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5G: A Manufacturing Game Changer

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5G—the next generation of wireless technology—is poised to revolutionize the manufacturing sector, accelerating Industry 4.0 by enabling faster speeds and better connectivity as we enter a new decade characterized by continued, explosive growth in the number and types of smart devices and their associated connectivity needs. While mobile consumers and companies across the globe have benefitted from the reliability of the current wireless generation, 4G/4G LTE, throughout the last decade, this technology is now reaching its limits (CB Insights, 2019).

With 5G, data rates will increase 10 times, from 1 Gb/s in 4G LTE to 10 Gb/s. Latency, the time delay before data transfer, will decrease from 60 ms with 4G LTE to 1-10 ms.

5G technologies will enable the following types of services (Figure 1):

- Enhanced mobile broadband (eMBB)
- Massive machine-type communication (mMTC)
- Ultra-reliable low-latency communications (URLLC) (5G ACIA, 2018).

The key features of 5G include:

- High bandwidth
- Ability to support a high volume of connected devices
- Low latency and battery saving
- Low energy operation

The deployment of small wireless appliances (or small cells) is necessary to deliver 5G service that is provided using high frequency, millimeter wave spectrum. Higher-frequency spectrum has far more bandwidth available and therefore can provide higher download speeds and more capacity than the lower-frequency spectrum used to provide traditional cell service. However, higher-frequency spectrum does not transmit signals as far or pass through obstacles like buildings or trees. To use millimeter wave spectrum for 5G service, small cells must be deployed relatively close to the end user receiving service. To serve an area such as a business district, small cells must be placed at intervals to form a grid, sometimes called a polygon, providing contiguous coverage sectors. Such coverage will require extensive small cell deployment.

Fig. 1. Selected target key performance indicators of 5G (from 5G ACIA, 2018)

Peak data rate	10 Gb/s (uplink) 20 Gb/s (downlink)	Connection Density	1 thousand-1 million devices/km^2	Reliability	99.999 % (of packets)
User experienced Data Rate	10-100 Mb/s	Battery Life	10 years	Position accuracy	<1 m - 10 m
Latency	1-10 ms	Availability	99.999% (of time)	Security	Strong privacy & security, and purification

These characteristics make 5G a game-changer for manufacturing, increasing the efficiency and flexibility of operations and offering a ubiquitous platform to integrate all the components of Industry 4.0. 5G can enable a high number of machines, people and objects in factories to communicate large amounts of data at very fast speeds. It also enables the use of augmented reality (AR) applications in manufacturing. The very low latency down to milliseconds allows further development of high performance, demanding applications in automation and control, and autonomous vehicles.

5G technology will also introduce a novel feature called network slicing. With network slicing, multiple logical/virtual networks each with its own requirements—but running simultaneously on a common physical infrastructure—can be created. This will result in more flexibility and better security for different applications running across one or more factories.

While this paper focuses on the next generation of cellular networks covering long range communications, shorter range networks are also evolving. The most widely known and used of these is Wi-Fi, which allows our multitude of devices to connect to the Internet when we are close to an access point or hotspot. The range of these access points is in the tens of meters, reaching up to 150 m outdoors. The new Wi-Fi generation will be called Wi-Fi 6, and is expected to be 4 times faster in dense environments than the current generation (Nelson, 2019). Wi-Fi 6 will also have increased network efficiency and result in extended battery life for client devices (Hill, 2019). Wi-Fi is expected to continue to work as a backup when the 5G network is not available. Similarly, technologies such as Bluetooth and Zigbee (Teel, 2018), which fall under the Personal Area Network (PAN) designation, are expected to continue to be used until 5G becomes fully available everywhere, including businesses and homes.

People

Now (1-2 years)

The first deployments of 5G in the United States began as early as 2018 and have been limited to a handful of large cities. This first stage of the technology focuses on providing the enhanced mobile broadband (eMBB) service. Unlike prior generations of mobile networks, 5G will not only interconnect people, but machines, objects and devices. 5G will revolutionize the manufacturing landscape, but its emergence is causing insecurities about the preparedness of the future workforce. The existing skills gap and the influx of new technologies in manufacturing while creating a few new occupation codes will require different technical skills and expanded job tasks, abilities and work activities. To prepare for the future of work, professionals need to adapt and reskill to meet the needs of Industry 4.0.

