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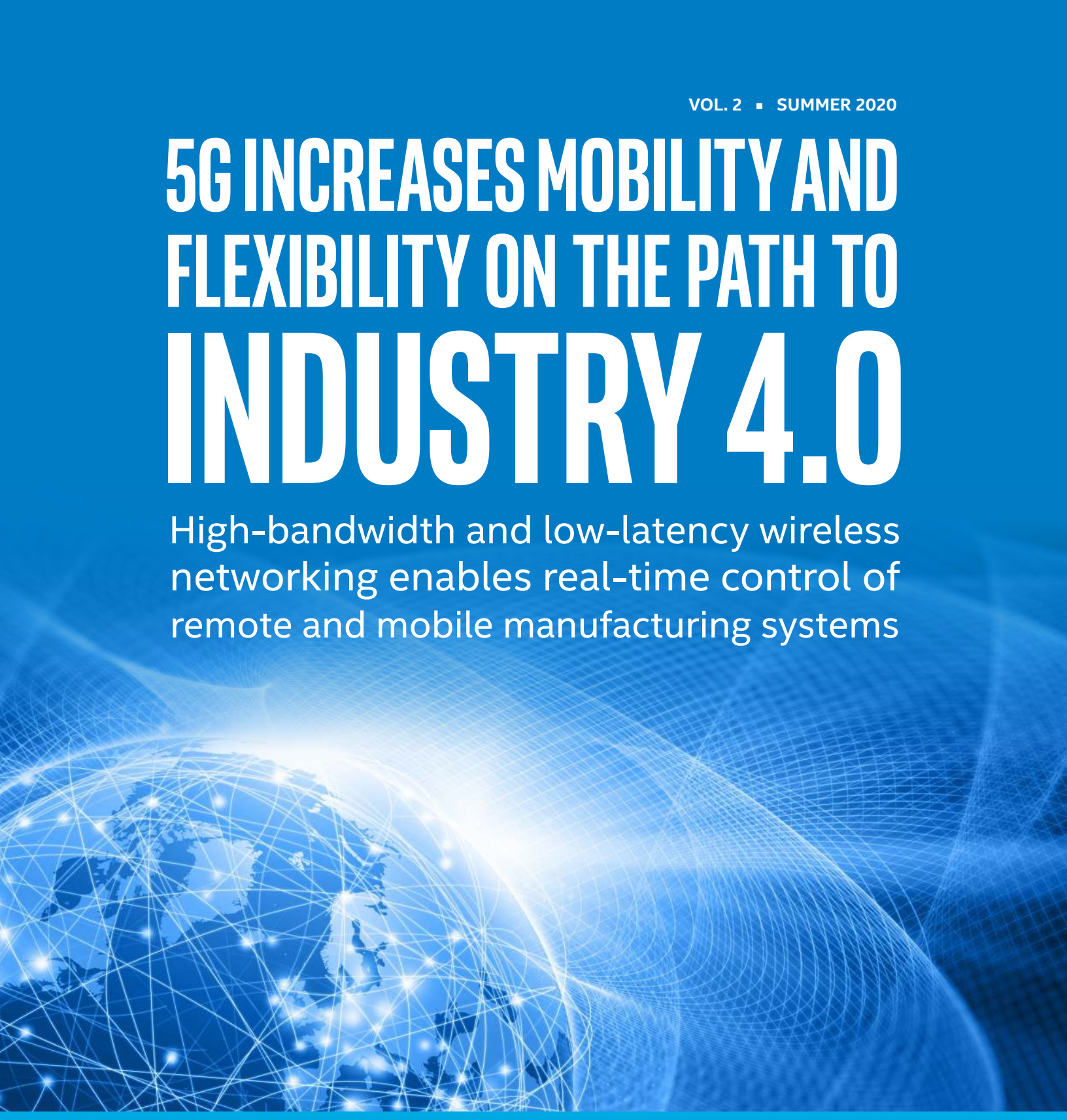
5G INCREASES MOBILITY AND FLEXIBILITY ON THE PATH TO INDUSTRY 4.0

