Qualcomm

Qualcomm webinar

23 June 2022

Realizing mission-critical industrial automation with 5G

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Qualcomm Technologies, Inc

@QCOMResearch

5G Accelerating Globally

210+
Operators with 5G commercially deployed

275+
Additional operators investing in 5G

750M+
5G smartphones to ship in 2022

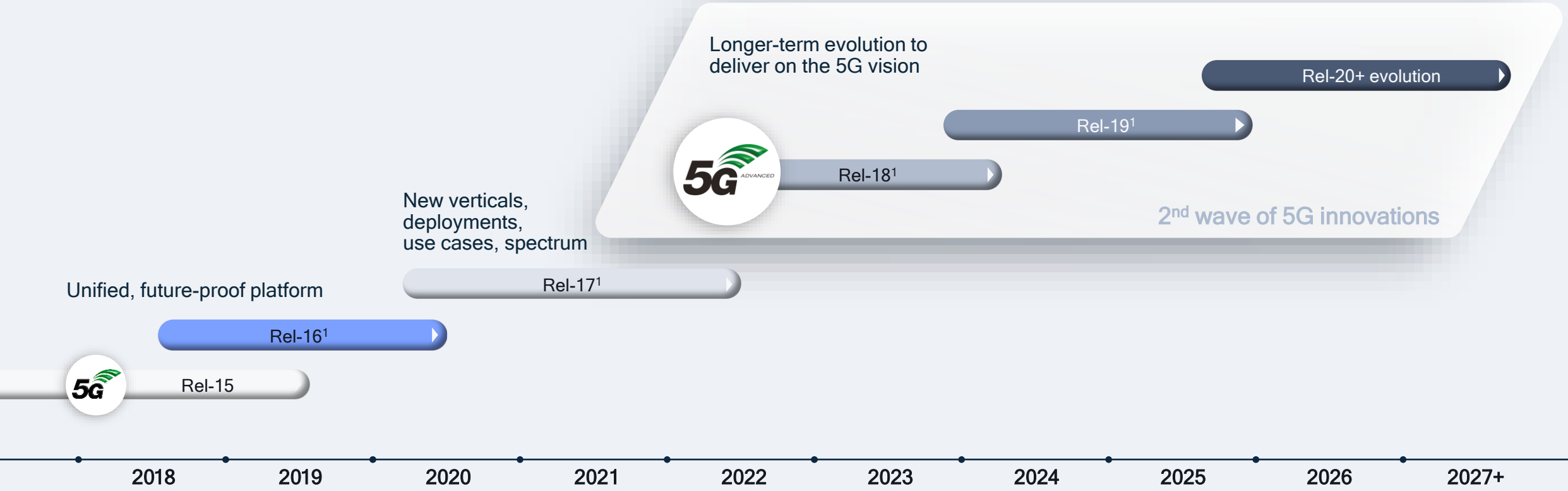
1B+
5G connections by 2023 – 2 years faster than 4G

5B+
5G smartphones to ship between 2020 and 2025

1,330+
5G designs launched or in development

Sources – 5G commercial networks, operators investing in 5G: GSA, May '22. 5G device shipment projections: Qualcomm estimates, Feb '22. 2023 5G connection projections: average of ABI (Sep '21), Ericsson (Jun '21) and GSMA Intelligence (Sep '21). 5G cumulative smartphone shipments: average of CCS Insight (Sept '21), Counterpoint Research (Dec '21), IDC (Nov '21), Strategy Analytics (Oct '21); Launched / announced devices: GSA, May '22.

Driving 5G Advanced for a full decade of 5G technology evolution



Rel-15 eMBB focus

- 5G NR foundation
- Sub-7 and mmWave
- Scalable & forward compatible
- Basic URLLC support
- mMTC via eMTC & NB-IoT

Rel-16 industry expansion

- Unlicensed spectrum (NR-U)
- IIoT with enhanced URLLC
- Integrated access/backhaul
- Sidelink (NR V2X), positioning
- Private network
- 5G broadcast
- eMTC/NB-IoT w/ 5G core
- Enhanced MIMO, device power, CA/DC, mobility

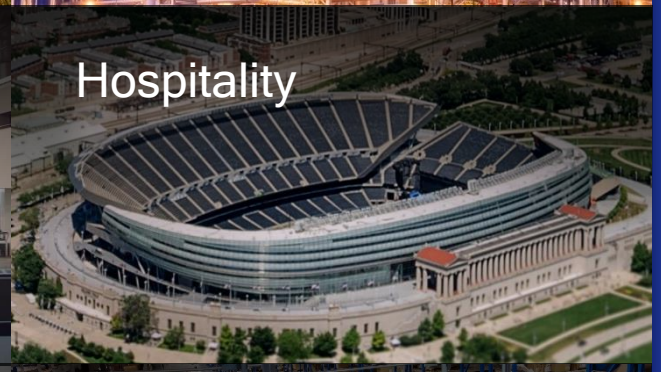
Rel-17 continued expansion

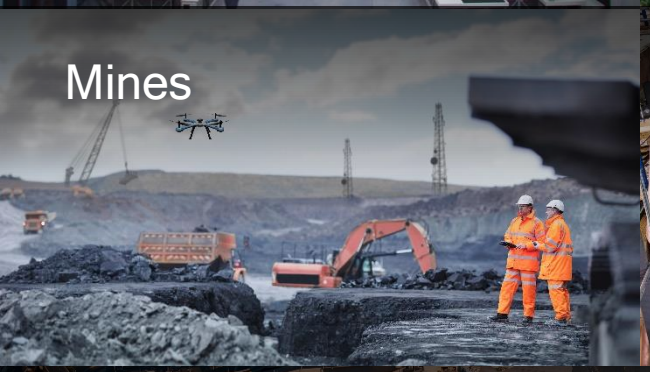
- Lower complexity NR-Light (RedCap)
- mmWave extension to 71GHz
- Non-terrestrial communication (satellites):
- Improved IIoT, positioning, V2X
- Enhanced IAB, RF repeaters

