PRIVATE WIRELESS MARKET

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ABSTRACT

Industry 4.0 operations enable you to fuse physical and digital processes by connecting everything from vehicles to sensors and mobile workers in the most flexible, affordable, secure and reliable way. By digitalizing operations, enterprises can easily transform data into insights and become more agile and proactive. To meet the requirements of AI, machine learning and automation, industries need highly reliable, low latency and secure wireless connectivity with high bandwidth. 4.9G/LTE and 5G industrial-grade private wireless net-works are the only wireless solutions available that have proven records to meet the demands of Industry 4.0 mission- and business-critical applications. They provide robust, secure and reliable connectivity for everything that is critical to your operations, from people and machines to sensors and analytics. Radio access points provide coverage of your outdoor and indoor spaces, similar to Wi-Fi, but you will need far fewer. Unlike Wi-Fi, there is a core network, which is the key to enabling mobility, ensuring security and maintaining quality-of-service parameters. The backhaul network is no different than what you would use to connect Wi-Fi access points, whether cabled Ethernet, passive optical LAN and/or microwave depending on the application and the distances served.

KEYWORDS: *Internet of things, Bluetooth Low Energy, Home Automation System, Android, Lightning System, Arduino.*

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Carlijn Williams *– Head of Marketing for Nokia's Enterprise Solutions business. She talks about how (5G) private wireless networks and solutions like edge cloud, devices and applications continue to change vertical industries. She gives insight in how industries can succeed in their digital transformation by using low latency, high bandwidth mission-critical communication networks. She believes topics like Automation, Security and AI-driven applications are vital to accelerate Industry 4.0. Dutch born, Carlijn holds a degree in Economics and Communications and lives in the UK.*

INTRODUCTION

Industry 4.0 operations enable you to fuse physical and digital processes by connecting everything from vehicles to sensors and mobile workers in the most flexible, affordable, secure and reliable way. By digitalizing operations, enterprises can easily transform data into insights and become more agile and proactive.

These highly collaborative, hybrid work environments and real-time responses are enabled by remote and autonomous technologies and advanced intelligence:

- a mission-critical private 4.9G/LTE or 5G wireless network that can help you digitalize your operational technology (OT) systems to make them infinitely more agile and resilient;
- a complementary Wi-Fi layer that can provide reliable connectivity for IT systems and non-business-critical OT use cases;
- an industrial edge that can unify industrial OT use cases and enable you to securely process your data on your premises;
- industrial devices that can enhance connectivity at any site and help you improve worker communication, productivity and safety;
- industrial applications that can cut through complexity and help accelerate your digital transformation.

4.9G/LTE and 5G are providing the next generation of private wireless networks for our connected world, supporting automation, safety, security and new levels of quality, efficiency and productivity.

To meet the requirements of AI, machine learning and automation, industries need highly reliable, low latency and secure wireless connectivity with high bandwidth. 4.9G/LTE and 5G industrial-grade private wireless networks are the only wireless solutions available that have proven records to meet the demands of Industry 4.0 mission- and business-critical applications. They provide robust, secure and reliable connectivity for everything that is critical to your operations, from people and machines to sensors and analytics.

Deploying the Nokia private wireless solution isn't much different than a Wi-Fi network, but there are a few extras to consider.

Radio access points provide coverage of your outdoor and indoor spaces, similar to Wi-Fi, but you will need far fewer. Unlike Wi-Fi, there is a core network, which is the key to enabling mobility, ensuring security and maintaining quality-of-service parameters. Depending on the size of your site, it can even run on a small desktop-sized edge server deployed in a server room.

The backhaul network is no different than what you would use to connect Wi-Fi access points, whether cabled Ethernet, passive optical LAN and/or microwave depending on the application and the distances served.

For most mission- and business-critical industrial applications, the Nokia private wireless network solution is the most cost-efficient compared to other wireless solutions.