Near (2-5 years)

The second release of 5G, expected to be completed in June 2020, will add an ultra-reliable, low-latency communications (URLLC) component. This component will enable advances in autonomous vehicles and robotics in manufacturing as well as health care, each with multiple impacts on people's lives. 5G will increase competitiveness with the growing role in automation, deployment of smart technologies

and accelerated need for talent. In the near future, the mismatch of skills will widen and working professionals that do not reskill will be displaced. “We currently cannot foresee which skills those technologies will entail. Nevertheless, by 2030, between 20 million and 50 million new tech jobs are expected to be created worldwide" (Randstad, 2020). For continued business growth and individual professional development, workers must add strategic value, make decisions, develop strategies for innovative change, learn and understand business processes, analytical thinking, and scale IT infrastructures. Businesses will invest in reskilling; however, if working professionals are unwilling to keep abreast of current technological advancements they will get left behind.

Far (+ 5 years)

The full potential of 5G is expected to be realized gradually and take more than a decade to be achieved. New applications and business models are expected to emerge in this timeframe. Industry will partner with workforce professionals and post-secondary education partners to build an education pathway to retain and reskill employees. Employees must understand the industry business strategy and the need for a return on educational investments via external training, internal training, mentorships, job rotations, adult apprenticeships, or a combination. Employees not retrained by industry must invest in their own human capital to ensure competency in occupational specific technical skills.

Process

The impact of 5G on the manufacturing sector and its business impact can be described by five use case families illustrated in Figure 2.

Fig. 2. Impact of 5G in Manufacturing (Bedo, 2014; Caminade, 2018)

Use case Family	Representative Scenarios	Dominant Impact
 **Time-critical process optimization inside factory**	Real-time closed loop communication between machines to increase efficiency and flexibility 3D augmented reality applications for training and maintenance 3D video-driven interaction between collaborative robots and humans	Increased efficiency Increased worker satisfaction Increased safety/security
 **Non time-critical in-factory communication**	Identification/tracing of objects/goods inside the factory Non-real-time sensor data capturing for process optimization Data capturing for design, simulation and forecasting of new products and production processes	Increased efficiency Increased flexibility Minimized stock levels Increased eco-sustainability (emissions, vibrations, noise)
 **Remote control**	Remote quality inspection/diagnostics Remote virtual back office	Increased product/ process quality
 **Intra-/inter-enterprise communication**	Identification/tracking of goods in the end-to-end value chain Reliable and secure interconnection of premises (intra-/ inter- enterprise) Exchanging data for simulation/design purposes; leveraging artificial intelligence/machine learning	Increased efficiency (cost, time)
 **Connected goods**	Connecting goods during product lifetime to monitor product characteristics, mobile robots that sense its surrounding context, and offering new data-driven services	Increasing sales (new products, services) Improved product/ process design

Now (1-2 years)

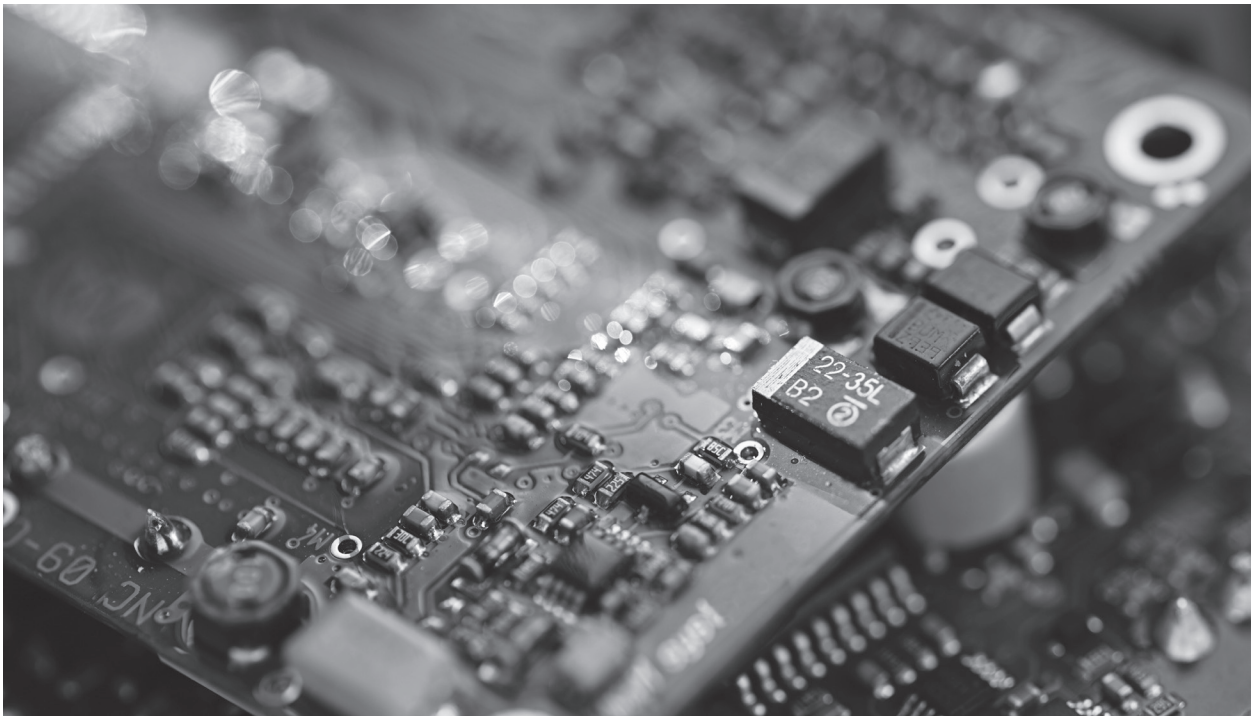
Several companies and academic institutions have started exploring the use of 5G for industrial applications. Ericsson, for example, began testing AR-enhanced troubleshooting using 5G at its electronic boards factory in Tallinn, Estonia in January 2018. Technicians troubleshooting an electronic circuit can pull up the schematics and instructions for repair in their field of vision using AR. Having the schematics overlaid on the image of physical circuit board resulted in time savings of up to 50%.