High-bandwidth and low-latency wireless networking enables real-time control of remote and mobile manufacturing systems



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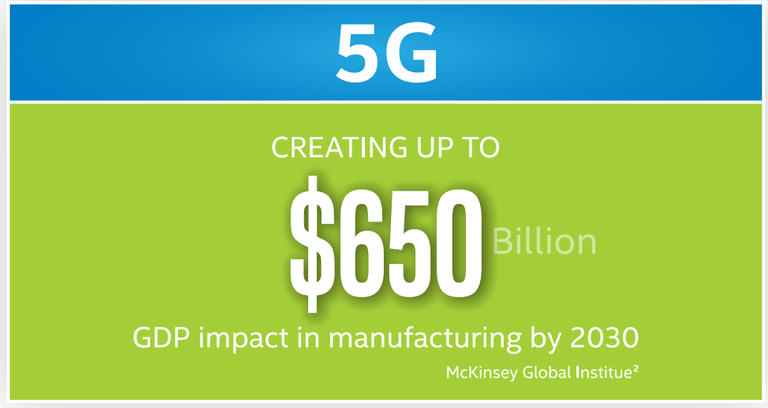
Wi-Fi and 3G/4G wireless technologies are sometimes used in industrial settings to connect mobile or "hard-to-wire" devices, such as autonomous mobile robots (AMRs), trucking fleets and Industrial plants that have a large geographic coverage area. However, these legacy wireless technologies were not designed for industrial operational technology (OT) levels of reliability, latency, throughput, and security, among other concerns.

Ricky Watts,
Industrial Solutions Senior Director at Intel

The next evolution of mobile "5G" was developed with the capability to address industrial OT requirements.

In addition, 5G technical improvements can increase the productivity gains anticipated from Industry 4.0, giving manufacturers the flexibility and performance needed to better automate their operations. Wired networks will continue to dominate industrial facilities; but when physical wires impede innovation, 5G can be a workable option.

5G brings the promise of enhanced bandwidth, sub 1-millisecond latency, 1,000 times the capacity of legacy wireless technology and massive machine-to-machine communication capability, unlocking the full potential of the Internet of Things (IoT) in industrial production.[1]



1. Caroline Chan, "Autonomous Manufacturing Comes to Life at the Intel 5G and IOT Innovation Center," May 21, 2019, https://blogs.intel.com/technology/2019/05/autonomous-manufacturing-comes-to-life-at-the-intel-5g-and-iot-innovation-center/#gs.80qsbx.

2. McKinsey Global Institute, "Connected world, An evolution in connectivity beyond the 5G revolution" February 2020, https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/connected-world-an-evolution-in-connectivity-beyond-the-5g-revolution.

WHY 5G IN MANUFACTURING

The next revolution in manufacturing, sometimes referred to as Industry 4.0, is a shift to more computerized and digitized processes, and the convergence of the top-floor and shop-floor systems: manufacturing and business. A main objective of this transition is to make better use of data to improve decision-making, planning, productivity, safety, quality, and other business aspects.

Advanced data analysis, via artificial intelligence (AI) and machine learning (ML), is being used to pull more actionable intelligence out of data than ever before.

A major challenge is collecting sensor data from remote and mobile manufacturing processes, like mobile robots; and this is where 5G can play a key role. 5G will also be cost competitive in many scenarios within a factory for new installations, where the cost to wire a device to the network can be more than $100 (USD) per foot.

5G offers a high-bandwidth, secure, and low-latency network capable of transmitting exceptionally large amounts of sensor data and supporting time-critical communications, like motion control.