Rel-18+ 5G-Advanced

- NR-Light evolution
- Full duplex
- Wireless AI/ML
- Boundless XR
- Green networks

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1





5G private networks will expand the market

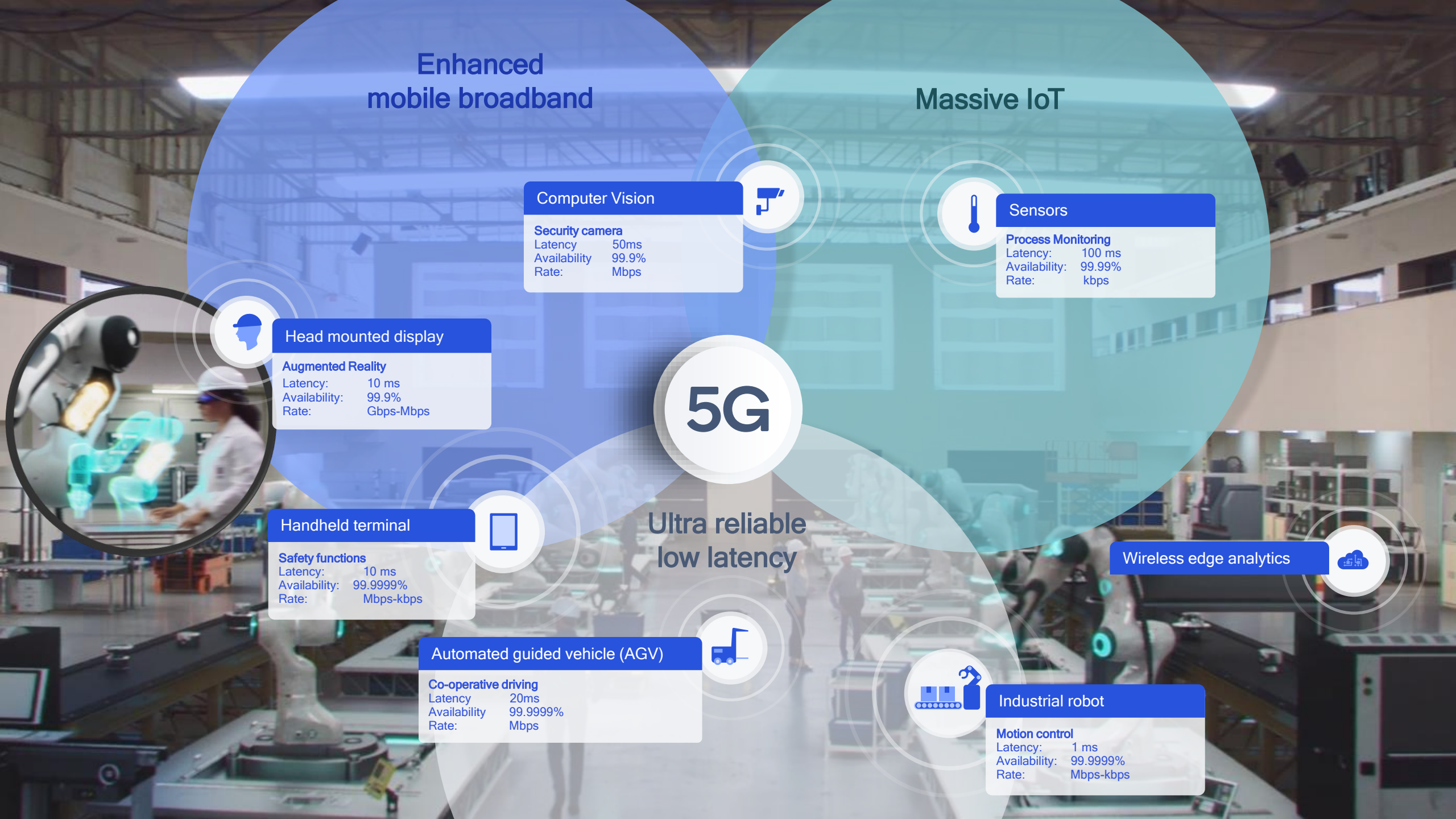
Wide range of industries from manufacturing and seaports to venues and enterprise

>$3.5B

global private LTE/5G market size by 2026 [1]

18% CAGR

1. Mobile Experts, “Private LTE/5G 2021” (Feb. 2021)


Enhanced mobile broadband
Massive IoT
Computer Vision
Security camera
Latency 50ms
Availability 99.9%
Rate: Mbps
Sensors
Process Monitoring
Latency: 100 ms
Availability: 99.99%
Rate: kbps
Head mounted display
Augmented Reality
Latency: 10 ms
Availability: 99.9%
Rate: Gbps-Mbps
5G
Ultra reliable low latency
Handheld terminal
Safety functions
Latency: 10 ms
Availability: 99.9999%
Rate: Mbps-kbps
Wireless edge analytics
Automated guided vehicle (AGV)
Co-operative driving
Latency 20ms
Availability 99.9999%
Rate: Mbps
Industrial robot
Motion control
Latency: 1 ms
Availability: 99.9999%
Rate: Mbps-kbps

5G private networks poised for growth

Growing momentum with early commercial deployments

A vibrant, global ecosystem led by 5G-ACIA, ready to scale

Comprehensive support for 5G private networks in 3GPP Rel-16

Ford
26 Oct. 2021

AT&T brings private 5G network, MEC to Ford's new electric vehicle factory

https://www.rcrwireless.com/20211026/5g/att-brings-private-5g-network-mec-to-fords-new-electric-vehicle-factory

Ferrovial
6 Oct. 2021

Ferrovial deploys one of the world's first 5G SA private wireless networks for its Silvertown Tunnel Construction site

https://newsroom.ferrovial.com/en/news/ferrovial-5g-in-silvertown/

Cologne Bonn Airport
25 May 2021

5G Network for Cologne/Bonn

https://www.cologne-bonn-airport.com/en/press/press-releases/5g-network-for-colognebonn.html

