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Industrial-grade private wireless for Industry 4.0 applications

White paper

Industry 4.0 is all about the digital transformation of the physical infrastructure we use to sustainably extract resources, move them to market, manufacture, power, operate and service all aspects of our technological world, including the management of our cities and the well-being of our citizens. A key element in the implementation of Industry 4.0 solutions is the next-generation of network connectivity, 4.9G/LTE today, and 5G, in the future. Current private/enterprise connectivity including CAT cabling and IT-based wireless systems, such as Wi-Fi, will prove insufficient. These systems will need to be supplemented or even fully replaced by more robust, reliable and secure wireless systems. In this paper, we look at these industrial-grade wireless networks and how they will contribute to the realization of Industry 4.0 applications.

Introduction

Digitalization powers industrial automation, increases business efficiencies, improves safety and enhances market agility. Industry 4.0 enables industries to fuse physical with digital processes by connecting all sensors, machines and workers in the most flexible way available. Tethering them to a wired network infrastructure is expensive and, ultimately, it will limit the possible applications of Industry 4.0. Industrial-grade private wireless will unleash its real potential by providing the most flexible and cost-effective way to implement a wide range of Industry 4.0 applications.

Wireless solutions that come from the IT world, such as Wi-Fi, can be adapted to industrial applications but often impose limitations, and they will fail to meet future requirements. They are well adapted to day-to-day business communications but are limited in reliability, security, predictable performance, multi-user capacity and mobility, all features which are required for operational applications that are business- or mission-critical.

If we look at mines, port terminals or airports, for example, Wi-Fi has been tried, but the areas requiring coverage are too vast and the environments too challenging. In both mining and port terminals, they are using remotely operated, autonomous vehicles, such as trucks, cranes and straddle carriers, which require mobile communications and high bandwidth video support. Wi-Fi has no support for mobility and no way to ensure quality of service (QoS) for the video.

In smart manufacturing, there are similar limitations. Wi-Fi signals do not propagate well in many industrial environments where building structures cause interference. Wi-Fi cannot support the mobile requirements of automated guided vehicles (AGVs) or the even some of the faster moving arms of robots. It has no support for the low power requirements of sensors and other IoT devices. And, it cannot support the high density of sensors, devices, robots, workers and vehicles that are operating in the typical manufacturing plant.

Fortunately, 3GPP technologies, such as 4.9G/LTE (and 5G in the near future), are available in configurations perfectly suited to building industrial-strength private wireless networks to support Industry 4.0. They bring the best features of wireless and cable connectivity (CAT cabling, field-bus, etc.) and have proven their capabilities both in large consumer mobile networks as well as in many industrial segments. The time is ripe for many industries to leverage private 4.9G/LTE, especially knowing that it will set them up for an easy evolution to 5G in the future.

