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Cloud Market Trend Report

Private Wireless and Local Cloud Trends

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Highlights

- **App opportunities.** Key apps for private wireless include remote machine control and monitoring (energy/utilities), autonomous guided vehicles (mining), real-time vehicle-to-vehicle communications (logistics), telemedicine, Augmented Reality/Virtual reality (AR/VR), video analytics, robotics, and smart factories – just to name a few.
- **Edge compute is a driver.** Standards work in 3GPP and ETSI has set the stage for multi-access edge compute (MEC) which will be important aspect of private wireless deployments. In addition, enterprises are looking at edge compute architectures that can address data analytics, data sovereignty, and security.
- **Spectrum is coming but will it be enough?** Spectrum is the key driver of wireless networks. The arrival of many different bands of spectrum for 5G networks, providing high bandwidth and low latency, provides fertile ground for new services and applications targeted at private wireless networks – but enterprises need more spectrum in the market.
- **Unlicensed spectrum opportunity.** In North America, the expansion of spectrum availability including Citizens Broadband Radio Services (CBRS) spectrum in the 3.5GHz band will extend the use of 5G technologies to private markets with unlicensed spectrum.
- **Ecosystem momentum.** Recent partnerships between 5G equipment vendors and cloud providers signal progress on ecosystem coordination. Efforts by large cloud operators such as Amazon and Microsoft to drive integration with cloud stacks and operator networks will help propel the market forward.
- **Private wireless projects ramp.** Projects counted by major telecommunications vendors increased through the second half of 2020 and into 2021. Ericsson, Huawei, and Nokia each claim steadily growing commercial momentum quarter-over-quarter.
- **LTE/5G evolution is a process.** Many private wireless use cases are in operation and will initially rely on 4G/LTE, evolving to 5G (including CBRS) gradually.
- **Digital transformation urgency grows.** The COVID-19 pandemic taught many organizations that they weren't ready for paradigm shifts in digitalization. 5G and private wireless are key elements for accelerating digital transformation projects.
- **Enterprise budgets are a barrier.** Even as CTOs, CIOs, and other technology strategists are bullish on the potential of private wireless as an important digital transformation enabler, CFOs are worried about how to pay for it.


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1. Introduction

Interest in private wireless networks is gaining momentum. As 5G standards and device availability continue to progress, large companies, municipalities, and utilities are all becoming interested in the ways that private wireless network(s) can help enable digital transformation use cases related to smart automation, smart infrastructure, and smart cities.

In our discussions with end users, organizations have expressed the desire to build better connectivity and cloud capabilities at the edge of private enterprise networks. This will drive a number of use cases (outlined in more detail later in this report) such as business analytics, customer experience, virtual reality/augmented reality (AR/VR), industrial automation, and other applications. These needs coincide with several favorable trends for organizations looking to build private wireless networks: 1) The evolution of wireless platforms and 5G toward standardized, virtualized components will drive down the cost of private wireless technology. 2) The launch of 5G has generated a lot of innovation and excitement about new private wireless platforms. 3) Private wireless applications can leverage additional resources, such as artificial intelligence (AI), developing in private, public, and hybrid cloud markets. While progress on the enabling technologies is being made, some of the fundamental hurdles that have stood in the way of broader private wireless network adoption remain in place.

This report will examine the state of the market today related to the mix of 4G/LTE, 5G, WiFi and edge-cloud technologies that may all have a role to play in private wireless network adoption. It will also review early private wireless projects to gauge where progress has been made vis-à-vis where material challenges remain. This report will also provide insights on network adoption considerations that large enterprises must work through in order to determine whether or not private wireless network projects make sense. Finally, it will review key players to watch in the space to help readers better understand the ecosystem of key suppliers that will make an impact on how this market evolves over the near-to-medium term.

2. Private Wireless Technology Overview

In broad terms, private wireless refers to any wireless communications network that is built for the private use of an entity such as a company, university, municipality or government agency. These networks share many of the same characteristics of public wireless networks that are owned and operated by communications service providers (CSPs).

Today, the overwhelming majority of initial private wireless network projects are based primarily on a mix of 4G/LTE and WiFi technologies.

However, to deliver the myriad use cases related to smart and/or autonomous infrastructure there is widespread agreement that 5G and edge cloud technologies must be leveraged if the true potential of private wireless networking is to be realized. In short, the key adoption drivers for 5G over 4G/LTE and WiFi can be summarized as follows:

- **Spectrum** – 5G offers increased flexibility in spectrum utilization that helps to support a wide variety of use cases and/or applications such as network slicing from a single network. In addition, the expansion of spectrum availability including Citizens Broadband Radio Services (CBRS) spectrum in the 3.5GHz band is providing more tools for extending the use of 5G technologies with unlicensed spectrum.
- **Latency** – 5G offers improvements on latency and connection reliability required to support precise industrial automation and autonomous robotic and/or vehicle operations.
- **Edge compute** – Specs in both the 3GPP and ETSI standards groups provide for MEC capabilities for compute-intensive applications. In addition, end users are looking at edge compute architectures that can address data analytics, data sovereignty, and security.
- **Link** – 5G offers increased wireless link budgets that enable untethered connections to replace and/or supplement wired connections for ultra-broadband applications.
- **Sync** – 5G offers very precise time synchronization for remote/distributed control of autonomous devices.
- **Security** – 5G offers enhanced security features at both the device and network level that enable nodes to securely exchange signaling data and user data between radio nodes and core network nodes.

