# The Benefit of 5G in the Factory


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## Introduction

With the arrival of 5G technology, the manufacturing industry faces its biggest transformation yet. Safer, flexible and more efficient manufacturing systems will be possible thanks to the ultra-low-latency and reliability of 5G connectivity. This enables continued automation of robots and warehouse transportation as well as cutting cables for true flexibility. In this whitepaper we describe the benefits of 5G in the factory and the impact on smart manufacturing.

## Cut the Wires

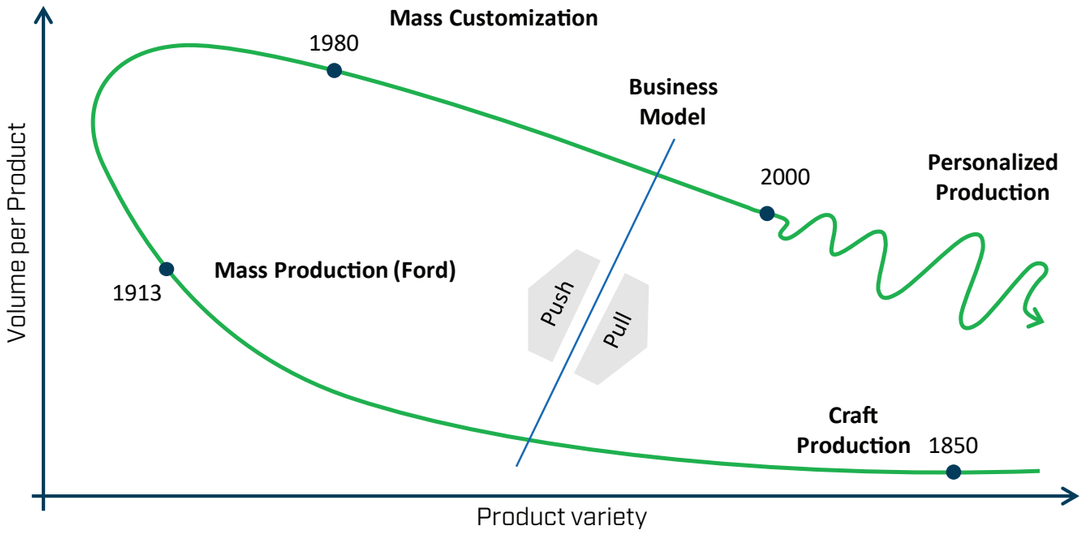


Figure 1. The evolution of industrial production (Hu SJ, 2011)

During the last 200 years we have seen a tremendous development of industrial production. During this time there has been a shift away from craft production and towards mass production. Mass production was a result of a technology push to make manufacturing more productive.
With mass production we lost the ability to produce customized products. The customer need for customized products, however, is still there. For this reason there is a strong market pull to make industrial production far more flexible than it is today.
Flexible production, however, is not allowed to increase the cost of production. At the contrary there is a need to increase automation in order to maintain quality and stay competitive. This is today a global trend. In some regions competitiveness is the main driving force. In others quality is the driving force.
During the last 30 years we have automated everything which can be automated in the factory using wired technology. The main processes which have so far not been automated is the integration of logistics, material handling and factory automation.
The integration of logistics, material handling and factory automation can only be achieved by using wireless technology. A vision of this is shown in Figure 2.



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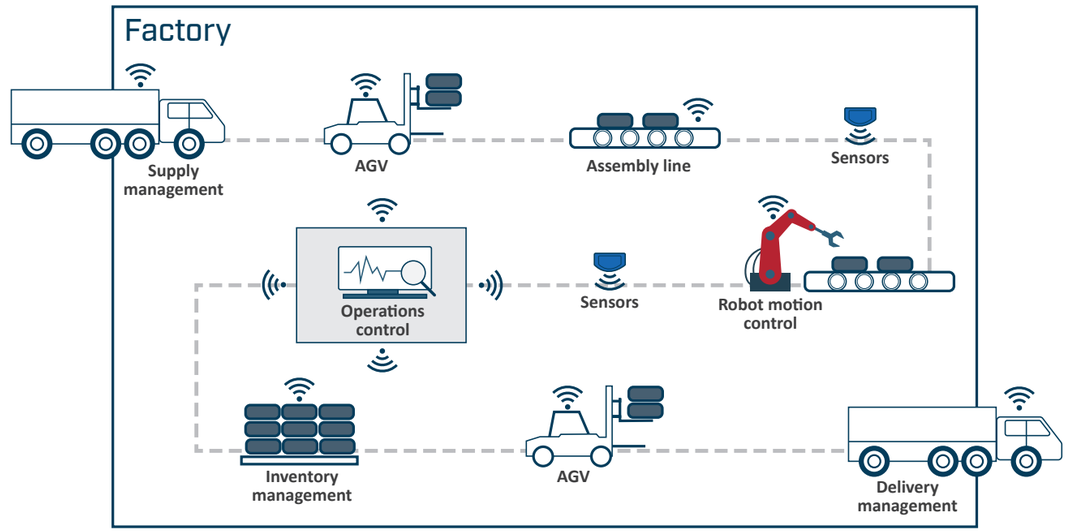


