some of the most forward-thinking are doing just that. BlackRock[7], the world's largest asset management firm with $10 trillion under management at year-end 2021, was Verizon's first private 5G customer. The financial giant will use the private 5G network to connect its trading floor, as well as other spaces in its new headquarters at 50 Hudson Yards in Manhattan. The partnership with Verizon should give BlackRock the opportunity to connect its private network to the carrier's public network, enabling users to roam easily if they are Verizon customers.

Three miles to the north of BlackRock's new Manhattan headquarters are the main offices of Blackstone, the asset manager that spun off BlackRock almost 30 years ago. Blackstone is headquartered at 345 Park Avenue, another building with a private cellular network. 345 Park uses a CBRS network built and operated by Crown Castle. Crown was invited to develop the network by New York's Rudin family, which owns the building and wanted a private network to connect sensors and IoT devices for energy management[8]. For Crown, the big payoff will come when and if carriers connect to the private network and make lease payments to Crown, just as they do in a traditional neutral-host DAS.

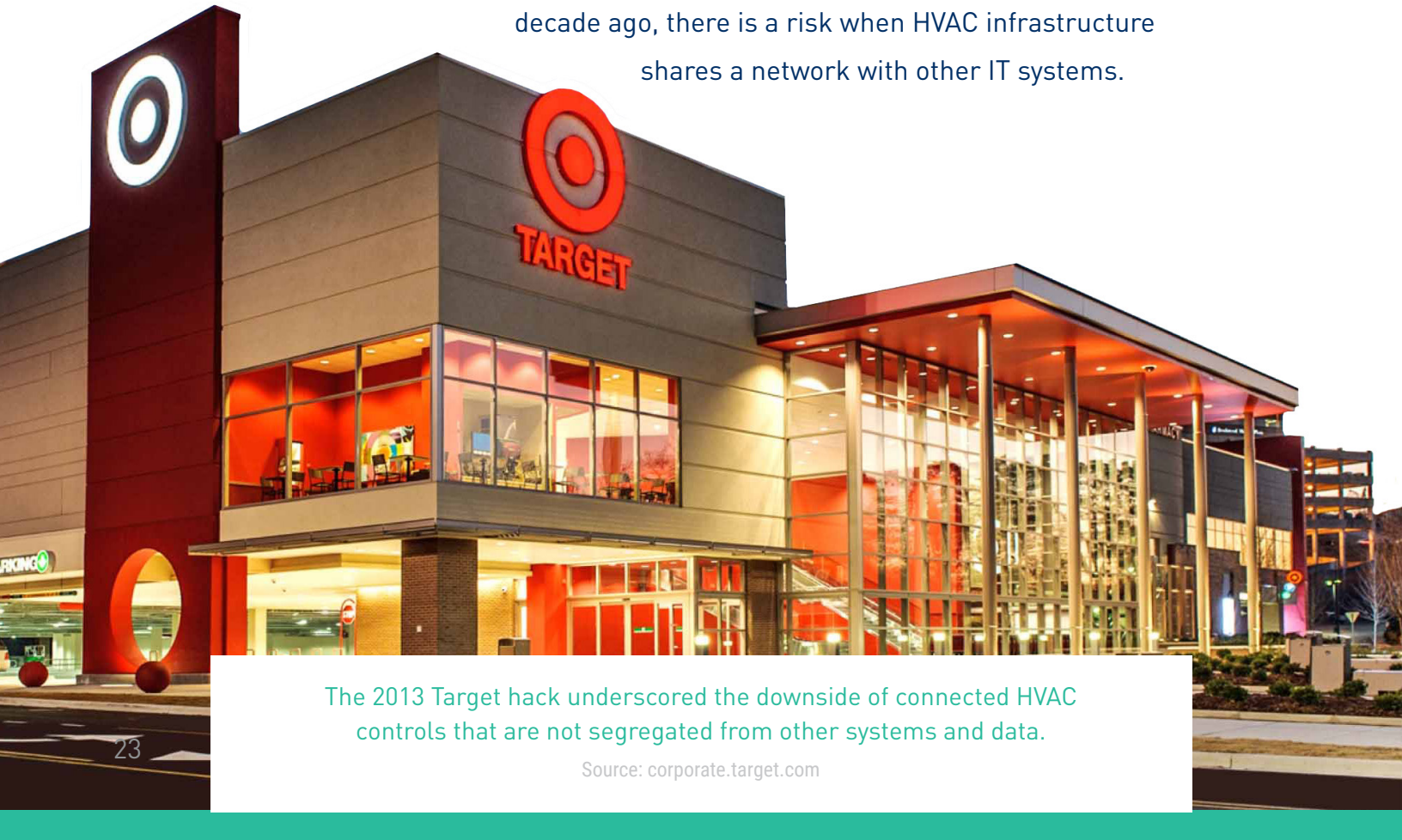
Neutral-host CBRS spectrum seems to be the holy grail for vendors and infrastructure providers that want to deploy unlicensed spectrum in heavily trafficked commercial buildings, but so far U.S. carriers have shown little interest in connecting to these systems. DAS, which uses licensed spectrum, remains the preferred way for carriers to ensure their subscribers maintain connections inside buildings.