In turn, these adoption drivers will be crucial to delivering on a private wireless value proposition. This includes the ability to enable ultra-reliable low-latency communications (URLLC) that guarantee almost perfectly stable network connections and sub-millisecond latency targets. Beyond ultra-fast and reliable connectivity, the ability to process vast amounts of data in near real-time will drive the need for edge cloud access to be sited very near, if not adjacent to the wireless network core.

Private Wireless Use Cases and Use Places

With the first public wireless networks dating back to the early 1970s, one might wonder what factors are driving the notion that private wireless networks are becoming necessary. After all, even the Internet of Things, which is a key private wireless driver, has been around since before the dawn of the 2010s. Simply put, the scale of connectivity requirements – both in terms of number of connections and the performance of those connections – required for large-scale

industrial automation and autonomous operations use cases is expected to overwhelm the ability of even 5G public wireless networks to meet.

The figure above categorizes many private wireless use cases by industry. As a strategic planning assumption, several of the use cases described here can be enabled in limited fashion by leveraging 4G/LTE and/or WiFi technology. However, to support the scale required to gain full value from a private wireless network investment, most use cases listed below will eventually require 5G and/or edge cloud technologies.

3. The State of Private Wireless Technology Today

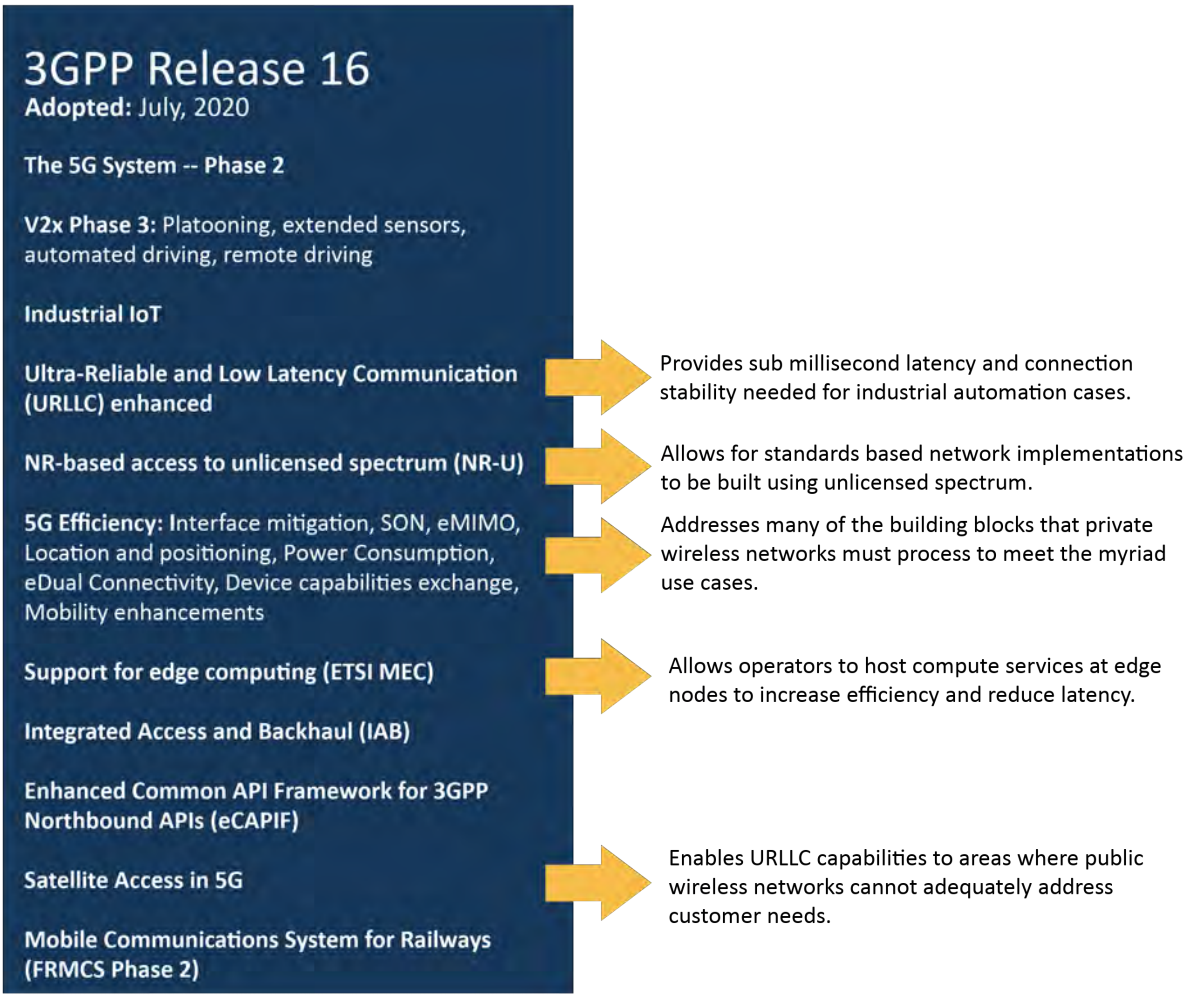
There is little doubt that private wireless networks are being hyped as one of the key opportunities associated with 5G technology development. In fact, Arthur D. Little has predicted that the private wireless market will grow to between $70 billion and $85 billion by 2025. Nokia claims more than 200 private wireless network customers, with many engagements in multiple networks. Additional global telecommunications giants such as Ericsson and Huawei claim hundreds of deployments of their own, many in conjunction with major global CSPs and/or cloud operators. However, despite the lofty predictions, and some seemingly impressive data

points from private wireless equipment suppliers, it is a fact that private wireless networks are in their infancy in 2021.