Agnico Eagle Finland
15 Mar. 2021

Telia to build a private 5G network for the Kittilä mine

https://agnicoeagle.fi/telia-to-build-a-private-5g-network-for-the-kittila-mine/

East-West Gate (EWG) terminal
2 Oct. 2021

Europe's first 5G railway terminal is being built in Hungary

https://dailynewshungary.com/europes-first-5g-railway-terminal-is-being-built-in-hungary/

Ban Chang Smart City
23 May 2021

Thailand's Ban Chang Smart City deploys Private 5G Network

https://www.convergedigest.com/2021/05/thailands-ban-chang-smart-city-deploys.html

Lawrence J. Ellison Institute
12 May 2021

USC cancer research center plans private 5G network

https://www.techrepublic.com/article/usc-cancer-research-center-plans-private-5g-network/

ASE
18 Aug. 2020

Chunghwa Telecom, ASE and Qualcomm Jointly Introduce Made-in-Taiwan Small Cell Base Stations for the First 5G mmWave Smart Factory in Taiwan

https://ase.aseglobal.com/en/press_room/content/5g_smart_factory_en

5G-Alliance for Connected Industries and Automation (5G-ACIA)

Ensure the best possible applicability of 5G technology for connected industries, in particular the manufacturing and process industries

Manufacturing and process operators	Technology providers	Network operators	Spectrum advocacy	Collaboration with global industry bodies

A joint communication and positioning/sensing technology platform for Industry 4.0

5G

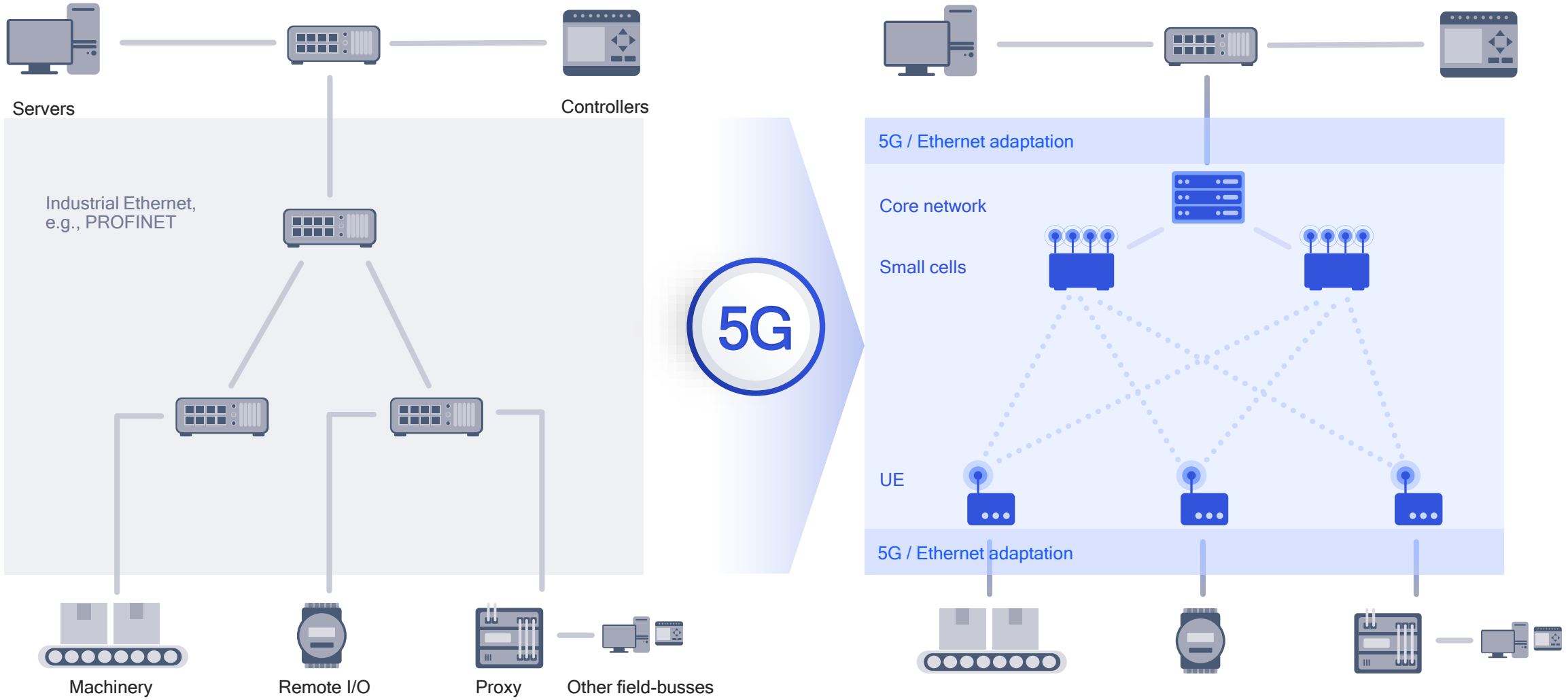
- Private 5G network
- Ethernet and Time Sensitive Networking (TSN)
- Ultra Reliable Low Latency Communication (URLLC) and 5G Sidelink
- Precise positioning
- Licensed, shared and unlicensed Spectrum