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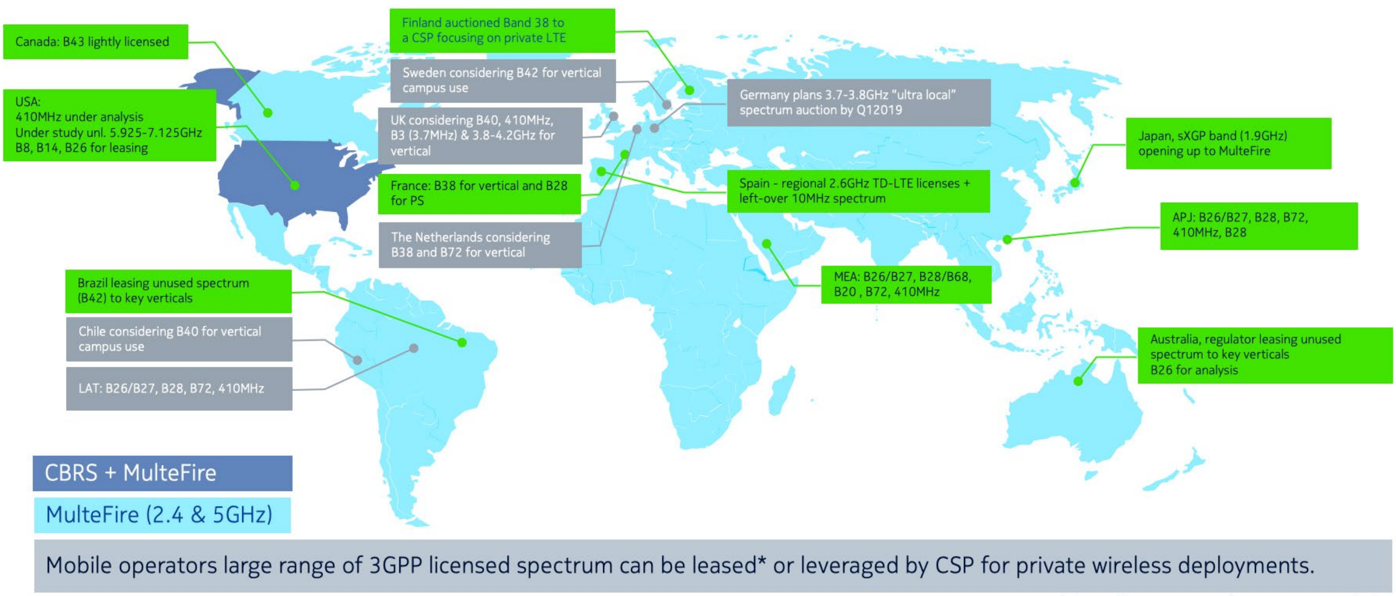
Spectrum options

Until recently, LTE technology was reserved for mobile operators who hold the vast share of LTE radio spectrum. But in response to pressure from industry and as a way to stimulate their country's industrial competitiveness, many governments around the world are releasing new LTE spectrum specially designated for private networks. Mobile operators are also realizing the private LTE opportunity and will lease spectrum for industrial campus use.

Figure 1. A snapshot (mid-2019) of shared, lightly licensed, unlicensed and licensed spectrum for industrial use worldwide.



**depending on country's spectrum regulation*

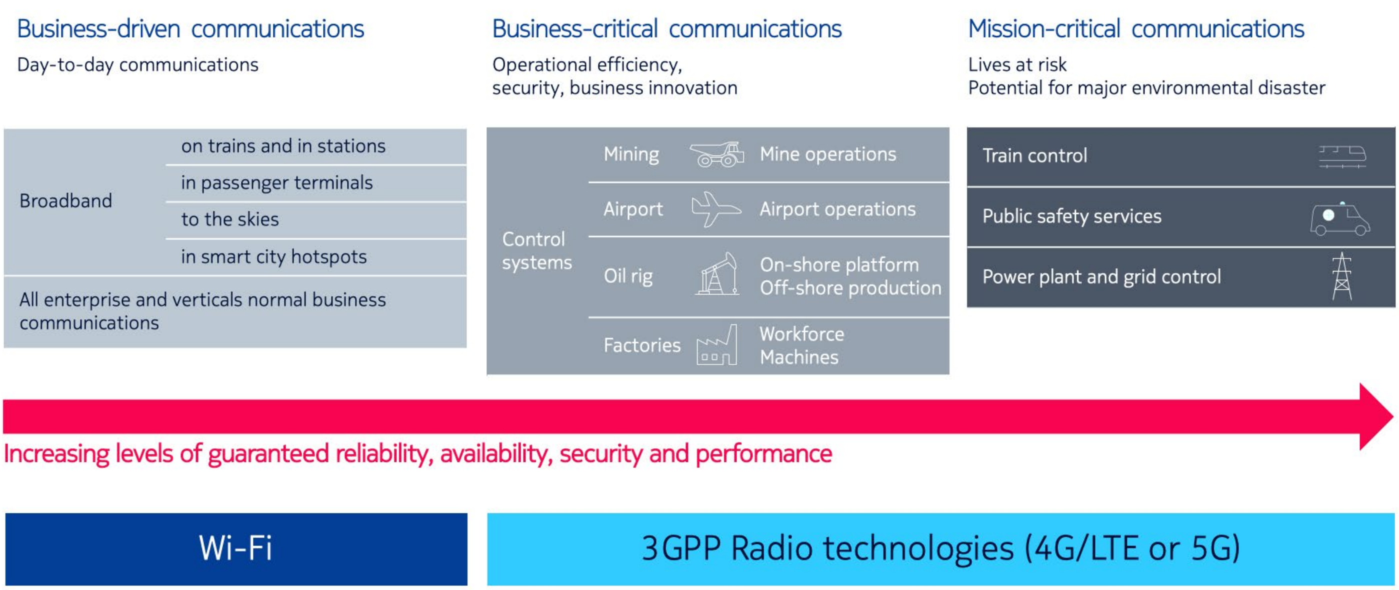
In the United States, the Federal Communications Commission established the shared commercial use of the Citizen Band Radio Service (CBRS) spectrum. CBRS can be implemented by enterprises for stand-alone campus networks, or by mobile operators to offer private LTE as a service to enterprises. Other governments are opening similar spectrum bands for the use of industry. Complementing the availability of new spectrum, flavors of LTE technology have been developed that can also operate in unlicensed or lightly licensed spectrum