Figure 2. Vision of the future factory (5G-ACAI, 2018)

- In this vision a truck arriving with material for the factory announce its arrival to the factory and communicate directly with an AGV. The AGV unloads the truck and delivers the material to an assembly line.
- Assembly lines, machines and robots in the factory are connected wirelessly in order to maintain a high degree of flexibility.
- Workers are mobile and use wireless devices to monitor and control the factory.
- Finished products are placed in an automated warehouse before they are loaded onto a truck.

| | WLAN | Bluetooth | RFID | DECT | Cellular | Ultra Wideband |
|---|---|---|---|---|---|---|
| Process control | Yes | Yes | | | | |
| Remote access | Yes | | | | Yes | |
| Remote monitoring | Yes | | | | Yes | |
| Sensor networks | | Yes | Yes | | | |
| AGV | Yes | | | | | |
| Wireless tools | Yes | Yes | | | | |
| MMI | Yes | Yes | | | | |
| Rotating parts | | Yes | | | | |
| Mobile machines | Yes | Yes | | | | |
| Object tracking | | Yes | Yes | | | Yes |
| Voice | Yes | | | Yes | Yes | |
| Video | Yes | | | | Yes | |

Figure 3. Today's use of wireless technologies in industrial production.

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The introduction of wireless technologies in industrial production has already started. Today we see a multitude of wireless technologies being used for different use cases in industrial production.
Initially wireless technologies were used for select non-critical applications, but increasingly wireless technology is becoming the norm and increasingly it is becoming more and more mission critical.
None of the wireless technologies used today have the reliability, scalability and performance which is needed for tomorrow's industrial production. From a technical perspective 5G cellular technology has the potential to meet all the requirements.

## 5G Cellular Networks

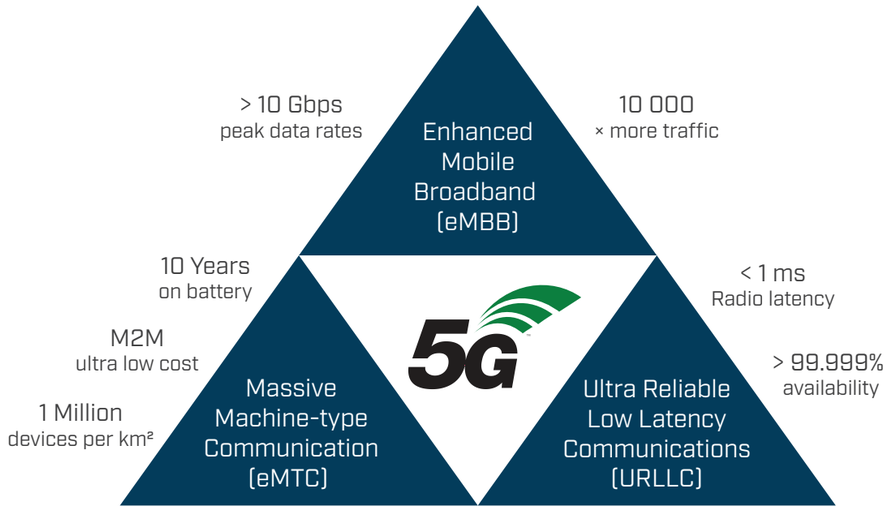


Figure 4. 5G Cellular Network Services

5G is the first cellular generation which specifically targets machine to machine communications. The different services are illustrated in Figure 4.
Massive Machine-type Communication (eMTC) allows vast numbers of battery operated low power devices to be connected. From an industrial production perspective this type of service will enable:

- Wireless sensor networks
- Location and asset tracking

Ultra-Reliable Low Latency Communications (URLLC) allows latency below 1 ms on the radio interface as well as availability exceeding 5-nines (99.999%). From an industrial production perspective this type of service will enable:

- Motion control
- Mobile robots
- Human remote control
- Mobile control panels with safety function



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Enhanced Mobile Broadband (eMBB) is primarily targeting residential internet access with speed and latency on par with fibre optical networks. From an industrial production perspective this type of service is suitable for:

- AGVs
- Augmented reality
- Remote access
- Inbound and outbound logistics

For the first time in the history of industrial production a single wireless technology offers the solution to all aspects of communications within the factory. The only area not suitable for 5G within industrial production is motion control with sub-millisecond cycle time requirements.