Dedicated and reliable networks optimized for local services

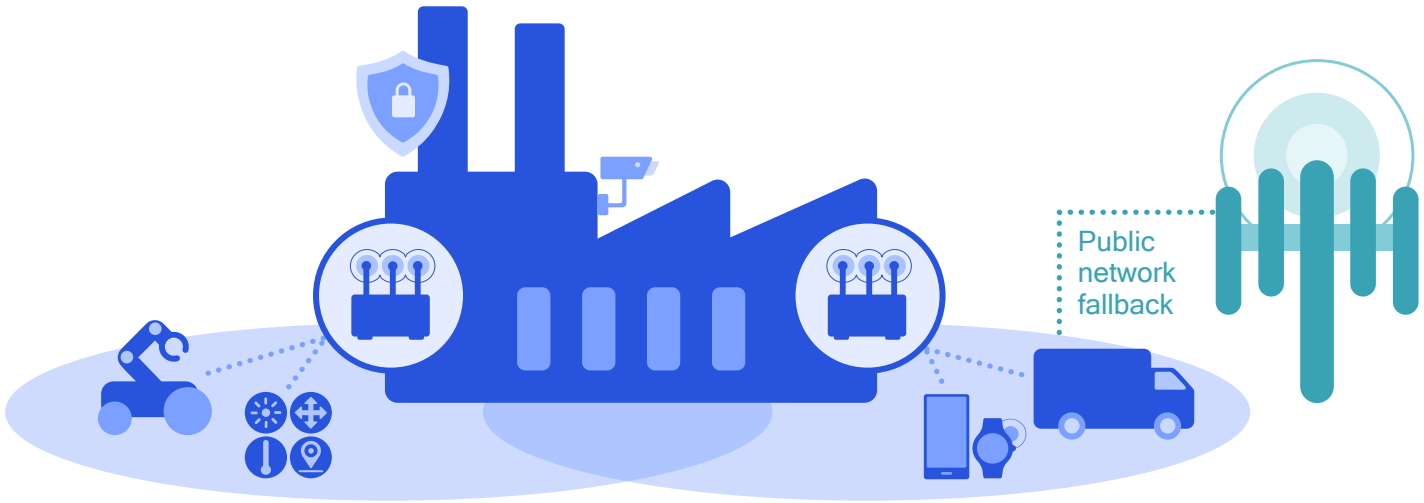
Scalable wireless connectivity on a future proof platform

Capabilities for new use-cases e.g., seamless mobility with wireless Industrial Ethernet

Upgrading existing industrial networks with wireless 5G



5G private networks bring benefits to industry and enterprise



Private network[1]

Dedicated

Local network, dedicated resources, independently managed

Secure

Cellular grade security, sensitive data stays on-premises

Optimized

Tailored performance for local applications, e.g., low latency, QoS[2]

5G

Coverage, capacity, and mobility

Outdoor/indoor, high data speeds, seamless handovers, public network fallback

Reliability and precise timing

Industrial grade reliability, latency and synchronization (eURLLC[3] and TSN[4])

Interoperability

Global standard, vast ecosystem, future proof with rich 5G roadmap

1. Also referred to as non-public network (NPN); 2. Quality of service; 3. Enhanced ultra-reliable low-latency communication; 4 Time sensitive network

Licensed spectrum

Exclusive use

Over 40 cellular bands globally to date

Shared spectrum

New spectrum sharing paradigms

Example: 2.3 GHz Europe / 3.5 GHz USA

Unlicensed spectrum

Shared use

Example: 2.4 GHz / 5 GHz / 60 GHz global

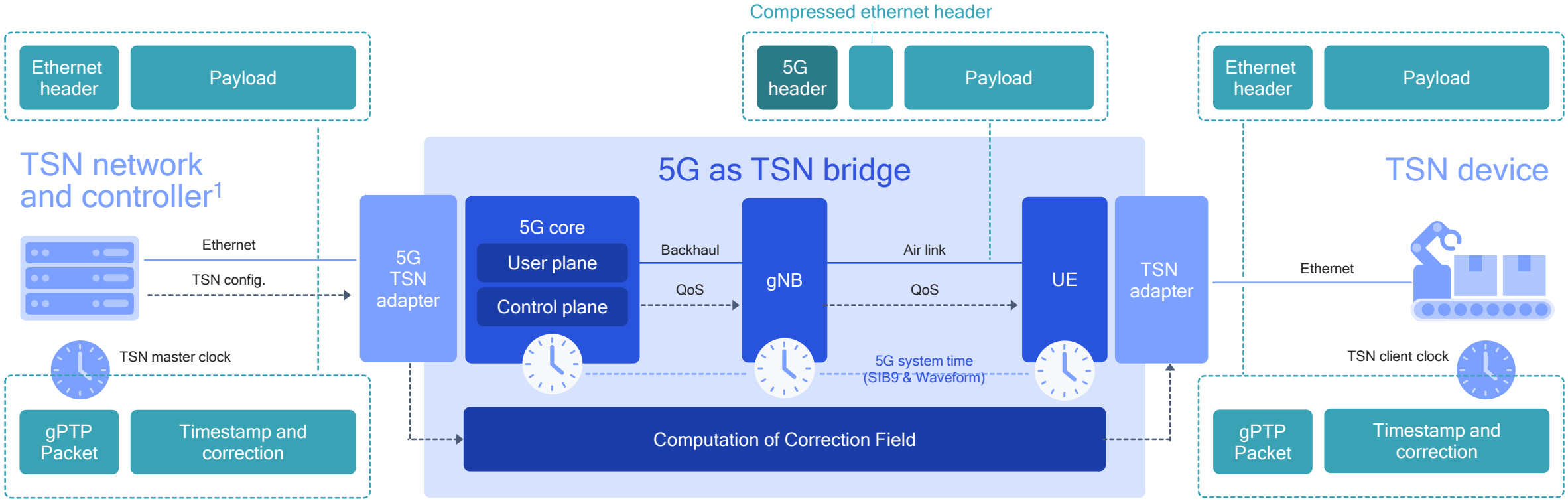
5G leverages all types of spectrum from a single standard with a global ecosystem

Global snapshot of spectrum optimized for industrial IoT / vertical / private network use – local licensing or sharing