5G AS AN INTEGRAL PART OF INDUSTRIAL NETWORKS: WHEN WIRELESS CROSSES THE CHASM

Endpoints connecting digital factories will be entirely new, including mobile robots and advanced sensor networks that feed real-time information into production systems for product/process optimization. 5G is integral because it supports time-sensitive networking (TSN) and deterministic networking natively. Furthermore, since 5G cellular connectivity is based on industry-wide standards, it will be supported by a large device ecosystem. Table 1 below compares the suitability of 5G, along with various qualities relative to other connectivity technologies.

Table 1. 5G Suitability for Manufacturing (Source: ABI Research, 5G and Edge Networks in Manufacturing, QTR 1, 2020)

Wireless technology	Mobility	High Throughput	Low Latency	Massive Connection	Last-Mile Deployment	Cost per Bit	Technology Evolution
5G	High	High	High	High	High	High	High
4G	High	Medium	Medium	Medium	High	Medium	Medium
Wi-Fi	Low	Medium	Low	Medium	Medium	High	Low
LPWAN	Low	Low	Low	High	Medium	Low	Low
Fixed (Cable)	Low	High	High	Low	Low	Low	Low

	Use Cases	From → To	Benefits
	Automated guided vehicles (AVGs) Autonomous mobile robots (AMRs)	AVGs/AMRs move along pre-defined lanes	AI and M2M communication help optimize paths and avoid collisions	Faster routes, and fewer traffic jams and collisions
	Part (and product) picking in warehouses and fulfillment centers	Parts must be situated in fixed locations and orientations	AI-based vision detects parts in various positions and locations	More efficient and accurate parts picking
	Collaborative robots (Cobots)	Cobots follow static, pre-programmed paths and actions	AI-based Cobots will be able to optimize their movements and improve communications with workers.	Greater situational adaption, resulting in increased safety and productivity
	Remote, off-premises sensors and actuators (e.g., farms, oil rigs, windfarms)	Devices communicate over 4G networks.	Devices communicate over 5G networks.	Faster and more reliable secure communications transfer large volumes of sensor data
	Safety monitoring of workers in hazardous areas (e.g., light curtain, lockout/tagout)	Workers are responsible for staying out of restricted or unsafe areas.	AI-based monitoring alerts when workers deviate from safety protocols or danger is imminent	Improved safety and crisis avoidance
	Flexible sensor placement (e.g., cameras to monitor quality, safety, or security)	Sensors are not deployed in some locations due to the difficulty or expense of wiring them to the network.	5G wireless can be deployed without having to lay a physical network connection.	Greater agility to improve productivity or change manufacturing processes
	Guided workflows (e.g., equipment repair) using augmented reality	Workflow assistance lacks visual support, necessitating on-site specialized technicians	Augmented reality enables off-site specialists to help non-expert technicians.	Faster and lower cost equipment repair through remote collaboration
	Visual quality inspection	Quality checks are performed by humans. Laser- and x-ray-based devices inspect materials	Computer vision detects quality defects, and machine learning increases detection rate.	Higher product quality and continuously improving inspections
	Line supervisory controls	Programmable logic controllers (PLCs) have wired connections.	Communication between PLCs and with IT personnel is wireless.	Increased PLC portability enhances placement flexibility

5G USE CASES IN MANUFACTURING

There are many remote and mobile devices, such as industrial cameras, actuators, robots, machines, display screens, and other systems, that require fast and reliable connectivity. In greenfield deployments, 5G could supersede wired networks by supporting lower deployment costs, and greater mobility and flexibility. The table below provides examples of 5G use case in manufacturing.

5G AND DETERMINISTIC PERFORMANCE

Many industrial control applications require low latency, ultra-reliable, and deterministic data communications to implement real-time interactive systems. Prior to 5G, these stringent performance targets could only be satisfied by hardwired networks. With Release 16, 5G can deliver the necessary network performance with the help of two key technology efforts:

Time-sensitive networking (TSN)

TSN-over-5G provides guaranteed message delivery time using time synchronization and traffic scheduling. Devices can be precisely synchronized over the network, eliminating the need for the signal-based synchronization methods that are common today.