5G is in the early days of its deployment and will provide further momentum to the market as more operators get involved and expand their networks. Many private wireless networks can be built using 4G/LTE and this likely accounts for the large majority of claimed private wireless deployments today. But, for private wireless to reach its true potential, 5G capabilities must be a key part of the puzzle. To this end, in order to realistically assess when production private wireless network deployments at scale will take off, it could be instructive to take a deeper look at the factors that will influence 5G technology deployments in the next few years.

3GPP Standards Roadmap

Standards are important to provide a common framework and agreement on a logical and effective path forward with new technologies. As such, if we are looking for indications as to when private wireless networks will be "ready for primetime," then 3GPP standards activity is a good place to find such signs. The below summarizes key features of the latest 3GPP release and maps those features to key attributes that will be required to support growth in private wireless networking.



To summarize, the features addressed in Release 16 provide guidance on how to overcome many of the hurdles facing private wireless network adoption at scale. First, in order to meet the requirements for industrial automation, smart infrastructure, and industry-specific use cases for in vertical such as healthcare, energy, transport, and others, URLLC is a must. Similarly, the capability to manage spectrum utilization will be vitally important. As important will be techniques to make signal propagation more effective, power consumption manageable, and network timing more precise.

Each of these challenges are addressed in Release 16, with further work and refinements expected to be addressed by Release 17, which is expected to be finalized in late 2021.

Spectrum Considerations

Arguably, the most significant market factor in the widespread penetration of 5G — and by extension, private wireless network growth is spectrum availability. For most folks familiar with the 5G market, the need for more and varied spectrum options compared to previous wireless technology generations is well known. In short, the capacity needed to satisfy 5G data rates, and the density of devices that will operate on a 5G network, makes it necessary to tap into a broader array of spectrum resources than have typically been available for 4G, 3G, etc.

As such, spectrum resources in low band, mid band, and high band frequency ranges are expected to be supported by 5G equipment manufacturers. Broad guidelines for each spectrum bands can be defined as follows:

- Low band: 1 GHz and below
- Mid band: Between 1 GHz and 6 GHz, including CBRS
- High band: Above 24 GHz

The 3GPP recommends supporting operations in all three categories, as well as several sub-categories within each band. But country and/or regional policy preferences/constraints — as well as the product development strategies of equipment suppliers — will dictate which bands will be utilized more heavily than others.

Licensed vs. Unlicensed

In addition to a variety of bands to carry signals, distinctions between licensed and unlicensed spectrum have taken on a more prominent role in 5G and private wireless strategy planning. Prior to 5G, unlicensed spectrum was largely the domain of WiFi, wireless landline phones, and remote control toys. Now, as private wireless deployment strategies contend with a variety of challenges related to signal degradation, interference, and/or a lack of adequate available licensed spectrum, operations in unlicensed bands will be more important. Referring back to the figure above, the 3GPP's work to formalize NR-U standards is a clear signal that 5G networks – both public and private – will need to rely on unlicensed spectrum to some extent. Unlicensed spectrum such as CBRS will provide more spectrum opportunities for private wireless going forward.

Beyond work in the 3GPP, national governments will have an extremely large role to play on the spectrum availability front. To date, a growing number of governments are being proactive in addressing the need for spectrum allocations to support private wireless networks.
Where governments have been proactive, the market has seen some of the greatest early private wireless momentum. For example, in Germany, where the government has made private wireless licenses available to the private sector at highly competitive prices, there has been substantial early work on private wireless. Other governments have taken a less direct approach, such as the United States where groups like the CBRS Alliance have been at the forefront of designing schemes that will enable a variety of public and private sector customers to gain access to spectrum for specialized (i.e., private) wireless network implementations. While these two examples are among the more high-profile activities, governments throughout Europe and industrialized countries in the Asia-Pacific region are all undertaking initiatives to make spectrum available for private wireless adoption.

mmWave Developments

One key to delivering on the capacity and density requirements to meet the varied requirements of private wireless networks will be the ability to deploy millimeter wave (mmWave) technology. With very short wavelengths, mmWave transmissions can not only support connections to a high number of devices in a relatively small cell, but also support the throughput requirements to deliver on the URLLC needs of many industrial automation, immersive experience, and autonomous guided vehicle (AGV) use cases that private wireless networks will be expected to meet. However, while mmWave technology has been used for many years for military and civil engineering purposes, building out the infrastructure required to support mmWave transmissions on a massive scale will take years.

To this end, expect mmWave technology applications and infrastructure build-outs to continue for most, if not the remainder of the decade.