One example is MulteFire, which is set to break LTE entirely free from licensed spectrum. The MulteFire specifications are based on 3GPP standards in order to minimize the differences to LTE and add key capabilities that are required for fair coexistence with other technologies in the unlicensed spectrum. This make LTE as simple to deploy as Wi-Fi and means enterprise can deploy private LTE networks without worrying about spectrum. For mobile operators, it means they can offer private LTE networks outside of the countries where they hold spectrum licenses and also create a truly plug-and-play enterprise private LTE offer.

Comparing private LTE to typical enterprise-level access media

Despite the benefits of wireless and mobile technologies and what they could bring in terms of pervasiveness, flexibility, ease and ability to connect anything —even inside machines — most enterprises tend to believe that the service quality, reliability and security needed for business-critical communications can only be achieved using CAT cables.

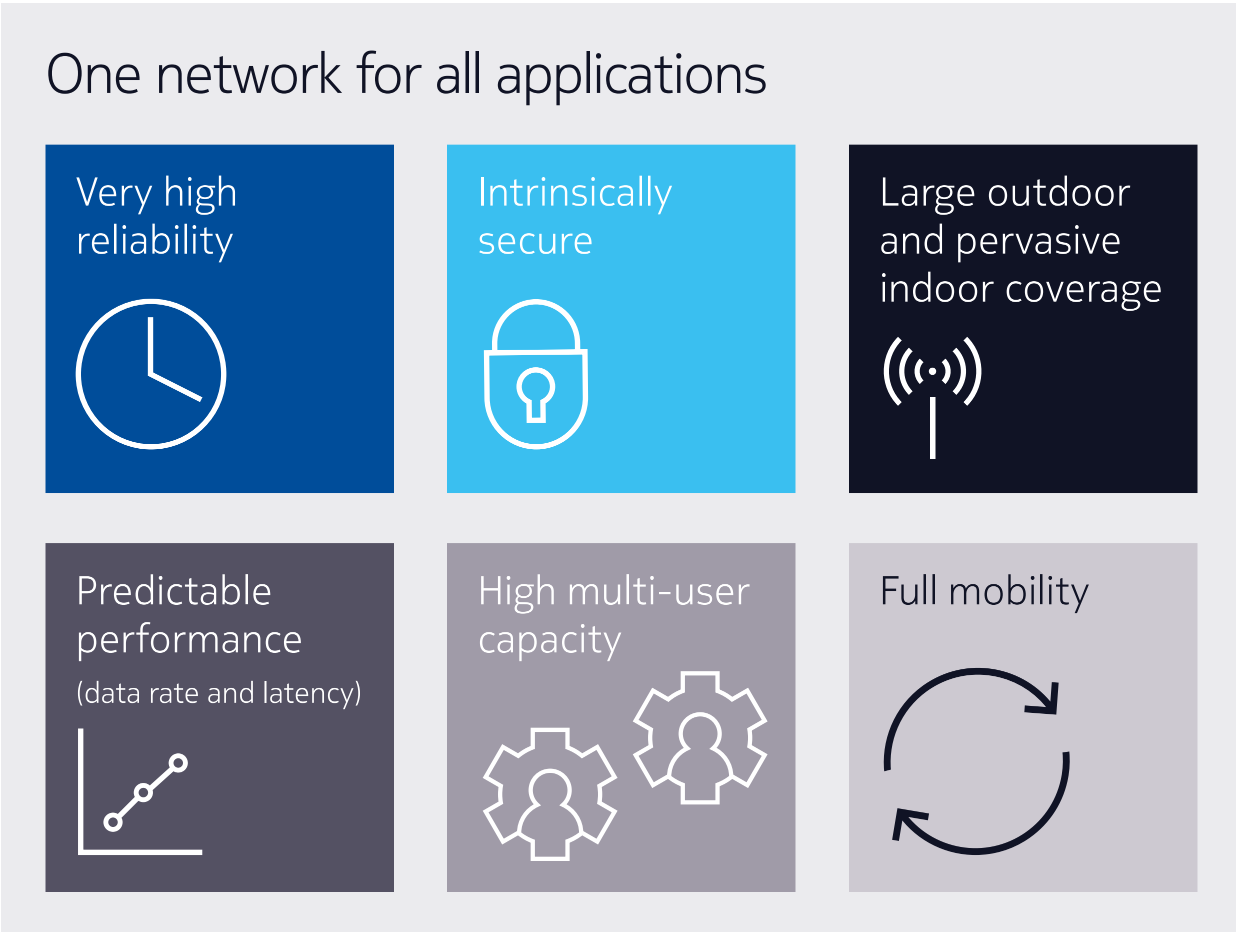
Figure 2. The different levels of criticality in enterprise networking and the capabilities of the two main wireless networking technologies compared.