5G Ultra-Reliable Low-Latency Communication (URLLC)

URLLC optimizes the delivery of data based on different traffic requirements that include low latency and high reliability. Development of this capability spans several domains: radio, end-to-end networking infrastructure, and application development.

5G TECHNICAL IMPROVEMENTS

Security built into the 5G spec

Private 5G networks

Ultra-high-definition streaming

Data rates as high as 20 Gbps

Real-time control

Latency of 1 millisecond or lower

Support more controllers and sensors

High density from advanced antenna technology

Fewer points of failure

Device-to-device communication redundancy

Greater determinism and data privacy

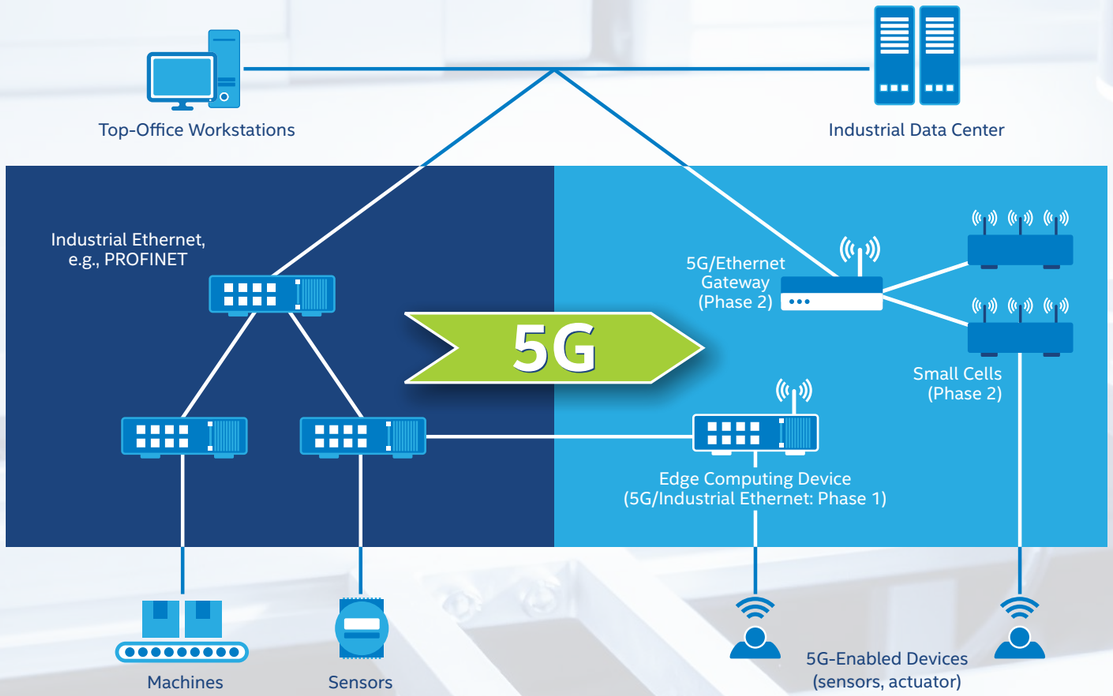
5G network split into multiple virtual networks

ADDING 5G TO INDUSTRIAL NETWORKS

Today's industrial networks (e.g., PROFINET*) are typically Ethernet-based with modified protocols to deliver low latency and determinism that support real-time control. Industrial Ethernet controllers connect manufacturing systems, sensors, actuators, etc. to programmable logic controllers (PLCs) and servers to create a control system.

With the integration of 5G on the factory floor, Industrial Ethernet controllers at the edge can be replaced with edge computing devices that act as gateways for 5G and industrial Ethernet communications, as shown on the right side of the figure below. For manufacturers employing 5G as their primary factory floor network, 5G small cells can replace the remaining Industrial Ethernet controllers.