Private wireless requires far fewer access points than other wireless solutions to cover the same area, which means less supporting infrastructure as well (power, cabling, poles, etc.). Engineering and planning the radio coverage is also much less expensive because of the characteristics of the radio spectrum used. Finally, you can consolidate all your current networks on a single 4.9G/LTE or 5G network, for significant operational cost savings.

Nokia has recognized that enterprise needs vary, thus we have two private versions of our industrial-grade private wireless solution. The Nokia Digital Automation Cloud (DAC) provides an integrated plug-and-play private wireless service solution and a digital automation platform with ready-to-run applications. Modular Private Wireless (MPW) solution offers all the elements needed to create a bespoke private wireless solution that is either completely autonomous or in a variety of hybrid configurations with third-party providers such as mobile operators.

Private wireless spectrum for industrial use is now available in many countries, and this is expected to grow. Many governments around the world are releasing spectrum specially designated for private networks. In Britain, Germany and Japan, private spectrum is only available for 5G, elsewhere it is also available for 4.9G/LTE. In the US, the CBRS initiative by the FCC, is based on spectrum that is shared with other organizations. The unique sharing schema is likely to be copied by other countries [1-6].

For those countries that don't have dedicated private spectrum for industry, there are many other solutions. Nokia has a range of CSP partners willing to lease spectrum (and you can ask your favorite CSP if they offer Nokia private wireless solutions). Finally, you can even deploy a private solution in the 5.x GHz unlicensed spectrum range with Multefire™, which provides a standardized LTE-based unlicensed technology and is available from Nokia. Private wireless based on trusted 4.9G/LTE can support almost all industrial use cases today and benefits from a large ecosystem of industrial devices, sensors and compatible systems.

For a few countries, licensed private spectrum is only available for 5G, otherwise 4.9G/LTE is the preferred choice at this time. It has a very developed industrial device ecosystem, with over 6,800 LTE-enabled non-phone-form-factor devices, and many industrial systems come with built-in 4.9G/LTE modems. Private wireless networks based on 4.9G/LTE will support 85% of industrial use cases. It gives you a competitive advantage, as you can start your Industry 4.0 transformation today. You will be able to easily add 5G when the 5G industrial ecosystem has matured.

NOT ALL PRIVATE WIRELESS SOLUTIONS ARE CREATED EQUAL

Given the very tight standards that 3GPP sets for 4.9G/LTE or 5G, it might be easy to assume that all solutions conforming to those standards are roughly equal when it comes to providing highly available and reliable wireless connectivity. But, as they say, the devil is in the

details. Conforming to the standard is only the beginning. How the components and solution architecture are executed can make for very unequal results.

HIGH AVAILABILITY

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High availability in the range of, or above, 99.95% is typically expected for systems supporting mission- and business-critical use cases, and it is something that many of the leading private wireless solutions can support. If well designed for the site where they are deployed, private wireless that uses 3GPP standard technologies, can meet or even exceed such requirements. Typical features of these systems include multiple layers of redundancy in the core (hardware and geographic), overlapping coverage of cells, redundant backhaul and transport, hot-software updates, and graceful redundant server switch-over. For edge-based solutions, they also require the ability to support continuous operation, even if losing the WAN connectivity to the cloud or central office location.

When more stringent requirements are required, our private wireless solution capabilities and enterprise design practices at Nokia can beef up the solution by using multiple radio spectrum bands to create multi-layer radio connectivity, geo-spatial separation of redundant small cells, and a third level of redundancy from a public network core or a centralized core at HQ, for example. Today, our Nokia Digital Automation Cloud (DAC) solution, gives us real-time benchmarks on how the customers' networks we are managing are operating. On average we have achieved 99.999% uptime in the last 3 months (including planned but also unplanned downtime). For the most stringent deployments, using either DAC or our Modular Private Wireless solution (MPW) and looking at the hundreds of networks we are operating, we are exceeding 5x9s.

