The Role of 5G in Private Networks for Industrial IoT

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Global economic output in 2035 enabled by 5G in the following five categories:

- Manufacturing: $3,364B
- Transport: $659B
- Construction: $742B
- Utilities: $273B
- Mining: $249B

> $5 Trillion

1. "The 5G economy: How 5G technology will contribute to the global economy" by IHS Economics / IHS Technology
Container ports

Real-time asset tracking

Local management for low latency and protection of sensitive data

On-premise compute and storage

Seamless interworking with public network

5G NR Private network

AR-guided execution
Global economic output in 2035 enabled by 5G in the following five categories:

- **Wind farms**
  - Turbine sensor
  - Blade sensors
  - Environmental sensors
  - Handheld computing
  - Vehicle tracking

**1. “The 5G economy: How 5G technology will contribute to the global economy” by IHS Economics / IHS Technology**

The 5G economy will drive significant growth across various sectors, with a particular focus on enhancing efficiency and productivity in industries such as utilities, mining, construction, transport, and manufacturing. The integration of 5G technology promises to revolutionize these sectors, leading to increased economic output and improved operational capabilities. For instance, drone inspection and monitoring systems will become more prevalent, enabling detailed and comprehensive assessments of infrastructure and assets. Additionally, the adoption of handheld computing devices will facilitate real-time data analysis and decision-making, while environmental sensors will help monitor and manage resources more effectively. Overall, the 5G economy is poised to transform the global landscape, fostering innovation and economic growth.
1. "The 5G economy: How 5G technology will contribute to the global economy" by IHS Economics / IHS Technology

Global economic output in 2035 enabled by 5G in the following five categories:

- **Process Monitoring**
  - Latency: 100 ms
  - Availability: 99.99%
  - Rate: kbps

- **Sensors**
  - Latency: 10 ms
  - Availability: 99.9999%
  - Rate: Mbps - kbps

- **Handheld terminal**
  - Augmented Reality
    - Latency: 10 ms
    - Availability: 99.9%
    - Rate: Gbps-Mbps

- **Head mounted display**
  - Safety functions
    - Latency: 10 ms
    - Availability: 99.9999%
    - Rate: Gbps-Mbps

- **Industrial robot**
  - Enhanced mobile broadband
    - Latency: 1 ms
    - Availability: 99.9999%
    - Rate: Mbps-kbps

- **Security camera**
  - Latency: 50ms
  - Availability: 99.9%
  - Rate: Mbps

- **Automated guided vehicle (AGV)**
  - Latency: 20ms
  - Availability: 99.9999%
  - Rate: Mbps

- **Motion control**
  - Latency: 1 ms
  - Availability: 99.9999%
  - Rate: Mbps-kbps

- **Edge computing and analytics**
  - Latency: 50ms
  - Availability: 99.9%
  - Rate: Mbps

**Utilities**
- $273B

**Mining**
- $742B

**Construction**
- $659B

**Transport**
- $3,364B

**Manufacturing**
- $249B
5G takes Industry 4.0 to the next level

- Single futureproof 5G network
- Scalable capacity and reliability
- Flexibility with wireless Ethernet

Connectivity | Security | Compute

- On-device processing and sensing
- CV and AI for autonomous machines
- Edge services and data privacy

Industry 1.0
Mechanization

Industry 2.0
Electrification

Industry 3.0
Digitalization

Industry 4.0
5G Connectivity
Driving the 5G roadmap and ecosystem expansion

**Rel-15**
- Commercialization
- eMBB deployments in both mmWave and sub-6 GHz.

**Rel-16**
- Commercialization
- New 5G NR technologies to evolve and expand the 5G ecosystem
- Expanded ecosystem:
  - Industrial IoT with eURLLC, 5G NR C-V2X...
  - Boundless XR...

**Rel-17+** evolution
- Continued evolution
- Integrated Access and Backhaul, Unlicensed/shared spectrum,...
- Continued eMBB evolution

Continue to evolve LTE in parallel as essential part of the 5G Platform

*Smartphone formfactor*, Connected laptops, CPE fixed access
*Private network, industrial IoT, Indoor mmW for enterprises, Boundless XR*...