USA 	• 3.5 GHz CBRS, exclusive & shared licenses • 37 - 37.6 GHz shared spectrum/local licenses, under evaluation
Germany 	• 3.7 - 3.8 GHz • 24.25 - 27.5 GHz, local licenses
U.K. 	• 3.8 - 4.2 GHz • 1781.7-1785/1876.7-1880 MHz • 24.25 - 26.5 GHz, local licenses
Sweden 	• 1780-1785/1875-1880 MHz • 3720 - 3800 MHz • 24.5 - 25.1 GHz
Finland 	• 2300 - 2320 MHz • Sub-licensing of 3.4 - 3.8 GHz • 24.5 - 25.1 GHz
Netherlands 	• 3410 - 3450 MHz for local industrial use • 3750 - 3800 MHz available with restrictions • 2.3 - 2.4 GHz (licensed shared access online booking system)
France 	• 2575 - 2615 MHz • 26.5 - 27.5 GHz (test licenses)
Czech Republic 	• 3.4 - 3.6 GHz, 2*20 MHz, Allocated in 2020 with a leasing option
Brazil 	• 3.7 - 3.8 GHz, under consideration • 27.5 - 27.9 GHz, allocation completed
Chile 	• 3.75 - 3.8 GHz
Australia 	• 24.25 - 27.5 GHz and 27.5 - 29.5 GHz for local licensing • 3.7 - 4.0 GHz for local area wireless broadband licensing in 2022
New Zealand 	• Licenses in 2575 - 2620 MHz may be assigned for localized use
Malaysia 	• 26.5 - 28.1 GHz will be assigned for the deployment of local/private networks
Singapore 	• Each operator has acquired 800 MHz of 26/28 GHz spectrum to deploy local networks
Hong Kong 	• 24.25 - 28.35 (400 MHz) available for local licenses
Japan 	• Phase 1: 2,575 - 2,595 MHz (NSA anchor) and 28.2 - 28.3 GHz; local licenses • Phase 2: 1888.5 - 1916.6 MHz (NSA anchor), 4.6 - 4.9 GHz (4.6 - 4.8 GHz indoor only, 4.8 - 4.9 GHz outdoor possible) & 28.3 - 29.1 GHz (150 MHz outdoor; total 250 MHz 28.2 - 28.45 MHz); local license. • Uplink heavy TDD config. using semi-sync allowed in sub-6 & 28 GHz
South Korea 	• 28.9 - 29.5 GHz for 5G specialized local applications
Taiwan 	• 4.8 - 4.9 GHz for 5G local private and enterprise licenses

5G brings support for Time Sensitive Networking (TSN)

A requirement for industrial automation and many other industrial IoT applications



1 The TSN network is controlled by a Central Network Controller (CNC). TSN and CNC are defined in a set of standards specified by IEEE 802.1.

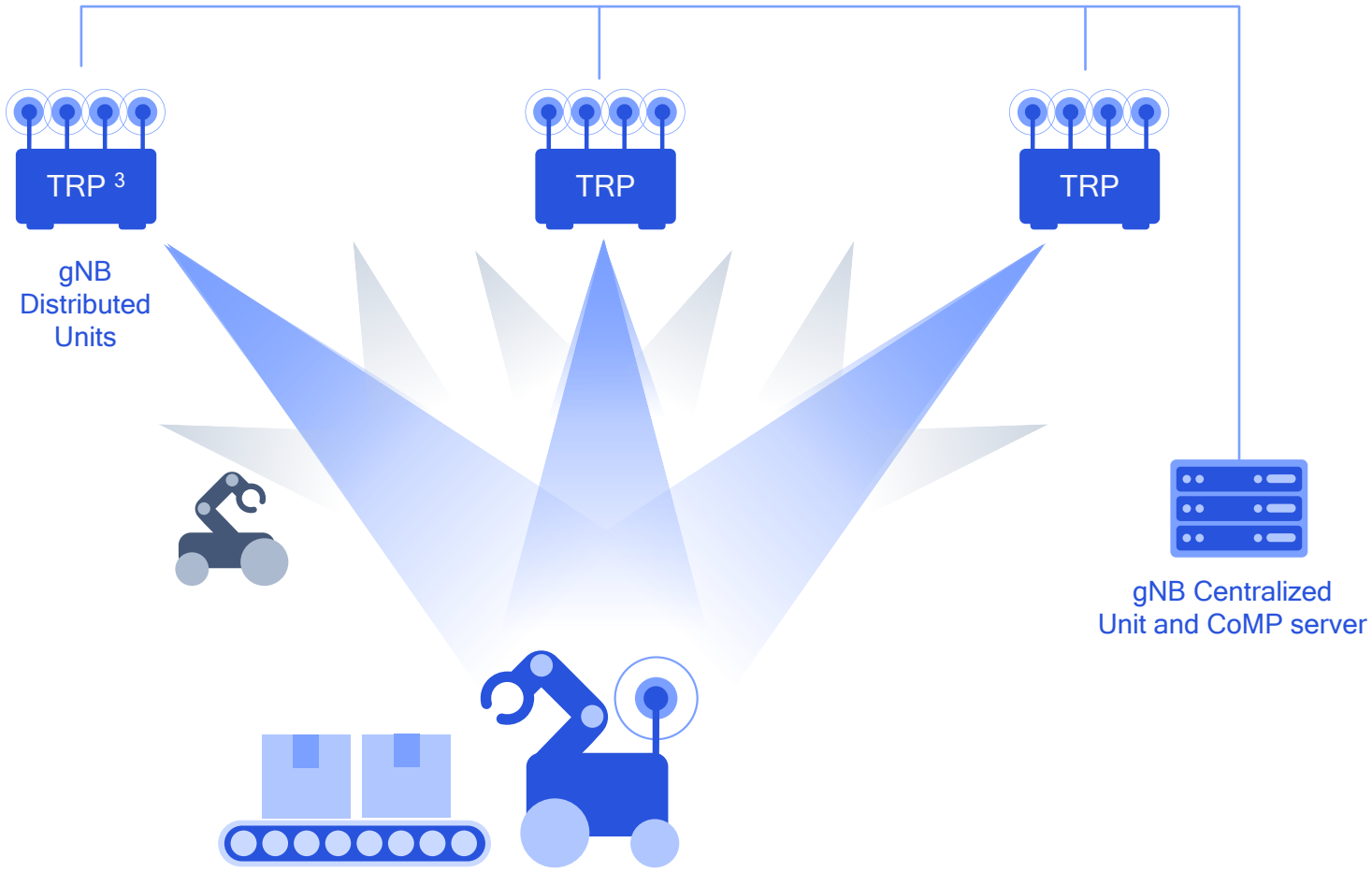
5G TSN adapters allow the 5G system to act as a TSN bridge with Ethernet connectivity