"People in the industry say CBRS really won't take off until the MNOs approve

CBRS-based neutral-host networks, but I don't really agree with that point of view," said analyst Norman Fekrat of Imagine Wireless. "That is a very mobile device centric view of the industry. CBRS is not all about mobile devices like smartphones. CBRS is really about an enterprise LAN that is wireless. There are a lot of non-mobile devices like video cameras, tablets, and narrowband and broadband IoT sensors that can connect to CBRS."

American Tower's Amit Shah, director of engineering, agrees that CBRS private networks can be a good way for building owners and venues to connect IoT devices, while smartphones will continue to use a DAS for connectivity. Shah spoke on a Connect (X) panel entitled The Intersection of Private Wireless and In-Building Wireless, and he predicted CBRS deployments will start in large venues, and success there will lead to deployments in smaller buildings.

Sustainability goals are likely to drive many IoT investments that will leverage private networks. Connected climate control solutions help companies monitor energy consumption, but as Target learned almost a decade ago, there is a risk when HVAC infrastructure shares a network with other IT systems.



The 2013 Target hack underscored the downside of connected HVAC controls that are not segregated from other systems and data.

Source: corporate.target.com

Cradlepoint, which sells gateways to connect CBRS networks to Wi-Fi, is seeing demand from retailers that want to segregate their HVAC controls onto private networks. And Cradlepoint's parent company, Ericsson, has direct experience with using a private network to connect climate control systems. The company installed a private 5G network in its 5G radio Texas factory and reported a 75% reduction in wastewater along with a 25% cut in energy consumption.

Private Networks In Destination Venues

Richard Coyle, president and CEO of ExteNet Systems, told WIA it will be 18-24 months before sports venues and hotels start to shift from DAS to private networks. His company has been involved in a number of CBRS proofs of concept, and more recently several of those transitioned to pilot projects. In addition, ExteNet is building a private 5G network at Austin's Circuit of the Americas, which hosts Formula One racing and minor league soccer[9].

"It's an evolving technology and I think the exciting part is everybody's starting to look at it now. It's going to be exciting to watch over the next 18-24 months," said Coyle. "Once they start understanding exactly what private wireless can and can't do, the natural progression is going to be to IoT," he added.

Coyle pointed out that customers have a lot to learn about private wireless and said infrastructure providers have a role to play here. "Our business model needs to change," he said. "We need to be more consultative on the front end so we can help educate them on where the benefits are."

He said point-of-sale systems are likely to be a primary use case for private networks in sports arenas, an assertion reinforced by the Petco Park network mentioned earlier. The park's CBRS network, developed by Boingo, supports digital ticketing and concession sales, which the state of California required as a condition of reopening during the COVID-19 pandemic. California legislators are discussing legalization of sports betting, an activity that would benefit enormously from low-latency private wireless networks.

Private Networks In Factories

Dell'Oro's Pongratz said the manufacturing vertical is dominating private 5G network deployments in Europe, China and North America. He said other industries making significant investments include utilities, mining and education, although these are still more likely to deploy LTE than 5G.

Factories often are named as an ideal use case for private wireless networks because many of them already connect tools and equipment to wired networks, and every time they reconfigure the floor they need to move cables and reconnect to power. 5G can offer the lightning-fast latencies needed to react in real-time if a machine malfunctions or a worker is in danger, and tools can be moved much faster without cables. Wireless factory floors facilitate the use of robotic arms and autonomous guided vehicles as well.

Connected cameras are also valuable in the factory setting. When paired with edge compute and artificial intelligence, these cameras can help factory operators spot product defects and machine vulnerabilities almost as soon as they develop.

"In the private mobile networks space, a video camera is worth thousands of IoT sensors," said analyst Norman Fekrat of Imagine Wireless. "The camera could have a SIM or it could be connected to a wired device that could be connected to a router that is part of the LTE/5G network. ... There are more and more of these video cameras in manufacturing."

Schneider Electric plans to connect smart cameras to private networks in Lexington, Kentucky, and Lincoln, Nebraska, using equipment provided by Celona. The manufacturer has developed a small, ruggedized edge data center to process images captured by smart cameras, which can be used to detect jitter on the production line.

John Deere was one of the first major U.S. manufacturers to commit to private cellular networks, buying CBRS PAL licenses in five midwestern counties in which it has factories. The company has said it eventually wants to build private 5G networks at all its domestic manufacturing plants, meaning it will likely need a carrier partner for the sites where it does not own spectrum. Deere has not named a partner yet, but former Verizon Business Group CEO Tami Erwin is a member of the John Deere board of directors and the farm equipment giant also uses Verizon's telematics solution to connect its tractors to the internet.