Another case study involving Ericsson's radio product manufacturing facility in Nanjing, China (Ericsson, 2019) illustrates the massive machine-type communication (mMTC) component of 5G. There are approximately 1,000 high-precision screwdrivers in the factory, which require calibration and lubrication based on their utilization time. The procedure has been mostly manual and documented in handwritten logs. The high-precision tools were fitted with real-time motion sensors that were attached to IoT modules. The data runs via a cellular IoT network over the company's private cloud and back-end systems, which make automatic calculations and intelligent analyses of the collected data. With connected screwdrivers, the factory will be able to replace manual tracking of tool usage data with an automated solution, cutting the amount of manual work by 50%. And since the cost per device is so low, the factory now plans to completely phase out manual tracking.

Near (2-5 years)

The ultra-reliable, low-latency communications (URLLC) component of 5G will be part of the second release of 5G, expected to be completed in June 2020. URLLC enables challenging and demanding motion control applications, where parts need to be quickly moved and/or rotated in a reliable, deterministic manner.

Nokia recently conducted a case study for robotic assembly operations comparing the performance between 4G and 5G technologies. In the same period of time, a robot assembled 12 parts in 4G and 31 parts in 5G, resulting in a 260% productivity gain with 5G (Caminade, 2018).



Far (+ 5 years)

There is a large diversity of applications in the industrial and manufacturing area with different requirements in terms of network coverage, bandwidth, mobility, latency, data integrity and density, as can be seen in Figure 3.

The high connectivity offered by 5G has the potential to bring substantial improvements and optimizations across the entire industry. In the context of Industry 4.0, 5G will support improvements in flexibility, versatility and productivity in future smart factories (5G ACIA, 2018).

In order to achieve this, 5G will need to satisfy common operational and functional requirements across the industry, which include dependable communication, support of functional safety, security and cost efficient and flexible processes. The security aspect will be especially important in the use of 5G. Previous industrial real-time communication systems were generally wired and isolated from the internet, and thus safe from remote attacks. With wireless technologies, a wide range of attacks becomes possible, including local vs remote and logical vs physical. While logical attacks exploit weaknesses in implementation or interfaces, physical attacks focus on hacking of or tampering of devices. The 5G system needs to be protected against both local and remote attacks. It also has to ensure device authentication and message confidentiality and integrity, as machine-to-machine communication expands.

With 5G, the industry will have the capability of deploying and operating private 5G networks in well-defined areas within a factory, for example. This will require acquiring spectrum either through direct licensing from spectrum regulators or subleasing from a mobile network operator. 5G will also work in conjunction with edge computing, which brings some of the cloud storage and computing functions to a site physically closer to the factory, to reduce bandwidth requirements and improve response times (Figure 4).

The three components of 5G—eMMB, mMTC and URLLC—individually and taken together, will enable a wide variety of applications. Figure 3 illustrates the diversity of industrial use cases and where they are placed along the continuum between the three types of 5G services.