A secure and contained cable environment, such as a CAT cable or fiber strand, is hard to beat in terms of reliability and security and will continue to be used for many fixed assets in industrial campuses. Nonetheless, 4.9G/LTE, and 5G in the future, are similarly reliable, predictable and secure, and they provide many advantages by being both wireless and mobile. Compared to Wi-Fi, 4.9G/LTE provides the most predictable performance (latency and data rate). It also has the highest multi-user capacity, allowing the connection of hundreds of devices, machines, or workers per access point (referred to as a base transceiver station (BTS) or eNodeB in cellular technology). This enables a very high density of devices in the same area.

Today 4G.9/LTE technology is reliably powering over 4Bn mobile subscribers around the world, with home-like, fixed-line broadband data rates. It has proven its performance in many challenging and tough environments; think, for instance, of the capacity requirement of stadiums with more than 100,000 spectators, or next-generation public safety networks with very stringent security and confidentially requirements. Finally, 4.9G/LTE supports full mobility with hand-over at speeds up to 350km/h, enabling stable connectivity of workers and equipment in the vehicles themselves or autonomous vehicle operation, such as drones, cranes, trucks and automated guided vehicles (AGVs).

Figure 3. The capabilities of 3GPP technologies such as 4G/LTE and 5G.



Many enterprises that have tried using IT-based wireless technologies, such as Wi-Fi, Wi-Fi MESH or even Bluetooth (for shorter distances), for operational critical connectivity rapidly realize their limitations. While, they are perfectly suited for office-type communications and will continue to be used in these applications, they were not designed, nor is their performance suitable, for critical communications.

Security is a key concern with wireless technologies such as Wi-Fi and Bluetooth, which have been shown to be easily hackable. In contrast, 4.9G/LTE and 5G have been designed from the ground up to be secure. They use end-to-end encryption with strong cyphers at the air interface and IPsec for data transport. SIM cards and eSIM ensure that devices have to be configured explicitly to even access the network. No public LTE network has ever been compromised — and this has been rigorously tested by public safety agencies that use LTE for mission-critical emergency communications.