In other words, the missing ingredient in achieving very high availability is the experience of delivering end-to-end solutions for decades, whether private wireless or other critical enterprise networks such as GSM-R, IP-MPLS, microwave and optical. Experience and the right feature set for critical networks are the key ingredients to providing networks.

THE IMPACT OF CRITICAL NETWORK EXPERIENCE

At Nokia, we pride ourselves on being the vendor with the longest experience both in private wireless and running critical networks. We have been delivering mission-critical GSM-R for railway operators for 30 years. And in private wireless, we pioneered the technology and have been leading the industry for nearly 10 years.

This experience means that we understand the requirements of the industry. We know how different a network is in an underground mine versus a factory and how the requirements of various use cases can differ widely. Our many years running critical networks in our focus 12 industrial and government and cities segments have been essential to improving our software across all elements of the solution and ensuring the code is as sturdy as it can be.

In this regard, our deep experience in the telecom sector is also a huge benefit. Many of the components and software that we use in our private wireless solutions are also running on the nationwide public networks of our several hundred mobile operator customers operating around the world. Due to the sheer size of public networks, we must ensure reliability for networks with anywhere from 10 to 100 million subscribers in some of the harshest environments in the world, including deep jungle, sub-Saharan deserts and arctic zones in the north and the south – not to mention the most difficult environment of all, dense metropolitan urban centers. These networks provide mobile connectivity for ever-more-demanding subscribers, but as well, the critical services running on these networks such as public safety and logistics. We know intimately what telco-grade reliability means, and we are leveraging the techniques used there for our private wireless customers, including the continuous software improvements since the early days of 2G, which means our software-code is also well-hardened.

End-to-end is key to total system reliability. It starts with individual elements, how they are assembled and, very importantly, how they all work together. Enterprise customers understand this as they rarely buy operational technology (OT) elements piecemeal for their more complex systems. They historically have relied on trusted system integrators to provide them complete machines or production lines.

Even if some of our solutions are modular and can operate with other supplier's elements, most enterprise prefers to trust a single supplier for their private wireless networks, and for good reason. Nokia private wireless solutions are all pre-integrated and tested to function well together, end to end. This is more impressive when you understand that we have one of the widest portfolios of key elements for private wireless. We provide elements ranging from industrial devices to radios, the backhaul and fronthaul network, the core and edge cloud (including the server hardware), IP-MPLS routing, microwave and optical links, plus operations and maintenance and, finally, the applications running on the network.

These are all pre-tested to work like a swiss-clock. In comparison, many of our competitors would need four to five partners just to assemble such a solution or, in other words, more chances for glitches, requirements for regression testing at every new software release (= downtime)

and, most importantly, the chance for multiple suppliers to pass the blame when things go wrong.

Still, even Nokia needs trusted partners to address every single use case in the market. But the point is that we need less than many others, and we take a systemic approach that we call "Segment Blueprints" to designing private wireless solutions that integrate, for example, specific industrial partners' elements, software, etc.

These blueprints go beyond our end-to-end solution and are created based on our learnings from deployments that we have had in each of the sub-segment we focus on. We create pre-integrated and tested solutions that can tackle the key use cases of each segment with a range of preferred partners assets. These systems go through our Enterprise services labs around the world to be tested and validated to reduce the need for customization and remove unwelcome surprises during deployment and operations. In conclusion, the availability of a private wireless solution is not something to take for granted when choosing a vendor. Experience in designing and running critical network is essential.

NOT ALL PRIVATE WIRELESS SOLUTIONS ARE EQUALLY RELIABLE

After discussing system availability in the last blog, I want to look at the reliability of private wireless connectivity. 3GPP standards are air-tight and deep by nature, but there are still many areas of differentiations when it comes to the implementation, which has a lot of impact on how a private wireless system performs.