Fig. 3: Industrial applications vs the components of 5G technology (5G ACIA, 2018)

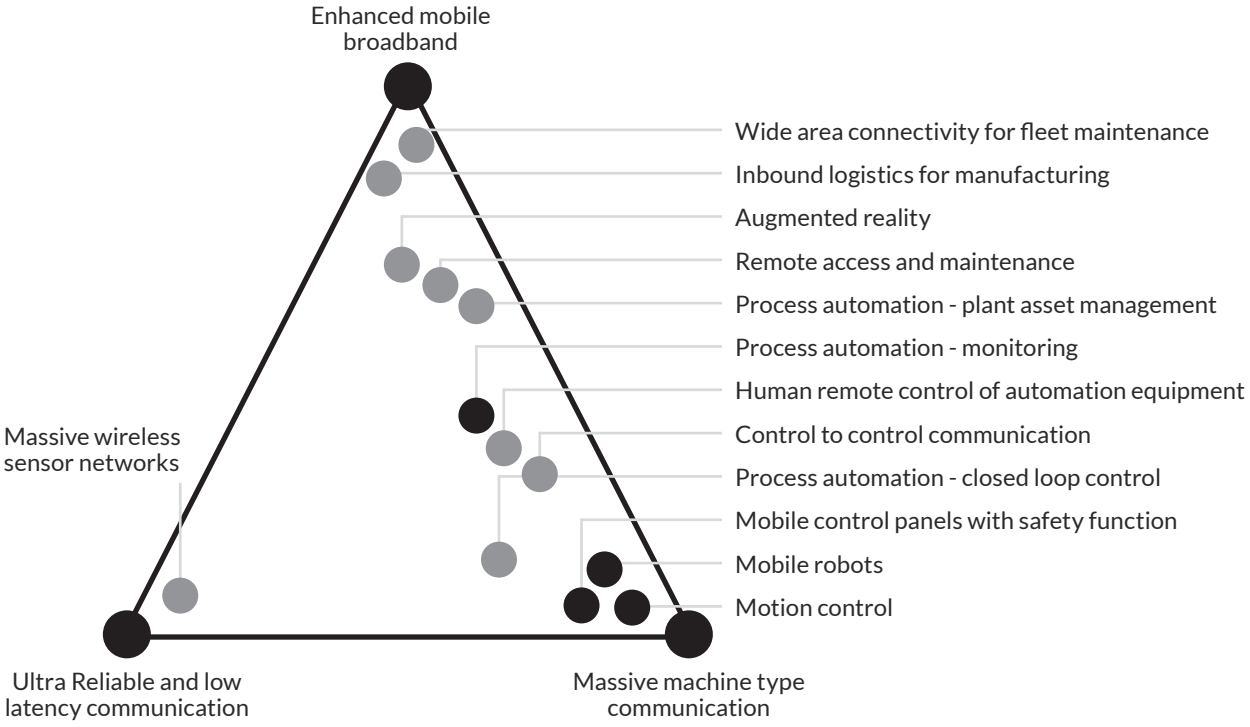
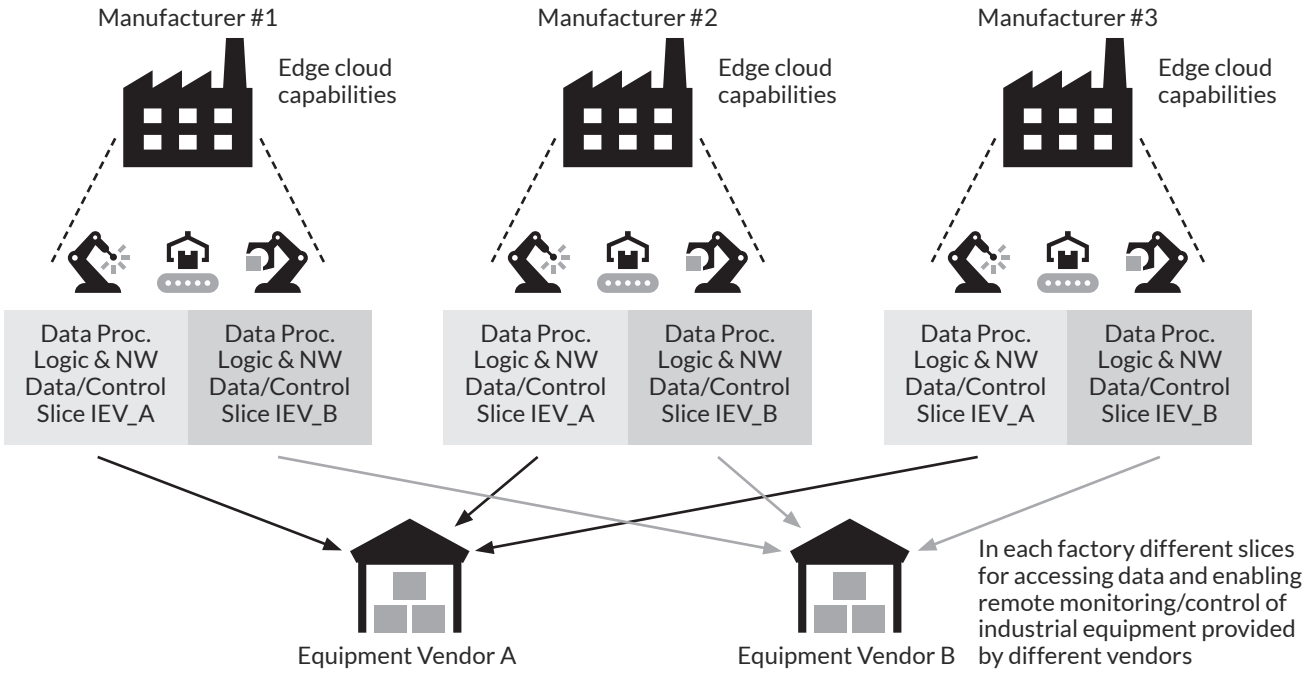