Adding 5G to Existing Industrial Networks



5G DEPLOYMENT OPTIONS

Manufacturers will be able to take advantage of mid-band 5G frequencies to deploy 5G private networks that provide highly secure and deterministic connectivity. The figure below shows deployment options that are in addition to the traditional public network.

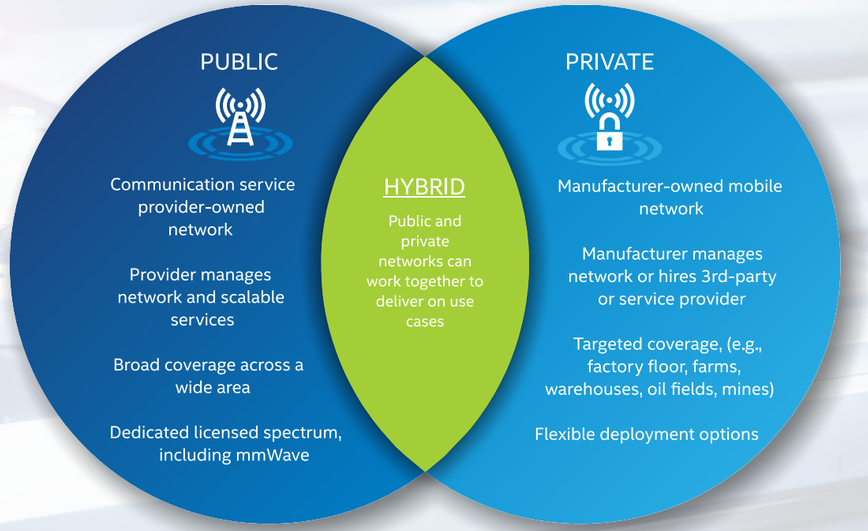
Some of the benefits derived from private networks include:

- Greater capacity and operational control to ensure network performance and latency requirements are met.
- More flexible and agile connectivity to accommodate manufacturing process changes.
- Increased security through exclusive network access to ensure greater data protection and privacy.

5G private networks can also be tailored to specific industrial and business requirements. (Note that 5G private networks must comply with local 5G license regulations.)

Some of the benefits derived from public networks include:

- Operated and managed by a third party, reducing operational complexity
- Broad coverage across a wide area



MULTI-VENDOR APPROACH TO THE INDUSTRIAL EDGE

There is a lot of proprietary networking equipment on factory floors as vendors offer their own version of Industrial Ethernet, such as EtherCAT*, PROFINET, and Modbus TCP*.

Some players in the 5G industry are driving standards for Open Radio Access Network technology (O-RAN) to build open solutions based on general-purpose, vendor-neutral hardware and software-defined technology.[3]

OpenRAN architectures utilizing small cells may be particularly well-suited for the manufacturing industry. They provide open interfaces within the mobile network and allow a transition from a limited number of verticalized vendors promoting proprietary "end-to-end" solutions to an open market of "best-of-breed" system designs offered by multiple vendors. The architecture has already allowed the entry of new vendors and types of equipment in the relatively closed mobile infrastructure supply chain.

OpenRAN is not a new technology, but an implementation approach promoting a more open, transparent, and modular ecosystem. It allows various stakeholders to bring their best-in-class technologies and contribute to building the next-generation telecommunications networks, including 5G. This will move the telco infrastructure market from a static, vertical market with few players using proprietary solutions to a dynamic, horizontal market with a multitude of players.

OPENRAN 5G SYSTEM FOR INDUSTRY 4.0

Intel and Baicells developed an OpenRAN 5G IoT system prototype that supports URLLC performance (sub-1 millisecond latency) in a compact design. These attributes allow for high performance and easy integration into existing deployments.

Deployments based on this solution can provide secure, dedicated communications via a wireless "express lane" for private networks between machines on the factory floor. The solution also provides open standardized interfaces compliant with the O-RAN Alliance so that it will easily integrate into existing infrastructure.