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The further we go with the radio technology (5G and 6G), the more the implementation approaches will be critical to achieving the promise of new and even more complex capabilities such as MIMO (massive-input, massive-out radio), uRLLC (ultra-reliable low-latency communications), TSN (time-sensitive networks), and so on.

DIFFERENT TYPES OF CELLS/RADIOS MATTER FOR PRIVATE WIRELESS RELIABILITY

Public networks are reliable by nature but also benefit from additional "elements" of reliability by the fact that they are made of multiple layers of redundant services. In many countries today, you still have 2G and 3G running alongside 4G/LTE and 5G. Within each radio technology, there are also layers of connectivity using two or three separate spectrum bands (e.g., LTE can operate in 800MHz, 1800MHz and 2.6GHz).

Finally, in some urban areas and hot spots, you can even have physically separated layers of the same technology in the same spectrum bands, for instance, LTE/4G macro radios (BTS) running at height in 2600MHz and LTE/4G small cells on the street, also running in 2600MHz. Because today's smartphones can often support all of these standards and bands, if something goes wrong with one layer, you have multiple layers to use as an alternative – in fact, most phones nowadays can connect to multiple layers at the same time to boost performance. Most of today's private wireless networks, in contrast, operate a single technology with a single band of spectrum. Thus, the reliability of this single layer coverage is very critical.

THE IMPACT OF CHOOSING THE WRONG TYPE OF RADIO FOR PRIVATE WIRELESS

For CSPs to provide basic coverage in houses, small shops and in small- to medium-size businesses, a new type of small cell was invented in 2005 called the Femtocell. Compared to traditional small cells that are macro BTSs shrunk in size with a less powerful radio (lower coverage), but the same features and capacity, Femtocells are even smaller radio access points with a minimum set of features and capabilities designed to provide cellular connectivity to just a few people in small and not very challenging radio environments. They need to be very cost effective for the business model to work, which means a much more relaxed approach to reliability, availability, and performance. Because of the layering in the public mobile network, if a Femto goes down, you will probably still be able to connect to another layer of the public network. And even if you cannot, the failure of the Femto only affects a few people for a short amount of time and, most of the time, not for critical use cases.

Femtocells are great, but only when used for the use cases for which they were created. Outside their "comfort zone" – the multi-layered public mobile network— they lack the performance and reliability, for example, that would be required by a typical Industry 4.0 application. This is similar to Wi-Fi – a great technology designed for IT needs, but rarely fit for OT needs. Today, there are many of these Femtocell (or cheap small cells) all-in-one chipsets available from chipset vendors.

These vendors not only provide the reference design but also the baseline software stack. It means virtually any company, even not a radio expert, can work with a contract manufacturer to rapidly build a range of private wireless radios based on these chipsets and baseline software. This is what is fueling the explosion in the market of many smaller players, start-ups or established 3GPP core companies, suddenly coming up with their own radio portfolio.

The problem is that these companies (often coming from the core side or even Wi-Fi side) lack the experience of running telco-grade 3GPP networks; meaning, they underestimate the importance of good radios. They do not necessarily understand the difference between a Femtocell and a real macro-parity small cell. The impact on private wireless performance and reliability can be dramatic.

TELCO-GRADE SMALL CELLS AND RADIOS

Nokia has over 30 years' experience creating and running telco-grade radio cells that reliably support hundreds and even thousands of simultaneous connections in the field, despite the difficult radio environments they operate in. The Nokia Flexi Zone all-in-one small cell range, which is built using the same purpose-built chipsets as our macro cells, can support transmission with up to 840 simultaneous users.

Our other telco competitors' all-in-one small cells, using off-the-shelf small cell chipsets, are already more in the range of 64-128 simultaneous users. And the smaller vendors, using off-the-shelf Femtocell chipsets, are often closer to 16-32 simultaneous users, which often isn't enough considering all the systems, assets, sensors and people that need to be connected in a typical industrial site; the sensor set for a single digitalized legacy machine could eat up the capacity of a single Femto-based cell. In addition, since they lack the processing power to simultaneously serve more users, they are also unable to run the same feature set as real small cells.