Timeline:
- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023+
Scalable wireless connectivity on a future proof platform

Dedicated and reliable networks optimized for local services

Capabilities for new use cases e.g. wireless Industrial Ethernet

Private 5G network

Licensed, shared and unlicensed Spectrum

Ultra Reliable Low Latency Communication (URLLC)

Time Sensitive Networking (TSN)

Positioning

Designing 5G to meet industrial IoT requirements
5G NR supports many industrial IoT use cases today; 3GPP Rel-16 brings additional capabilities.
Private networks
(non-public networks)
Private 5G networks for Industrial IoT use cases

Optimized
Tailored for industrial applications, e.g., QoS, latency

Dedicated
Local network, easy to deploy, independently manage

Secure
Cellular grade security and keeping sensitive data local

Optimizing private LTE for Industrial IoT today
New opportunities and scalability with 5G NR capabilities
3GPP roadmap with regular releases providing new features

1. Also referred to as non-public network (NPN)
Multiple private network architectures for flexible deployments

1. There are different levels of integration of public and private network architectures, e.g., shared RAN, shared control plane, shared user plane. This example shows shared control plane.
Spectrum for private 5G networks
Multiple spectrum options for Private 5G NR networks

Licensed spectrum owned by mobile network operators
Operators can allocate spectrum in a specific area for industrial IoT (e.g., mines)

Dedicated spectrum with optional synchronized sharing
In some region's spectrum is dedicated for industrial IoT use (e.g., 3.7GHz Germany).

Unlicensed spectrum with asynchronous sharing
NR-U with asynchronous sharing can be used for private 5G networks that do not require eURLLC

Unlicensed spectrum with synchronized sharing
Synchronized sharing can provide significant capacity gains and eURLLC
5G NR in unlicensed spectrum (NR-U) part of 3GPP R16
For wide range of deployments – also opportunity for new sharing paradigms

Asynchronized sharing
Evolutionary path: existing coexistence rules in unlicensed spectrum

Synchronized sharing
Revolutionary path: new rules for time synchronized sharing in unlicensed and shared spectrum

Time synchronization
Provides great potential to share spectrum more efficiently

5G CoMP
Predictable sharing
Spatial sharing
Synchronized sharing vital for many IIoT applications

5G CoMP
- Key enabler for ultra-reliable low latency communication (eURLLC)
- Significantly increased network capacity

Predictable sharing
- Prioritized resources for each deployment → predictable quality of service (QoS)
- Opportunistic sharing of unused resources

Spatial sharing
- Spatial division multiplexing can enable adjacent deployments to simultaneous use of the same spectrum
- Increased network capacity

Synchronized sharing
Revolutionary path: new rules for time synchronized sharing in unlicensed and shared spectrum
Unlicensed spectrum can support demanding industrial IoT

URLLC services feasible using synchronized sharing in controlled environments and today’s regulation rules

Today, unlicensed spectrum offers unpredictable QoS

Regular LBT\(^1\) using random access results in unpredictable Quality of Service (QoS), e.g., latencies

In controlled environments, QoS become more predictable

No interference from other networks, but still random access within the private network

Synchronized sharing support predictable QoS and CoMP

Today’s regulation includes FBE\(^2\), which support predictable QoS and CoMP—a key technology for URLLC

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1. Listen before talk (LBT) with load based equipment rule (LBE), such as CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance); 2. Frame Based Equipment
Synchronized sharing—opportunity to share more efficiently

Example USA 6 GHz

New 6 GHz unlicensed band in USA; allocate a portion where time synchronized operation has priority

If no networks use time sync. in the allocated portion, the entire 6GHz band is shared as usual

If a network use time sync. in the allocated portion, then others must be time sync. compatible to operate in this portion

1) Proposal included in Qualcomm's comments to the FCC Notice of Proposed Rulemaking.
eURLLC

Enhanced ultra-reliable low latency communication
5G NR provides flexibility to reach millisecond latencies