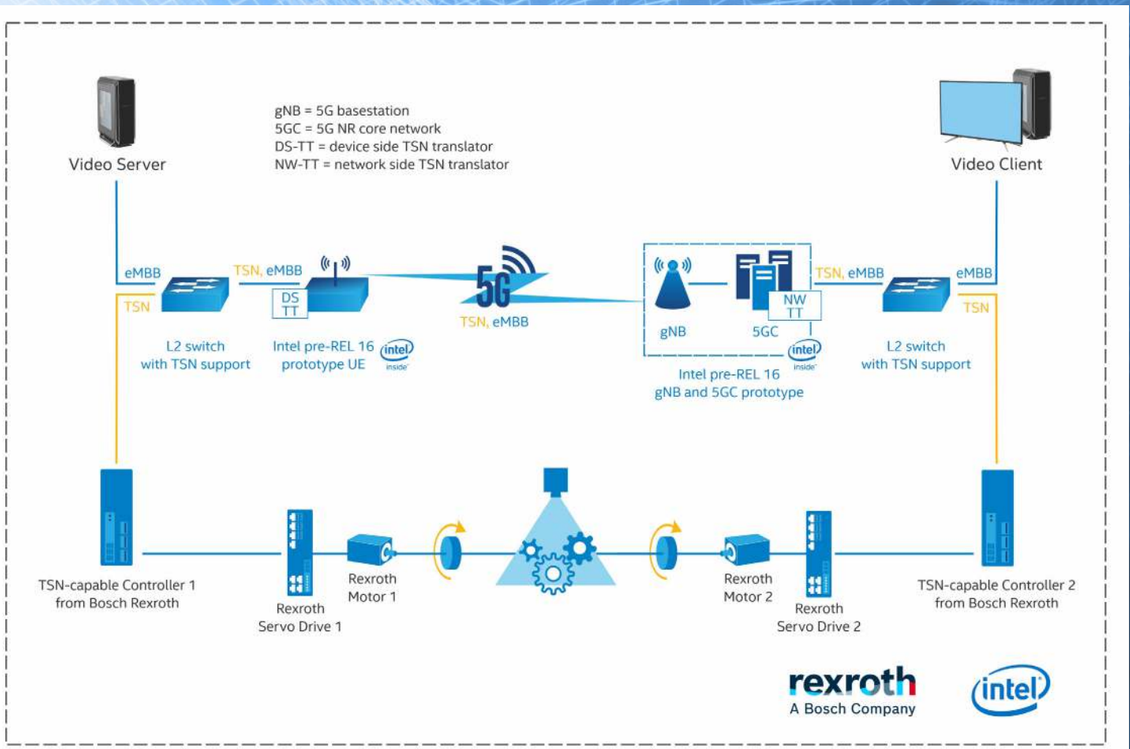
Small cell configurations based on the concepts demonstrated by Intel and Baicells can provide a wide range of benefits for manufacturers, including:

- Enabling time-sensitive applications such as machine vision, video surveillance, augmented reality, and industrial automation
- Significantly reducing cost and resource allocations for cabling deployments
- Enhancing data sovereignty and privacy via private networks
- Increasing flexibility in factory floor configuration
- Improving the reliability and resiliency of factory operations
- Advancing communications with remote robotics and autonomous fleets in industrial settings

3. Telecom Infra Project (TIP), "OpenRAN," https://telecominfraproject.com/openran.

INTEL AND BOSCH REXROTH

Bosch Rexroth engaged with Intel to create a proof of concept (PoC) to support TSN services over a 5G network. The demonstration is one of the first to showcase 5G New Radio (NR) Release-16 TSN-over-5G features. The key enablers for TSN-over-5G are: TSN synchronization over a 5G system, TSN Ethernet operation over a 5G system, 5G URLLC transmission, 5G end-to-end quality-of-service (QoS) management, and intelligent scheduler algorithms.