THE SCHEDULER AND WHY YOU SHOULD CARE

One of the greatest areas of differentiation when it comes to radio performance is the software and in particular the software for the scheduler, which is the application that manages users or devices connecting to the radio cell. In a nutshell, the better the scheduler, the more simultaneous devices can be served with reliable performance and the better the performance will be when the radio environment gets tough.

Scheduler design and implementation are a key differentiator between the large telco vendors; hence, it is a big R&D investment area and really influences field performance. How many users you can reliably support simultaneously, how much performance you will get in different areas of the cells, how well it manages interference, and even how far and/or deep the coverage goes are heavily influenced by the strength and capabilities of the scheduler.

The scheduler is something that network vendors have spent years developing since the early days of 3GPP technologies, and the oldest telco vendors have over 30 years of experience in developing and perfecting powerful, intelligent and feature-rich schedulers to deliver reliable performance in real conditions.

This deep experience and software intelligence does not come as part of the included reference design and baseline software stack provided with the merchant Femto/small cell chipsets being used by many small cell vendors today. That is why, in challenging radio environments like industrial sites, there is a real-life performance difference, even beyond multi-user capacity, between a good radio and a bad one.

When it comes to Nokia, the scheduler performance has always been one of our strengths; we have plenty of independent public network testing showing the superiority of our scheduler. That is why, when we developed our range of small cells (largely used for private wireless), we decided to do what was needed to have the same scheduler and the same advanced features in our all-in-one Flexi Zone small cells as on our macro cells, so that the performance would not be sub-par. Nokia's small cell performance clearly puts us leagues ahead of other private wireless vendors, and provides a world of difference from the smaller private wireless vendors, whose improvised radio portfolio is based on off-the-shelf Femto/small cell chipsets with baseline software and scheduler.

In conclusion, just as with availability, which I covered in the first blog, the reliable connectivity expected from private wireless is not something to take for granted when choosing a vendor. Meeting the 3GPP standard is no guarantee of actual performance. Look for a vendor that has deep experience designing and running critical networks and, ideally, running public mobile networks. This ensures that their solution will be carrier grade and high performance.

Think about the end-to-end integration and testing they can provide. And don't dismiss the importance of reliable, optimized and feature-rich software that has evolved over decades. The choice of system architecture and the quality of the radio should not be underestimated if you want to meet the critical requirements needed for today and tomorrow's Industry 4.0 applications.

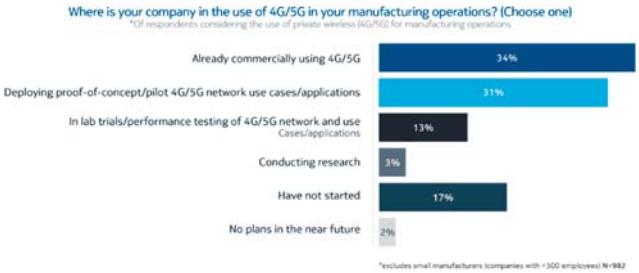
THE STATE OF THE PRIVATE WIRELESS MARKET 2022 FOR INDUSTRY 4.0

Over the last few years private wireless has proven to be the critical enabler to accelerate Industry 4.0. Its reliability, flexibility and mobility enable industries to adopt applications that have increased productivity, efficiency and sustainability. Nokia has led the private wireless revolution from the beginning, establishing the first private wireless network in 2012 with Rio Tinto, launching the world's first 5G SA capable private wireless solution in 2020, and working recently with NASA on their plans to put private wireless on the moon. As the pandemic winds down and we assess the private wireless market in 2022, what are the takeaways?

From the beginning, one of the challenges in developing the market has been to prove the relevance of the technology. Our efforts in the last decade have been about demonstrating capabilities and establishing trust. The good news in 2022 is that for most of the enterprise customers being surveyed, the importance of private wireless is now well established as the prime wireless connectivity solution for reliably connecting OT critical use cases assets.