Mapping of TSN configurations to 5G QoS framework for deterministic messaging and traffic shaping

Precise time synchronization with generalized Precision Time Protocol (gPTP) at microsecond level

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

- 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

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

5G NR URLLC for new mission-critical services

A platform for tomorrow's more autonomous world

Ultra-low millisecond e2e latency

Faster, more flexible frame structure; also new non-orthogonal uplink access

High reliability targeting < 10^{-5} BLER[1]

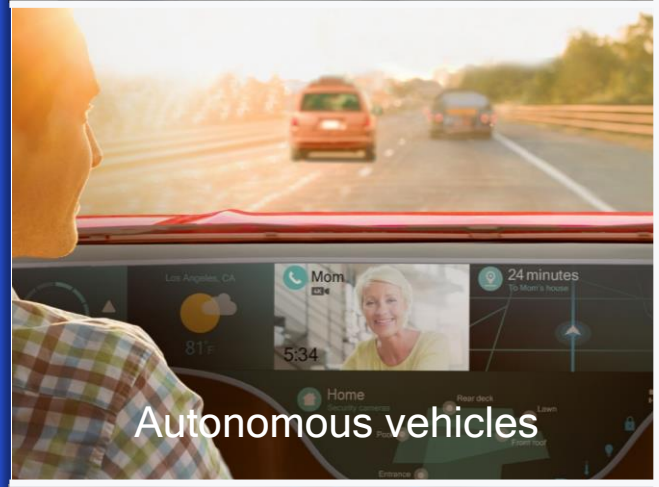
Ultra reliable transmissions that can be time multiplexed with nominal traffic through puncturing

High availability

Simultaneous links with dual connectivity for failure tolerance and extreme mobility