INSIGHTS FROM A TECHNOLOGY JOURNALIST[4]

Enno de Boer leads McKinsey & Company's global work in digital manufacturing and collaboration with the World Economic Forum on technology adoption

FIVE WAYS THAT 5G WILL REVOLUTIONIZE MANUFACTURING

With data speeds slated to be much faster than today's 4G networks and lag reduced to virtually zero, 5G appears to promise unending opportunities to strengthen connectivity and digitization.

But which potential applications deserve manufacturers' attention? Five show particularly strong potential for boosting factory productivity:

Cloud control of machines

In factory automation, machines are controlled by PLCs that are physically nearby, whereas 5G could enable PLCs to be virtualized in the cloud, wirelessly controlling machines in real time at a fraction of the current cost.

Augmented reality

5G on the shop floor enables the streaming of high-quality instructions, as well as lag-free augmented reality, to guide workers through the steps they need to make, allowing them to undertake advanced tasks without waiting for specialist engineers or incurring costly machine downtime.

Perceptive AI eyes on the factory floor

5G will allow real-time streaming of data to the cloud and the use of live video analytics. For example, a security camera could see a disturbance, identify if there is an imminent threat or danger, and dispatch a drone or alert a worker to investigate.

High-speed decisioning

5G speeds up the decision-cycle time, allowing massive amounts of data to be ingested, processed, and actioned in near real time. For example, manufacturers in heavy industries could sell excess energy back to the grid when machines aren't running and prices are favorable.

Shop floor Internet of Things

Factories are creating more data than ever before, but transmission through wired networks is expensive to scale. 5G supports high connection density with tens of thousands of endpoints, thereby truly enabling the use of industrial data at scale.

4. Enno de Boer et. al., Mckinsey & Company, "Five ways that 5G will revolutionize manufacturing," October 18, 2019, https://www.mckinsey.com/business-functions/operations/our-insights/operations-blog/five-ways-that-5g-will-revolutionize-manufacturing.

CONCLUSION

The journey to Industry 4.0 requires connecting to all the devices critical to industrial processes. 5G can be key to connect to those hard-to-wire devices, and in the future, may be the primary industrial network.

Intel's flexible solutions, extensive ecosystem, and focus on convergence mak it possible for manufacturers to consolidate data and applications at the edge at a lower total cost of ownership (TCO), driving the deployment of intelligence from edge to cloud and helping realize the power and increased efficiency of Industry 4.0.

Companies choose Intel to help them accelerate the development of data-centric, interoperable Industrial IoT solutions so they can seize the massive innovation potential of Industry 4.0 and gain a competitive technological and competition advantage.

RESOURCES

Big data and IoT are enabling industrial process transformation. Intel and its ecosystem partners deliver industrial solutions optimized for scalable Intel® architecture, designed to reliably interoperate with the entire industrial environment.

Intel® Internet of Things Solutions Alliance
Members of the Intel® Internet of Things Solutions Alliance provide the hardware, software, firmware, tools, and systems integration that developers need to take a leading role in IoT.

Intel's Edge Insights for Industrial
Taking advantage of modern microservices architecture, this solution integrates data from sensor networks, operational sources, external providers, and industrial systems, and allows machines to communicate interchangeably across different protocols.

Intel® Smart Edge
This multi-access edge (MEC) platform for industrial use cases for on-premise enterprise deployments that require low latency, private mobility, simplicity, and open architecture.

Light-Guidance and the Intel® Connected Logistics Platform (Intel® CLP)
This pre-certified track-and-trace solution is designed to help companies of all sizes ease warehouse management in the supply chain, combining elements smart tags, a proprietary Wireless Sensor Network, Intel® technology-based smart gateways, and an optional smartphone application.

Intel® IoT Gateway Development Kits
Intel IoT Gateway development kits enable solution providers to quickly develop, prototype, and deploy intelligent gateways. Available for purchase from several vendors, the kits also maintain interoperability between new intelligent infrastructure and legacy systems, including sensors and data center servers.

For more information about Intel® solutions for industrial automation, visit **intel.com/industrial.**