Edge Cloud and Edge Compute Considerations

Not an explicit requirement for private wireless networking, the edge cloud concept will nevertheless be a key consideration in private wireless projects. A wireless network can enable network access, and facilitate communications between devices. However, in order to process the mountains of data that will be generated by sensors, analytics platforms, robots and other devices, very low latency cloud access is a must. To enable these hyper-fast round-trips, data cannot always be expected to travel to and from cloud data centers. The cloud must reside close, if not adjacent, to the places where data is being generated. Here is where cloud providers have a key role to play in the 5G, and by extension, the private wireless network ecosystem. As outlined above, the 3GPP, through work with ETSI, has specific standards for implementing edge compute. This can enable the communications network to assign compute capabilities closer to the user to increase compute efficiency, reduce latency, and manage the load on the communications network. Additional considerations for edge compute include data sovereignty and security, reduced backhaul (bandwidth/reliability) demands and dependencies, and the capability to better architect a deterministic system for supporting the network functions and applications.

One important strategic planning assumption that entities looking to leverage 5G must consider is: “Where exactly is the edge?” Truthfully, there is no clear demarcation point. In reality, the edge resides wherever compute resources are required to make a massive IoT, industrial automation, AR/VR, or any other URLLC use case work properly. On a practical level, this will require substantial cooperation between CSPs, network equipment suppliers, cloud providers, and private wireless network customers. However, because edge cloud has many more applications beyond enabling the use cases that will run over a private wireless network, expect these progress on this front to evolve somewhat independent of work on private wireless network. At the same time, expect edge cloud planning to be a key consideration of almost any private wireless project.

Fronthaul/Backhaul

Some of the correlated considerations in 5G and edge cloud deployments include the strategies for enabling high-speed fronthaul and backhaul transmissions between radio access networks and mobile core and cloud facilities. In public wireless network deployments, backhaul (and now fronthaul) considerations are a foundational planning assumption.

However, this area represents an often overlooked requirement when enterprises or some other entity consider a private wireless networking project. While this requirement/hurdle can be overcome, it can often represent a substantial cost that must be factored into any ROI model for a private wireless network project.

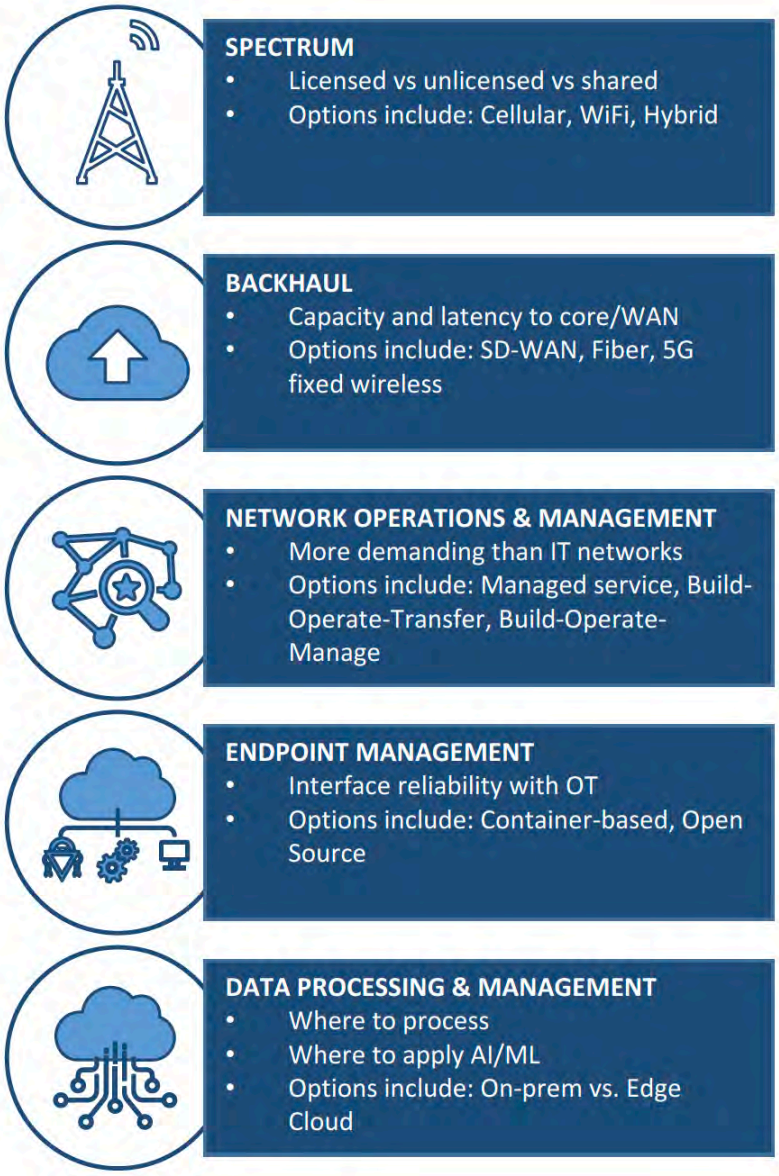
4. Private Wireless Adoption Trends

As pointed out above, sources from consultancies to network equipment suppliers claim that hundreds of private wireless network projects are currently underway worldwide. Of course, this is a far cry from the addressable market of millions of potential candidates in the form of large enterprises, municipal governments, utilities, universities, and other entities. In the previous section, we outlined key technology trends that will influence the pace at which this market develops. Now, we turn our attention to some of the more practical business concerns that the potential consumers of private wireless technology face when considering adoption.