## Frequency Spectrum

| | < 1 GHz | 1-3 GHz | 3-5 GHz | 5-8 GHz | 24-28 GHz | 37-40 GHz | 64-71 GHz |
|---|---|---|---|---|---|---|---|
| US | 600 MHz | 1900 MHz<br>2500 MHz | 3100 – 3550 MHz<br>3550 – 3700 MHz<br>3700 – 4200 MHz | 5180 - 5350 MHz<br>5470 - 5835 MHz<br>5925 - 7125 MHz | 27.50 – 28.35 GHz | 37-40 GHz | 64 – 71 GHz |
| EU | 694 – 790 MHz | | 3400 – 3800 MHz | 5150 - 5350 MHz<br>5470 - 5875 MHz | 24.25 – 27.50 GHz | | |
| China | | | 3300 – 3600 MHz<br>4400 – 4500 MHz<br>4800 – 4990 MHz | 5170 - 5330 MHz<br>5735 - 5835 MHz | 24.25 – 27.50 GHz<br>37.00 – 43.50 GHz | | |
| Japan | | | 3600 – 4200 MHz<br>4400 – 4900 MHz | 5180 - 5330 MHz<br>5490 - 5710 MHz | 27.50 – 28.25 GHz | | |
| Korea | | | 3400 – 3700 MHz | 150 - 5330 MHz<br>5490 - 5650 MHz | 6.50 – 29.50 GHz | | |
| Australia | | | 3400 – 3700 MHz | 150 - 5330 MHz<br>5490 - 5835 MHz | 24.25 – 27.50 GHz | | |

Figure 5. 5G relevant frequency bands for different parts of the world. Green text denote unlicensed or shared bands (CableFree, u.d.).

5G is primarily intended for public networks in licensed bands, but it is also possible to use as a private network:

- Private network in unlicensed band
- Private network in licensed band (own radio license or sublicensed from a cellular operator)
- Semi-private network using network slicing of public network.

For some factory owners it is important to own and control the communications infrastructure. In this case it is relevant to use either unlicensed frequencies or to get a license to operate in a licensed band.
The advantage of using unlicensed spectrum is that it is easy to deploy without obtaining a license first. The downside is the possibility of interference from other users in the area as well as limitations in transmit power.
In case the factory owner prefers to use licensed frequencies a license can be obtained from the government or alternatively sublicensed from a mobile operator.
Factory owners looking to outsource the operation of the factory 5G network can make an agreement with a public mobile operator to provide the service. The service level agreement will cover aspects such as availability, coverage, bandwidth, life cycle management etc.

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Generally you get better coverage with lower frequencies. Lower frequencies, however, are also in high demand from mobile operators, broadcasters, emergency services and other users of the radio spectrum.
Licensed spectrum is available around 3.5 GHz as well as in the 26 GHz band in most countries. For unlicensed deployment of 5G the 5 GHz ISM band is a good candidate. In the 5 GHz ISM band 5G will be sharing the spectrum with WLAN.

## 5G for Industrial Automation

The main driver for 5G within industrial production is to automate the processes which today cannot be automated using wired technology. There is, however, also a need to migrate some of today's PLC communications from industrial Ethernet to 5G. The driver for this is increased flexibility, increased reliability and reduced cost for some use cases.
5G PLC communications might only be a small fraction of the total traffic on the 5G factory network. It is, however, the most demanding due to requirements on real time performance and reliability.
For PLC communications, we need low latency and high availability. Low latency and high availability is already supported by the 5G new radio (NR) interface. Only for motion control applications will 5G not be fast enough.

| Network | Market Share | Layer | Cycle time | Real-time extensions |
|---|---|---|---|---|
| EtherNet/IP | 33% | UDP/IP | ~ 1 ms | No |
| PROFINET IO | 26% | Ethernet | ~ 1 ms | No |
| PROFINET IRT | | Ethernet | 250 µs (31,25 µs) | Yes |
| EtherCAT | 15% | Ethernet | 12.5 µs | Yes |
| Modbus/TCP | 9% | TCP/IP | ~ 10 ms | No |
| POWERLINK | 9% | Ethernet | 100 µs | Yes |
| SERCOS III | < 9% | Ethernet | 62 µs | Yes |
| CC-Link IE Field | < 9% | Ethernet | ~ 20 µs | Yes |

Figure 6. Industrial Ethernet protocols and typically achievable cycle times. (HMS Networks, 2018)

Unfortunately most Industrial Ethernet protocols do not rely on TCP/IP and have various extensions to the Ethernet standard in order to support low latency and high reliability. With today's cellular standards only TCP/IP traffic is supported. This means that most of the Industrial Ethernet protocols listed in Figure 6 will not be compatible with 5G. Only EtherNet/IP and Modbus TCP will be supported on 5G directly.
In order to improve the support of Industrial Ethernet 3GPP is standardizing Ethernet as a service on 5G. This standardization also includes the support of time sensitive networks (TSN). At the same time most Industrial Ethernet protocols are being updated in order to replace proprietary real-time extensions with TSN. This means that once this standardization work is finalized it will be possible to support Industrial Ethernet on 5G networks.