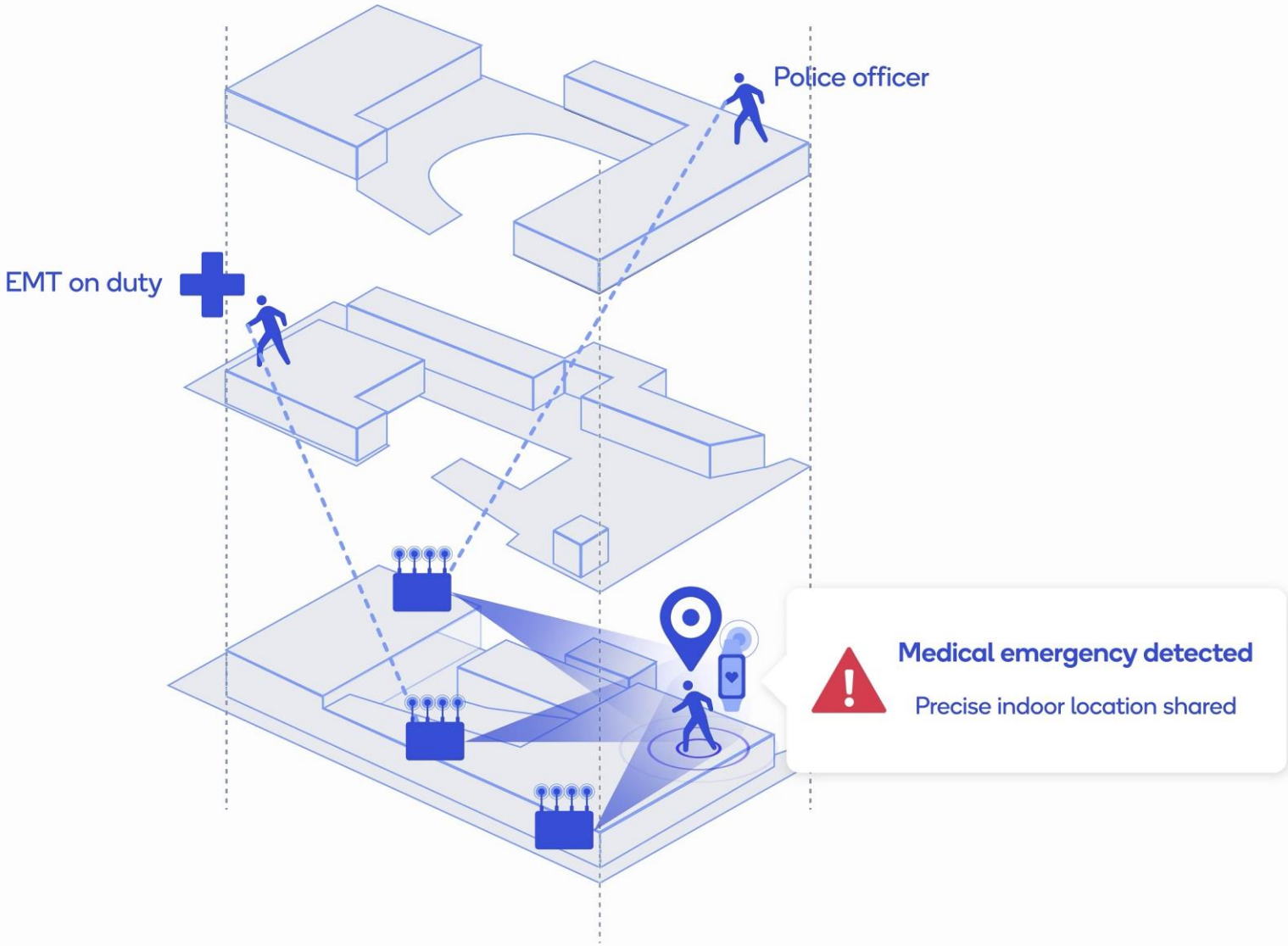
[1] Block Error Rate

Source sample text



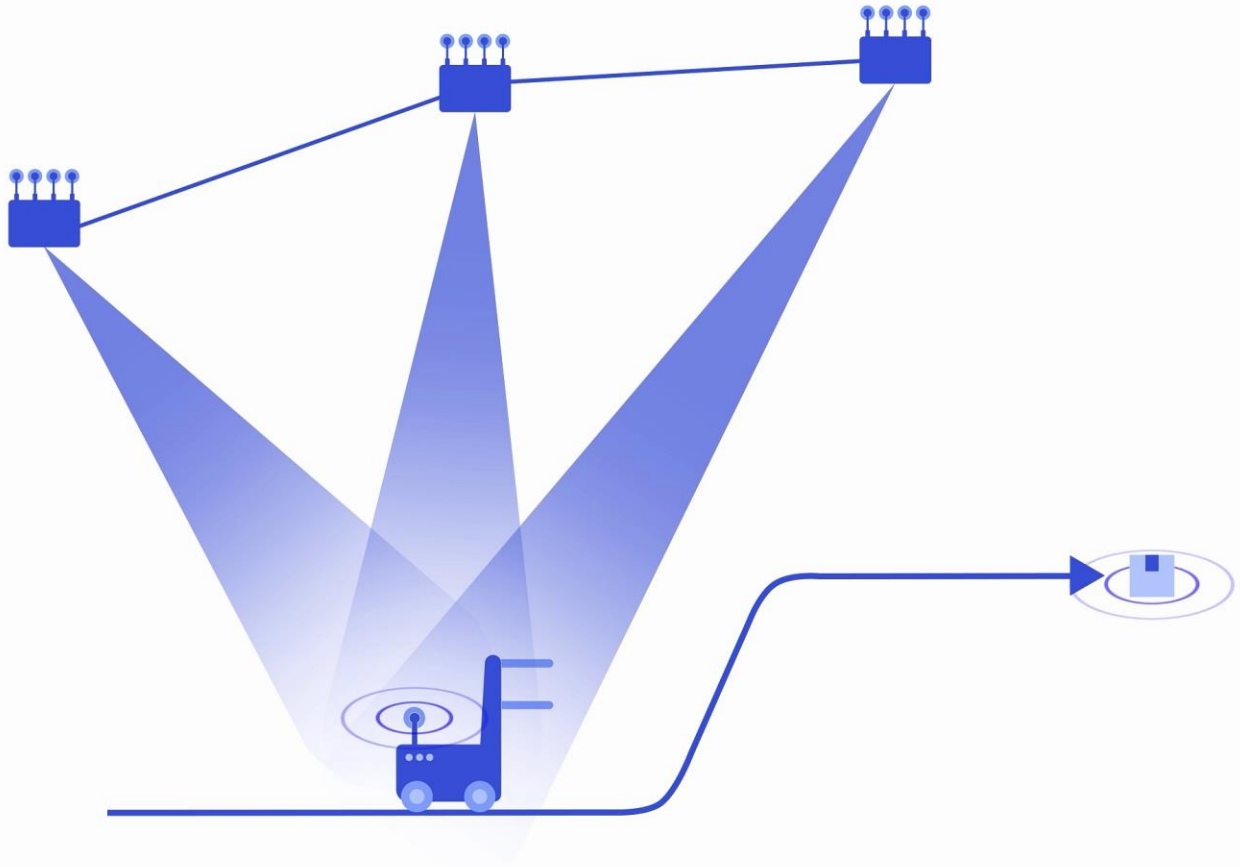
Indoor precise positioning has many industrial applications

Locating personnel in emergencies



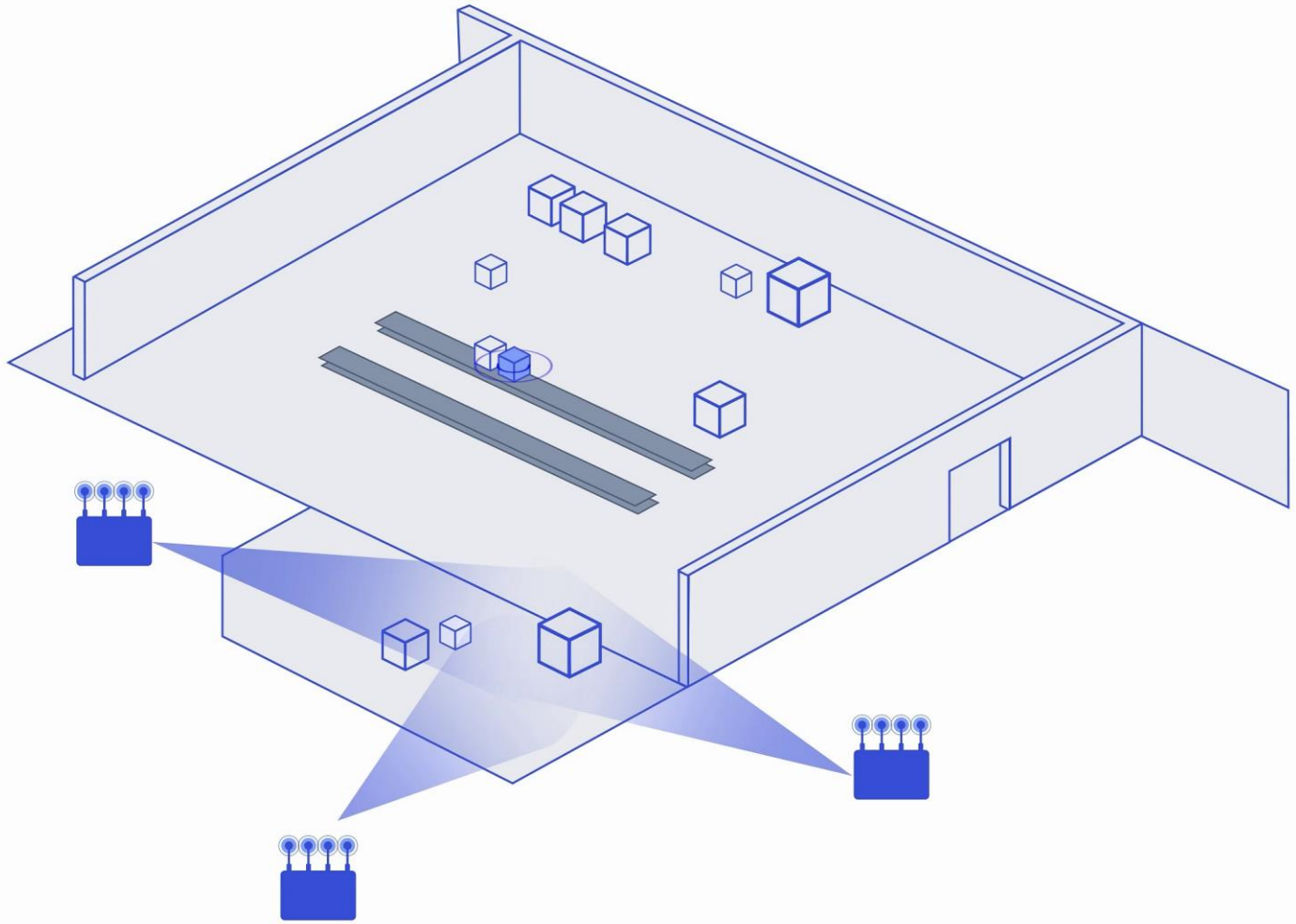
Indoor precise positioning has many industrial applications