In order for industrial automation to be widely deployed in a manufacturing environment, there must be strict synchronization limits and a high-degree of network reliability for precision processes and work-place safety. Wi-Fi is classified as a “best effort” networking technology, meaning it will do its best but there are no guarantees around quality.

In private LTE deployments, network reliability can equal the most stringent levels of the old telephone system (five nines or 99.999% uptime) — very high predictability. End-to-end latency of private LTE networks tends to be in the 9–15ms range and, in future releases, latency will be 2–8ms. With 5G, it will be less than 1ms.

Besides security and predictability, reach is also a key concern. For industrial automation applications in manufacturing facilities, open pit mines, ports and power utilities, an LTE network can cover areas up to 20,000km^2. Whether in a high ceiling environment (most industrial campuses) or outdoor, the number of LTE cells can be significantly lower than with Wi-Fi. The gain can vary but if we take an open pit mine environment as an example, we have seen cases where 150+ outdoor Wi-Fi access points were replaced by 10 micro BTS small cells to provide much-improved coverage, including inside the key buildings of the mine and a much wider coverage area around the mine.

In addition to supporting high-data-rate, low-latency applications, recent LTE standards define new low-data-rate device classes (LTE-M and NB-IoT). These were specifically designed to address low-data-rate IoT sensors. Due to the reduced complexity and data rates of these devices, the LTE-M and NB-IoT modems can run several years on battery power alone, making deployment of sensors in campuses, or even inside machines, very straight forward.

This is a critical point when looking at the feasibility and ease of adding IoT sensors to your industrial process and workflow. Wi-Fi and Bluetooth impose much higher power requirements on connecting devices and sensors, so either you need to connect them to the grid (a problem if you are trying to add sensors inside an older machine) or use batteries that do not last very long. The ability to connect thousands of workers, devices and sensors per LTE small cell without installing additional wiring can more than offset the upfront investment required for a private LTE network.

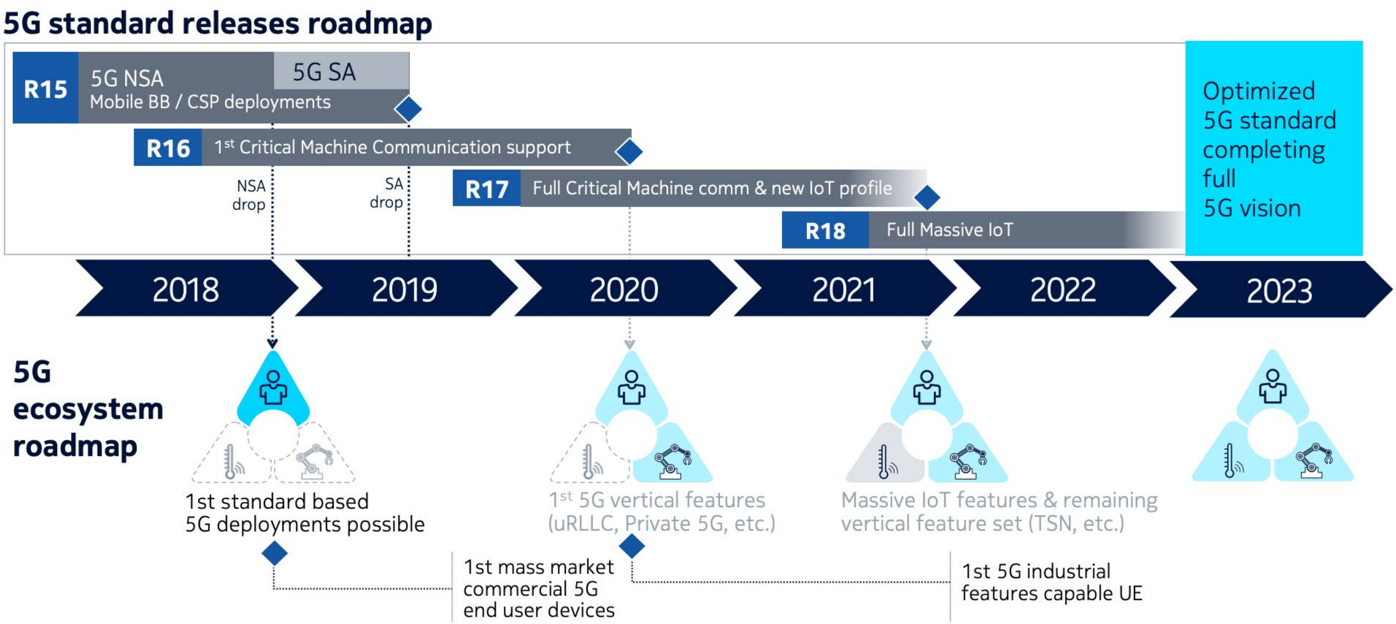
Wait for 5G or go with LTE?