In the meantime it is possible to deploy GWs which adapt the Industrial Ethernet protocols to 5G. An example of this is shown in Figure 7.
In this example Ethernet is tunnelled over IP and the IP quality of service header field is marked depending on the real-time requirements of the underlying PROFINET traffic. On the cellular network the non-real time traffic is carried using a default bearer. Real time traffic on the other hand is carried on a dedicated bearer which provides guaranteed bitrate and low latency. With this setup it is possible to support Industrial Ethernet on 5G with cycle times down to a couple of milliseconds.



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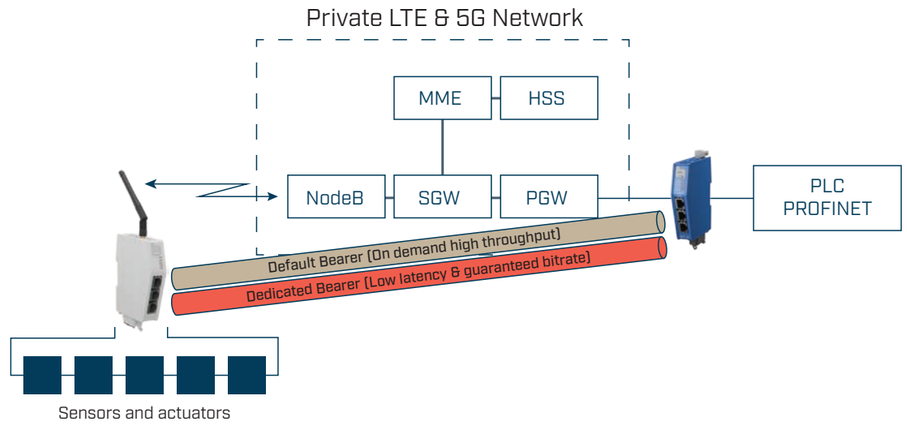


Figure 7 Tunnelling of Industrial Ethernet on a cellular network.

## 5G Rollout

The standardization of 5G is ongoing within 3GPP. At the same time venders and operators are trying out the technology in a number of trials around the world.
The initial phase of 5G deployment is based in 3GPP release 15. This release is primarily focused on enhanced mobile broadband (eMBB) and is used for early deployment of residential wireless broadband service.
3GPP release 16 will be the release covering Ultra-Reliable Low Latency Communications (URLLC). This release will be ready at the end of 2019. 5G radio modules and network infrastructure supporting release 16 are expected early 2020.

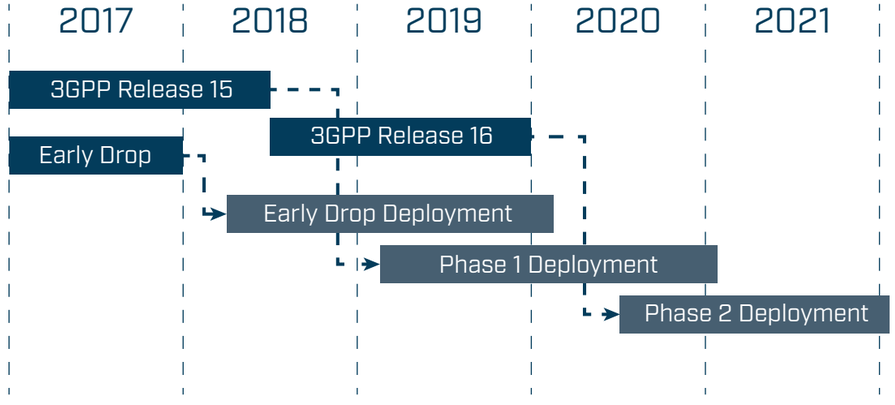


Figure 8 5G Rollout Plan (5G-ACAI, 2018)

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## Conclusion

Industrial production is undergoing its fourth revolution. The goal is to increase flexibility and at the same time increase automation. Ideally production in the factory should be handled completely without any manual tasks. Only in case of failures or other exception cases should humans need to intervene.

The fourth industrial revolution can only succeed by relying heavily on wireless communications in the factory. From a technical perspective 5G is the technology which is best suited for the future factory!

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