One of the most obvious impediments facing private wireless adoption is the wide range of transformation initiatives that technology and finance leaders must consider. The majority of IT budgets in most companies are earmarked each year for “keep the lights on” projects; in other words, projects that keep a business, or other entity, operating in its current state. Next, even in cases where the entity has carved out an “innovation budget” for projects aimed at supporting digital transformation efforts, there are generally dozens, if not more, projects that compete for pieces of this budget at any given time. To this end, one way to look at the likelihood of private wireless network adoption is through the lens of the ROI it can generate for the entity.

Network Requirements and Challenges

As outlined above, there are many technology development avenues to watch for signs that the private wireless network market is maturing. Many of these development tracks map directly into ROI considerations that enterprises and other entities must weigh before embarking on a private wireless network project. The figure below outlines the primary investments that building a private wireless network requires. It further highlights some of the high level challenges that must be overcome, and options for addressing the challenges.



Spectrum, backhaul, and data processing (i.e., edge cloud) are all important factors that impact ROI calculations when considering a private wireless network project. Two additional areas that also have material impact on a project's ROI have to do with managing endpoints, and managing the network once it is built.

Endpoint management can be particularly challenging when those endpoints consist of legacy operational technology (OT) that must interface with the wireless network as part of a larger IoT system. In an industrial setting, legacy OT, while oftentimes expensive and unwieldy to maintain, is often delivering positive ROI. In addition, where the OT is involved in managing processes that could stop production or harm product output if it goes down, companies can be reluctant to trade the known reliability of older tech for the risk of newer, possibly unproven controls.

While businesses of all sizes generally have decades of experience in managing IT networks, few have experience managing telecom networks. As such, a major consideration outside the cost to build a private wireless network is the cost to operate, manage, and maintain the network upon completion. Here is where CSPs and specialty firms have a potentially important role to play. Offering to provide network operations, administration and management (OA&M) as a managed service – or some other arrangement such as Build-Operate-Manage (BOM) or Build-Operate-Transfer (BOT) – can help to fill a critical knowledge gap that many potential private wireless network customers have.

Example Projects

Out of the hundreds of private wireless network projects claimed in the market, there are relatively few public examples to look to for guidance. At this point, many of the projects are concentrating on building networks based on a mix of 4G/LTE and WiFi. Most of these examples have ambitions to add in 5G capabilities to complete the value proposition. However, at this point, in researching what capabilities are currently in production, Lufthansa (highlighted below) is one of the few that is publicly pointing to substantial use of 5G technology in its current private wireless network.

While it might be possible to comment on dozens of project examples, the three presented below (BASF, Lufthansa, and John Deere) were chosen because they provide a glimpse at an array of the most commonly cited use cases that make private wireless networks an attractive investment option vis-à-vis the many competing project initiatives facing most companies/ entities today.

BASF

The German chemical manufacturer began planning a private LTE network in 2019 with the goal of building a network capable of managing large AGVs that transport chemicals around its 10 km2 Ludwigshafen campus. The company also has said that it can enable increased worker productivity via tablet workstations and augmented reality that can be accessed throughout the campus.

Since operationalizing the network in 2020, the company has expanded the scope of its private wireless network ambitions and is now piloting 5G capabilities with DT and Nokia serving as key partners. Nokia notes that BASF has deployed a full dual redundant 4.9G (LTE) private wireless network for one of its facilities and that this is the most advanced project running real applications and real operations. The 5G private wireless networks in the other sites are mostly trials and PoCs. Interestingly, Nokia told us that a full ecosystem to support 5G private wireless is still “three to six years” away.

In late 2020, the company expanded its plans to include a private 5G network at a 250-acre complex in Spain. While the project is still ramping up, early information released about the project does help to underscore the need to enlist an ecosystem of partners to facilitate the project. For the Spanish network project, BASF’s partners include:

- Cellnex (infrastructure and services company) as prime integrator
- Masmovil (mobile network operator) for spectrum licenses
- Nokia for the 5G networking equipment
- Lenovo and Nearby Computing (Spanish technology integrator) for edge computing capabilities

Lufthansa

In 2020, Nokia announced that it has completed the deployment of a private 5G network for Lufthansa Technik that will allow the company to use augmented and virtual reality to provide completed cabin visualizations to technicians, which will help them to optimize wiring configurations and other pre-fab component placement. In addition, the company is using 5G to create a "Virtual Table Inspection" project, which according to Nokia, will enable customers to be "guided through the engine shop using a third-party mobile device that provides real-time, high-resolution video streaming with mechanics and engineers. This will allow virtual inspection of dismantled parts enabling joint decision-making about inspected components."

Interestingly, while Lufthansa's adoption strategy was developed well before the Covid-19 pandemic materialized, once it did the company found that the newly operationalized private wireless network played an important role in helping its business adjust to the challenges of doing business in the midst of the pandemic. In an interview with the online news journal, Enterprise IoT Insights, Claudius Noack, IT consultant at Lufthansa Industry Solutions said that the company's 5G-enabled private network helped the airline to do engine inspections remotely when Covid-19 severely curtailed the ability to have a full complement of staff onsite. According to Noack, "If we had not set up that network, we would not have been able to do any engine inspections at all. So, really, 5G kept my business alive – that is the business case."