Fig. 4: Different network slices can be created in each factory by each equipment vendor (from Mantyla, 2017)



Technology Evolution

Now (1-2 years)

5G deployment began in cellular networks in a handful of large cities across the Unites States in 2018. By the end of 2019, most major wireless carriers had launched or were close to launching 5G mobile services. These include Verizon, AT&T, T-Mobile and Sprint. At the same time, 5G capable smartphones have appeared on the market, such as the Samsung Galaxy 10 5G, the Motorola 5G upgradeable Z4 and others. The first deployments of 5G have focused on providing the enhanced mobile broadband (eMBB) service of the 5G technology, under the first version of 5G called Release 15.

Today, there are several 5G manufacturing pioneers, including Ericsson, Nokia, Audi and BMW. "Audi, for example, has already started testing 5G for robotic motion control. Nokia's 5G Oulu factory is using 5G for in-factory connectivity, a combination of edge computing and cloud computing, and IoT analytics. BMW Brilliance Automotive in China is working to enable full 5G wireless coverage at all of its plants" (Korolov, 2020).

5G can simplify connecting home smart devices such as security cameras, smart locks, and digital assistants, as well as IIoT devices, eliminating the need for short range networks. This will however have the drawback of being locked-in to a service provider and having to pay recurring charges.

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However, while most manufacturing companies recognize the importance of implementing 5G, so far most are in the planning stage, where they are setting aside resources for future implementation. "This is expected to be costly, as many manufacturing sites don't even have Wi-Fi at this time. As a result, early adoption will be slowed, with uptake limited to islands on the manufacturing floor that will expand as equipment and back end systems are upgraded. Total cost can vary greatly depending on the amount of 5G compatible infrastructure a company already has in place" (Korolov, 2020).

Near (2-5 years)

The second release of 5G, Release 16, is underway with an expected completion date of June 2020 (Weissberger, 2019). This release adds another key component of 5G, ultra-reliable, low-latency communications (URLLC). The addition of URLLC will enable developments in three areas: automotive, Industrial IoT and operation in unlicensed bands. In the automotive arena, the low latency will enable cellular V2X (vehicle-to-everything) communications for autonomous vehicles. In IIOT, 5G cellular communication has the potential to replace the wired Ethernet traditionally used in manufacturing. For this to take place, time sensitive networking (TSN) and high reliability capabilities must be achieved. Finally, the use of unlicensed bands will allow small companies who cannot license dedicated spectrum of their own to benefit from the 5G capabilities. However, a licensed spectrum remains the preferred version when demands for latency and reliability are high. Release 16 will also include the network slicing feature.

Far (+ 5 years)

The next planned release of 5G is Release 17, which will see enhancements to eMBB, IIoT, achieving parts localization accuracy in the centimeter range, expansion of wearables and industrial sensors, and other advanced features (Ericsson, 2019). The manufacturing sector is expected to contribute $234 billion USD to the total revenues from 5G by 2026 (5G ACIA, 2018).

Action Items

- As 5G becomes a reality, the manufacturing industry must communicate its requirements to the 5G community. The benefits of 5G will be fully realized only if the manufacturing ecosystem will be extended to include the telecom, electronics industry, and IT domains, with close collaboration between all the players in the ecosystem.
- The use of 5G in the manufacturing industry requires validation through testbeds and trials. A new knowledge base needs to be created based on common testbeds and extended field trials, bringing together players from different industries.
- 5G's emergence is causing insecurities about the preparedness of the future workforce. The influx of new technologies in manufacturing will require different technical skills and expanded job tasks, abilities and work activities. To prepare for the future of work, professionals must adapt and reskill to meet the needs of Industry 4.0.

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