In addition to CBRS, public carriers also may use other bands for private wireless, including the adjacent C-Band. Accenture's umlaut unit[10] recently

acquired 100 megahertz of C-Band spectrum from the German government and is using it to create a 5G testbed at its German headquarters to enable companies to test applications on a private 5G network.

Some manufacturers are building private networks without carrier assistance. Some are even bypassing traditional network equipment vendors by building their own radios and core networks. Foxconn and Siemens, two of the first global manufacturers to deploy private cellular networks, are developing their own 5G infrastructure.

Open RAN: An Open Question For Private Networks

Wireless carriers have spoken frequently about the complexity of integrating Radio Access Network (RAN) technologies from more than one vendor, so it seems likely that implementing Open RAN (ORAN) in an enterprise environment will be challenging, even for experienced systems integrators. Still, a number of vendors are arguing that open architectures will be the key to unlocking the value of private 5G networks in enterprise environments.

"What will be key to successful deployments is adopting an approach where networks can adapt and a programmable infrastructure is leveraged, including xHaul routers with support for hard and soft network slicing combined with the broader ecosystem of open RAN technology partners," said Jürgen Hatheier, international CTO at Ciena.

Andrew Jun, CTO of ADRF, sees the ORAN question as a financial one for companies evaluating private networks. "Private networks have been cost prohibitive to many enterprises," said Jun. He said turnkey private network

services provided by MNOs could be too expensive and/or insecure for many enterprises, and that cloud-based ORAN solutions could be the answer. "With open RAN, enterprises can afford smaller-scale and on-demand private networks," he argued.

Jun explained that disaggregation of network functions enables price competition, while cloud-based infrastructure will reduce costs further. He said open RAN Radio Units (RUs) need to be onsite, and on-premise servers can run Distributed Units (DUs) as virtualized functions. The rest of the network could be in a remote cloud on shared infrastructure.

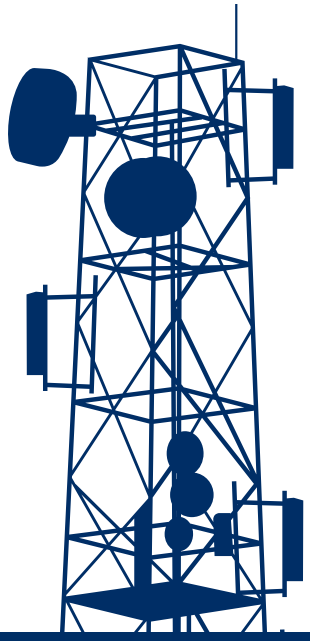
Conclusion

Private wireless networks can provide the secure, reliable, high-speed connectivity necessary to support an increasing number of enterprise applications. As such, private wireless networks represent an emerging opportunity for the wireless infrastructure industry because they expand the addressable market for hardware, software and services. Providers of wireless infrastructure can now engage with new potential customers, including public institutions, manufacturers, utilities, healthcare providers and event venues.

All four of the leading U.S. mobile network operators are sizing up the private network opportunity, and some are already making bullish revenue projections. But with spectrum available to enterprise users today, some customers may bypass MNOs altogether. The tools are in place to allow a company to stand up its own network, but devices will not be able to move from the private network to a public network without the help of an MNO. As more applications reside in the cloud, public cloud providers are also eyeing the private wireless market.

Most of the organizations that could benefit from a private wireless network do

not have the expertise to select, integrate and operate the infrastructure they need. Here customers will rely heavily on vendors, network operators and systems integrators. Companies in all parts of the wireless industry have an important role to play in educating new customers and helping them understand and deploy private wireless networks.



Appendix

1. **Commscope Scraps CBRS Sas Business, Keeps Esc Connection With Google**
2. **Private Network Complexities, Opportunities Abound**
3. **Rudin Uses Nantum OS To Reduce Strain On NYC Energy Grid**
4. **Dish Hints At Cisco, Amazon, Dell Ties To Hit Enterprise Market**
5. **U.S. Military Partners With Wireless Industry For 5G Test Bed**
6. **Discovery Park District At Purdue Wins Award For Its Private Wireless Project**
7. **Blackrock Partners With Verizon For Private 5G Network At New State-Of-The-Art NYC HQ**
8. **The Rudin Family In Collaboration With Crown Castle Launches First Multi-Tenant Citizens Broadband Radio Service Network (CBRS)**
9. **Extenet Systems Fuels New 5G Network For Circuit Of The Americas**
10. **Accenture Completes Acquisition Of umlaut**

The Wireless Infrastructure Association advocates for the deployment of wireless infrastructure across the United States, representing the companies that make up the wireless infrastructure ecosystem.

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