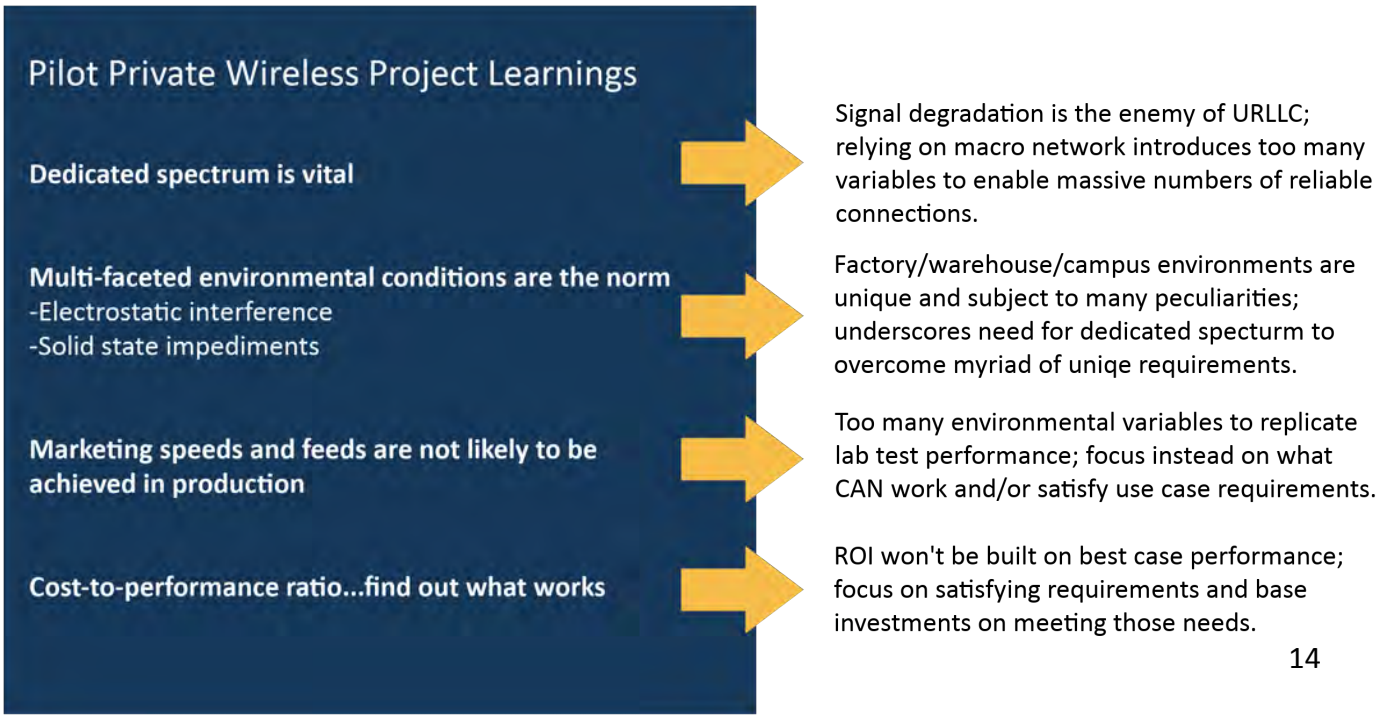
John Deere

In late 2020, the American farm equipment manufacturer purchased five CBRS licenses with the idea of building a private 5G network that can help with asset tracking, inventory management, and more efficient R&D activities. While all of these tasks can be accomplished now via wired connections, the ability to connect factories that are often located in rural areas is expensive, time-consuming, and very difficult to reconfigure once in place. The company believes 5G enabled by private networks will allow John Deere to design a more flexible, nimble and connected facility, creating opportunity for further advancement and greater efficiency that will transform the manufacturing process.

Aside from the factory automation use cases described above, private wireless networks can add value to a variety of use cases that are outside the walls of a factory setting. For years, this company has used GPS-directed tractors that can steer the vehicles to enable very precise seed planting. According to company marketing materials, a single John Deere tractor and planter can precisely plant more than 700 corn seeds and 2,800 soybean seeds every second. However, using 4G/LTE connectivity available from public wireless networks has its limits. Even though planting can be made more precise via GPS, tractors must still be manned. However, with the combination of 5G and edge computing technologies, John Deere believes that it can enable fully autonomous farm equipment that does not need to be manned. In turn, this will free up John Deer customers to reclaim hours of time each day spent in tractors to focus on higher value activities.

Pilot Project Feedback

As with any nascent technology, early project feedback is extremely important to moving the market forward. In terms of early private wireless project learnings, a number of points stand out. Figure 4 summarizes major feedback themes from project leaders at companies that have undertaken private wireless projects to date. If a major theme emerges from the feedback gleaned from early pilot project experience, it is that private wireless customers should avoid becoming enamored with the performance claims made in CSP and equipment supplier marketing. In most production networks – be it a telecom network or an IT network - the claims made on any test conducted in a controlled environment will not match real-world deployment performance. While this phenomenon is well understood among networking professionals, it becomes particularly salient when considering private wireless networks.



On one hand, many use cases can perform adequately without reaching theoretical (i.e., advertised) best-case performance. In these instances, the advice given by those that have undertaken private wireless projects is to focus on what performance level is adequate to make the use case work. On the other hand, for use cases where highly precise performance is necessary (such as when a few centimeters of remote control variance can mean the difference between a robot performing a task successfully and injuring a human co-worker), focusing on overcoming obstacles such as signal propagation in a given environment or deploying robust edge compute capabilities should be the objective.