- **Wide-area**
  - e.g., FDD 700 MHz

- **Indoor/Outdoor**
  - e.g., TDD 3-7 GHz

- **mmWave**
  - e.g., TDD 28 GHz

**Example**

Based on 30 kHz SCS

**Lower latency from...**

- Shorter slot with higher subcarrier spacing (SCS)
- Fast UE processing with data + control in same slot
- Mini-slots allowing DL and UL data in same slot
- Flexible slot structure with fast DL/UL switching
- Using CoMP to avoid re-transmissions
5G CoMP achieves ultra-reliability

Spatial diversity for eURLLC\(^1\) to reach 99.9999% reliability\(^2\)

Coordinated Multi Point (CoMP) creates spatial diversity with redundant communication paths

1. Enhanced ultra-reliable low latency communication; 2. A performance requirements for communication service availability in 3GPP TS 22.104; 3. Transmission/Reception Point

- Other diversity methods such as frequency and time diversity are not sufficient for URLLC
- CoMP is facilitated by denser deployment of small cells with high bandwidth backhaul
TSN
Time Sensitive Networking—
a collection of IEEE 802.1Q standards
5G adds support for TSN Ethernet adaptation and QoS

- TSN defines adapters for interworking with TSN devices and systems.
- TSN adapter maps TSN configurations to 5G QoS framework.
- TSN adapter provides Ethernet functions such as loop detection.
- 5G provides efficient transport of Ethernet frames via header compression.
5G adds support for TSN time synchronization with gPTP

Industrial operation require microsecond accurate time to each device

5G provides precise synchronization to a common 5G system time

Computation of correction field for gPTP timestamp and interworking

5G Rel-16 can interwork with existing wired TSN systems without changes
Positioning
3GPP Rel-16 introduces 5G NR positioning

Multiple positioning technologies
Industrial IoT specific use case requirements, e.g., 20 cm for logistics

- Round trip time
- Time difference of arrival
- Angle of arrival
- New positioning reference signals
- New industrial IoT channel model

Sensor fusion
Improving accuracy with sensor fusion and on-device processing

Network
- Cloud data
- GNSS
- Uplink positioning

On-device
- Accelerometer
- Gyroscope
- Compass
- Computer vision

1. One of the performance requirements in 3GPP TS 22.104
5G Industrial IoT testbed to drive and track progress in standards

Over-the-air testbed to demonstrate new IIoT functionality such as CoMP, eURLLC, and TSN
Demonstrations of 5G CoMP at MWC Barcelona 2019

5G CoMP for capacity

Synchronized sharing with 5G CoMP in shared/unlicensed spectrum provides higher network capacity and perceived data speeds.

With synchronized sharing, adjacent deployments to simultaneous use of the same spectrum.

5G CoMP for ultra-reliability

Industry-first demo of 99.9999% ultra-reliability in a 5G NR over-the-air testbed using CoMP

5G CoMP provides spatial diversity that can overcome blocking in challenging radio environments

1) One of the performance requirements in 3GPP TS 22.104
Strong industry collaboration around 5G Industrial IoT

Kickstarted 5G for Industrial IoT with 10+ live ecosystem demonstrations at Hannover Messe 2019 based on Rel-15

Research collaboration with Bosch announced Feb. 2019

5G Alliance for Connected Industries and Automation (5G-ACIA)—advancing 5G for the industrial domain
Extending 5G to industrial IoT

5G can serve many industrial IoT applications today and 3GPP Rel-16 bringing additional functionality such as eURLLC for wireless industrial Ethernet

Multiple spectrum options

There are multiple deployment and spectrum options for private 5G industrial IoT networks with NR-U being part of 3GPP Rel-16.

Summary

Synchronized sharing

Synchronized sharing support industrial IoT in unlicensed spectrum (e.g. 5GHz & 6GHz) and sharing dedicated spectrum (e.g. 3.7GHz Germany)

5G testbeds to drive standard

Utilizing over-the-air testbeds with our 5G NR mobile test devices to research new functionality, e.g. 5G CoMP, and to drive and track progress in standard
Thank you

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