With all the buzz surrounding 5G, it is fair to ask the question about whether it makes sense to wait for 5G or to invest now in 4.9G/LTE? Based on several years of research on the topic by Nokia Bell Labs and our experience of deploying private LTE, we believe that 85–90 percent of today’s industrial applications can be run on LTE.

This is the reason why many large enterprises that are keen to embrace Industry 4.0 are deploying private LTE networks today, as they believe it will give them a competitive advantage and a strong head start when 5G becomes available.

As in previous 3GPP technologies, 5G standards were built on top of LTE with important enhancements relevant for specific vertical industry applications covering features such as data-rate capacity, latency, reliability, scalability and flexibility. Today the 5G 3GPP standardization is still under development with releases planned as follows:

Figure 4. The 5G industry roadmap.



- R15 was the first 5G release with a focus on enhanced mobile broadband applications (higher data rate), which is mainly for video applications and has limited applicability to the needs of Industry 4.0
- A later update to R15 will bring the 5G SA architecture, which is the required baseline architecture for all of 5G's future industrial benefits
- R16 (planned for mid-2020) will bring the first set of Industry 4.0 features (such as ultra-reliable low latency) with expected devices in 2022-2023 timeframe; R16 also defines the standards for private 5G networks, which includes network slicing, or the ability to allocate end-to-end network resources to a specific enterprise or application
- The full 5G industrial feature set will come with R17 (targeted for standardization in 2022 with devices 1-1.5 years later) and R18, which will provide 5G massive IoT, time sensitive networking (TSN) and other features key to industrial applications. Until then, LTE will be needed and many networks will run a combination of LTE and 5G.

While some industries in countries with early access to vertical 5G spectrum (e.g., Germany) may be tempted to deploy 5G from R15, most analysts believe R16 should be the target for enterprises to start deploying 5G. In effect, R16 defines private 5G network functions and capabilities, so anything before may not be standard compliant. In addition, it is important for enterprise to recognize that it will take several years to have a healthy ecosystem of 5G devices that support the R16 feature sets. It may take even longer to benefit from R17 features (for example TSN), and early adopters of 5G may need a device swap.

For this reason, we expect most industrial private wireless deployments to smoothly evolve by adding 5G cells to their current 4G deployments. They will go through a long phase where 4G and 5G will be in operation simultaneously to support all use cases, only moving away from 4G when the 5G ecosystem has fully developed.

Conclusion

Much of the discussion around Industry 4.0 and IoT neglects an essential consideration: how to cost-effectively, reliably and securely connect all of these sensors and devices together? Cabling is inflexible and would prove very expensive to use for connecting a large number of IoT sensors, devices and machines. Wi-Fi does not meet the performance, mobility or security specifications.

Fortunately, 4.9G/LTE and 5G, in the near future, have been specifically designed to do the job and countries around the world, understanding the key role it will play, are releasing spectrum specifically for industrial campus use. What makes this especially exciting is that 4.9G/LTE is a field-proven and pressure-tested technology with a mature ecosystem. So, although it may represent a new and game-changing opportunity for many enterprise users, it doesn't have as many risks as new technologies often do.

Private 4.9G/LTE networks are the next generation of industrial wireless technologies and are available now. They already provide the control, security and agility that industries need to get their Industry 4.0 transformation underway, and they will continue to play a key role even as 5G is introduced to handle the most demanding use cases as they develop.

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