PRIVATE WIRELESS IS HERE TO STAY

At this year's Mobile World Congress, private wireless was the main topic of the show. Based on research by Omdia – the Private LTE and 5G Network Tracker 1Q22, the top market for private wireless by number of announcements is manufacturing (28%) followed by transport and logistics (15%) and energy and mining (13%). According to Omdia Private LTE and 5G Network Enterprise Survey Insight – 2021 says that 78% of the surveyed enterprises are considering or already using private wireless technology, and 91% of those that are yet to deploy a private network view it as the desired technology for future deployments. When asked, 66% of enterprises expect a full return on their investment within two years.



4G/5G Adoption (Source: ABI Research)

Zooming in on the manufacturing market, 65% of executives say they are already using 4G/5G commercially or are piloting use cases (ABI). Only 2% of the manufacturing respondents said they have no plans to deploy private wireless.

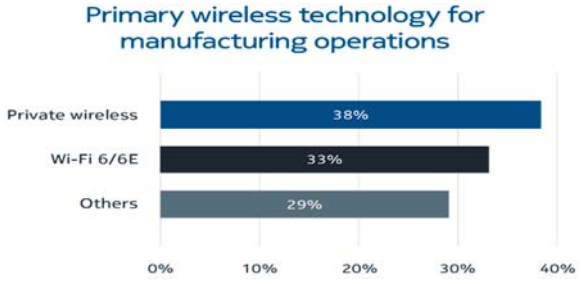
AN INDUSTRY 4.0 PLATFORM ENABLER

Our view of private wireless has always been that it would enable the digitization of physical industries. It is a necessary connectivity layer to support big data, industrial IoT, edge clouds, digital twins and analytics based on AI and machine learning (ML). These Industry 4.0 technologies will make widespread automation possible, allow for greater agility and resilience, and optimize processes within businesses and throughout their supply chains.

A GOOD RELATIONSHIP WITH WI-FI

A key shift we also see this year is the relationship between private networks and Wi-Fi. Private wireless 4.9G/LTE and 5G are enabling new OT applications that require high bandwidth, low latency like video inspection for example. However, Wi-Fi is not going away and there are a lot of industrial brownfield assets that connect via Wi-Fi. Having the right technology mix for the right applications is vital to transform businesses. Where basic connectivity for non-mission critical OT use cases is enough, Wi-Fi will continue to play a vital role.

While private wireless is gaining significant traction in all OT segments and will overtime dominate, currently Wi-Fi and especially the Wi-Fi 6/6E is also perceived as a viable wireless technology for certain non-business critical manufacturing operations. Wi-Fi doesn't require spectrum and can connect many assets that do not need mission critical connectivity. Daily IT applications for example that work in a static environment can be very well served by legacy Wi-FI 5 or Wi-FI 6.



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When it comes to OT use cases, such as important sensors inside machines, powering worker AR solution for critical repairs, remote control of a port cranes, or connection for autonomous mobile robot, private wireless is now seen as the prime solution providing the deep and wide reliable coverage and the predictable performance required to run such applications. Still, between IT and OT critical use cases, there are also less critical OT use cases – such as the plant manager MES access, static part storage solution, deskless worker information systems – that can tolerate variations in datarate and latency, and will not break the OT process if connectivity drops for a few seconds where Wi-Fi 6 and 6E can play a role.

CONCLUSION

2022 looks as if it is the start of the next phase of private wireless, with adoption beginning to climb the S-curve. We're seeing general enterprise acceptance of private wireless as a key technology in realizing Industry 4.0 ambitions [7, 8]. The ecosystem around 4.9G/LTE is there and 5G is developing with many new players becoming involved. End user devices are rapidly being developed and additional spectrum is coming available. It will be interesting to see how private wireless unfolds in 2022.

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