5. Key Players to Watch

Unlike previous wireless generations where the market has been dominated by two classes of players – network equipment suppliers and CSPs – the private wireless market is a large and varied ecosystem that now also includes many cloud operators offering specialized services such as data analytics. This ecosystem includes the two aforementioned groups, as well as edge cloud providers, professional services companies, and the potential to include ancillary players such as satellite companies, real-estate firms, and IoT specialists.

Communication Service Providers

Perpetually under threat of becoming "just pipe providers" by each successive broadband technology generation, it would seem that CSPs could be particularly vulnerable to succumbing to this prediction at the proverbial hands of private wireless. But it's also a new opportunity. The story goes like this:

- As licensed and unlicensed spectrum becomes increasing available to private network owners, enterprises, et. al. have less of a requirement to use CSP networks for their wireless network needs.
- With cloud providers becoming more active in offering edge cloud offerings, enterprises, et. al. have less need to rely on CSPs to provide edge compute options.
- As network equipment providers take aim at growing their presence in the enterprise by selling wireless networking gear directly to private wireless customers, these customers have less need to buy wireless services from CSPs.
- Alternative carriers, such as the Rakuten/Ligato Networks partnership, cropping up to build private wireless platforms, enterprises, et. al. may find better alternatives for the very bread and butter services that CSPs offer.

That said, despite a mountain of "ifs" facing CSPs in the private wireless space, they retain key assets such as spectrum and large customer bases and they are strongly positioned as a critical player in most any "carrier-grade" private wireless ecosystem play. Although all of the threats listed above could materialize to varying degrees, none of the alternative players mentioned above has the amount of experience in building, operating, and maintaining wireless networks that CSPs possess. Many enterprises have expressed the need for strong operator integrator partners. The importance of this fact cannot be overstated when considering the rigid parameters that must be met to meeting the requirements of so many use cases that depend on URLLC-type network performance.

To this end, CSPs are playing a prominent role in most publicly announced private wireless deals to date. The early signs indicate a trend toward increased partnerships among the cloud operators and services providers, with the business leaders tasks with working out commercial arrangements that benefit both sides. Expect this trend to continue as more private wireless network projects get announced; especially ones undertaken by Global 500-scale enterprises, major utilities, large universities, and government/municipalities.

Key players in this space include virtually every major national wireless operator in the world (e.g., **AT&T**, **Verizon, T-Mobile** (USA), **Vodafone** (EMEA), **Telefonica** (Europe/CALA), **DT** (Germany/Europe), **Telstra** (Australia), **China Mobile** (PRC), etc.

Network Equipment Suppliers

When citing equipment suppliers as a key ecosystem player in the private wireless market, it should be noted that this refers primarily to the "Big 3" telecom equipment manufacturers — **Ericsson**, **Huawei** and **Nokia** (with **ZTE** and **Samsung** rounding out the top 5) — but there is also a strong group alternative providers and startups using open and cloud-native technologies to help address needs, shunning the traditional approach of vertically integrated systems.

The Big 3 players are well positioned, but emerging ecosystems being formed by the cloud operators also need to be watched. The reasons that a customer might favor the "Big 3" is that they have large body of experience selling and integrating the equipment needed to build the network(s). Similar to CSPs, most publicly announced private wireless projects to date have prominently featured one of the Big 3 as a key partner. However, in unlicensed environments, there is a new opportunity in prem-based deployments to deliver economical approaches using disaggregated systems, including lightweight cores and open RANs.

In addition, private wireless networks offer opportunities to drive integration with enterprise systems. Some of the equipment suppliers that stand to benefit from a boom in private network projects include WiFi players such as **Cisco**, **HPE (Aruba), Extreme Networks**, and **Cambium Networks**. Having strong WiFi assets is important, because WiFi 6 will be a part of many private wireless network plans, which has already been spotted by some players. For example, **Ericsson**'s recent acquisition of Cradlepoint has potential to blend Ericsson's traditional RAN and CSP expertise with Cradlepoint's targeted enterprise wireless (including 5G and WiFi) and cloud software offerings. Similarly, Open RAN (ORAN) and virtual EPC (vEPC) vendors such as **Altiostar**, **Celona, Parallel Wireless**, **Mavenir**, and **Quortus** could find opportunity with customers looking to exploit cost advantages promised by open architecture models.

Finally, telecom software providers, such as **Amdocs**, **Netcracker**, and a number of smaller players could also stand to gain from a proliferation of private wireless networks, particularly as they have a role to play in helping to orchestrate interactions between private wireless networks and IT/OT systems.

Edge Cloud Providers

Edge cloud providers have always had a strong claim to being a primary IoT ecosystem provider and they have recently increased their influence. As IoT system requirements become increasingly reliant on AI and other automation technologies to enable concepts such as autonomous driving, smart infrastructure, etc. the ability to tap into cloud resources at the edge (i.e., wherever compute is required) will be critical. To this end, the role that edge cloud providers have in the private wireless ecosystem is similarly straightforward. If one big driver of private wireless is IoT-enabled industrial automation, the same need for edge computing is present.

Arguably, the most obvious sign of commitment to the private wireless market by a cloud provider has recently come from Microsoft. In the first half of 2020, the company announced the acquisitions of Affirmed Networks and Metaswitch Networks, both key players in delivering cloud-native functions to communications networks. The company says the acquisitions are intended to help make Azure Edge Cloud meet the needs of its large telecom partners such as AT&T. Microsoft has been very aggressive about forging the relationships to build a more robust cloud-based ecosystem for the communications market, including the many partners involved in the Azure Edge Stack. The Metaswitch technology is best positioned for helping the private wireless edge, giving Microsoft some core technologies and capabilities in lightweight cloud native network functions built using efficient microservices methodologies.

The other cloud operators, including **Amazon** and **Google,** are active as well, having beefed up their telecom teams. In terms of ecosystem development, partnership announcements made in Q1 2021 (such as Nokia's March 15, 2021 press release barrage featuring AWS, Google, and Microsoft) between network equipment providers and cloud providers signal that key suppliers in the private wireless ecosystem are formalizing collaboration efforts needed to deliver on the full promise that 5G and edge cloud-enabled private wireless networks can deliver.

Other leading edge cloud technology providers are "household names" and include: **Alibaba**, **IBM (Red Hat)**, **HPE**, **Dell,** and **VMware.** VMware, already a leader with Red Hat in CSP virtualization platforms, has been adding functionality and integration to its software-defined wide-area networking (SD-WAN) platform VeloCloud, seeing SD-WAN endpoints as a key piece of the wireless edge strategy. Likewise, HPE's Aruba division has become the home of recent HPE acquisition Silver Peak, which offers a high-powered blend of Aruba's enterprise wireless and security offerings which are being integrated with Silver Peak SD-WAN. Amazon is building Outposts as an on-premises extension of its public cloud services, providing a fully managed service that offers the same AWS infrastructure, AWS services, APIs, and tools to any datacenter, co-location space, or on-premises facility for a truly consistent hybrid experience.

Professional Services

Technology integrators have a potentially important role to play in managing the ecosystem complexity involved in build out a private wireless network. While most large network equipment suppliers offer network integration and other professional services (this list includes each of the Big 3, Amdocs, Netcracker to name a few), the choice of prime integrator can be as unique as the potential number of private wireless networks.

The value prop for a third-party integrator for private wireless networks is similar to the value prop for any network integration project: "single throat to choke" project management, unbiased input into technology selection, and experience with similar projects across a range of use cases, requirements, company operating models, and geographies.

6. Conclusion — Where to From Here?

Opinions on the potential for private wireless networks can differ according to a number of vectors, including size by technology, size by geography, size by vertical market, etc. However, as cited above, various top line estimates seem to peg the global opportunity at approximately $70-85 billion by 2025. Regardless of the pace at which LTE gives way to 5G, this equates to an exponential increase in private wireless projects over the next five years.

Aside from big growth numbers, however, there are a few key points to keep in mind when thinking about the near-term future of this market. These points are summarized below.

- **Enterprise technology planners see the value in private wireless.** Evident by quotes from company representatives in private wireless project press releases, large companies see private wireless as a key, if not indispensable, factor in enabling large-scale industrial automation projects. In many cases, the number of varied network requirements to support massive IoT, immersive experiences, distributed workforces, autonomous vehicles and many other applications are such that relying on CSP-supplied public wireless networks will be insufficient. Beyond the headlines, conversations with enterprise technologists in preparation for this report echoed many of the same sentiments quoted in private wireless project announcements. This holds true across the range of industries highlighted in this report.

- **Spectrum and ecosystem support are key.** With a wide range of desired use cases already established, many deployments will come down the availability of spectrum, which varies widely throughout the globe. In North America, government efforts to promote unlicensed spectrum such as CBRS is promising and could accelerate private wireless adoption. Another factor will be the maturity of the ecosystem, with private wireless creating a unique blend of technology assets from the CSP, cloud operator, and enterprise technology space. Futuriom sees major efforts by cloud providers such as Microsoft to become trusted providers of integrated private wireless technology stacks as a positive development in the market.

- **Enterprise technology buyers are concerned about near-term 5G availability and private wireless project economics.** Even as CTOs, CIOs, and other technology strategists are bullish on the potential of private wireless as an important digital transformation enabler, CFOs are worried about how to pay for it. Private wireless networks are expensive propositions that often do not directly build on previous technology modernization investments. To this end, for companies that are constantly weighing technology investments in terms of potential

near-term impact on quarterly results, private wireless initiatives will face an uphill battle in some camps within large enterprises. To overcome this sobering reality, some private wireless projects are being undertaken in a consortium manner that involve an anchor company, a municipality with a stake in promoting itself as a digital hub, and other stakeholders such as national CSPs that are looking for project experience and proof points to support future growth. As interest in private wireless grows, expect to see increasingly creative commercial partnerships engaged to help make the economics work.

- **Private wireless networks are a matter of "when," not "if."** Despite material financial and operational challenges associated with building and operating a private wireless network, it is nearly impossible to imagine a vision for a fully connected society without private wireless networks. As digital society use cases come closer to fruition, CSP networks are unlikely to be able to meet the massive connectivity needs of all networking requirements. In the near term, private wireless network momentum will be constrained by the pace of commercial 5G network roll-outs. However, as 5G technology becomes more mature and widespread, private wireless networks based on 5G will become increasingly attainable. To this end, pay attention to the technology development factors outlined in the opening sections of this paper and predicting the pace of private wireless adoption will be more akin to a map reading exercise than crystal ball-gazing.