Navigating automated guided vehicles (AGVs)



Indoor precise positioning has many industrial applications

Tracking assets and routing packages



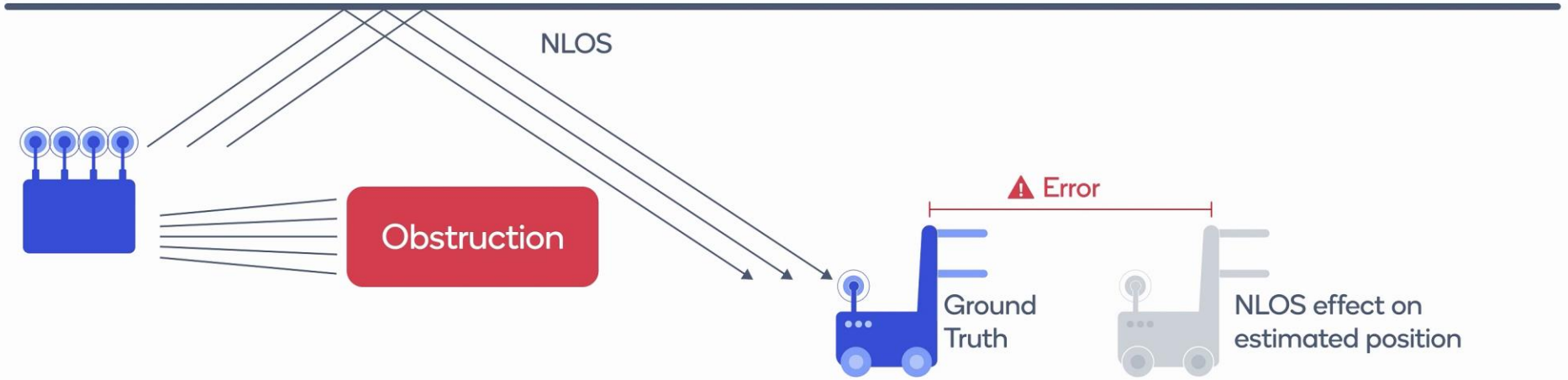
Industrial precise positioning needs good NLOS performance

Multipath

Numerous indoor surfaces generate multiple reflections

Non-line of sight (NLOS)

Variety of indoor obstructions block line of sight

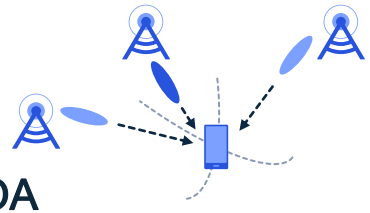


5G brings multiple positioning techniques

For different deployment scenarios and use-cases

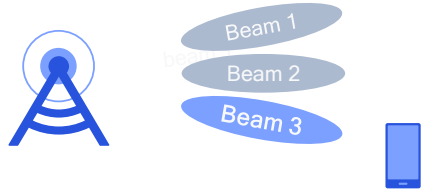
Cell-ID

The network reports the location of the cell-site serving the device or the centroid of its coverage



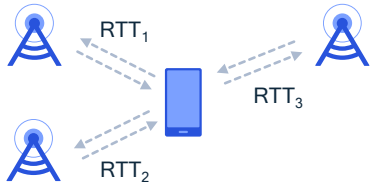
DL-TDOA

The device measures the time difference of arrival (TDOA) of downlink positioning reference signals (PRS) from different cells and cell-sites



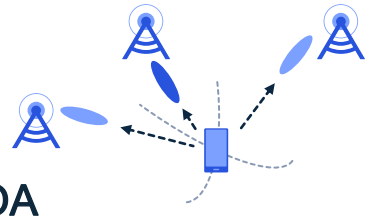
DL-AoD

The device measures and reports the strength with which it receives PRS for each beam, where the angle of the beam is known



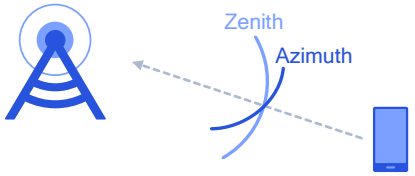
MC-RTT

Time differences between downlink PRS from multiple cells and uplink SRS are reported either by the cell-site or the device



UL-RTOA

The network measures the relative time of arrival (RTOA) of the device's sounding (SRS) from different cells and cell-sites



UL-AoA

The network measures the azimuth and zenith of arrival of SRS from the device relative to a reference direction

AoA: Angle of arrival; AoD: Angle of departure; DL: Downlink; MC: Multi-cell; ML: Machine learning; PRS: Positioning reference signals; RTT: Round-trip time; SRS: Sounding reference signals; UL: Uplink

Leveraging time of flight and angular resolution to deliver precise positioning

5G brings multiple positioning techniques

Mobile World Congress - Barcelona, 2022

Cell-ID

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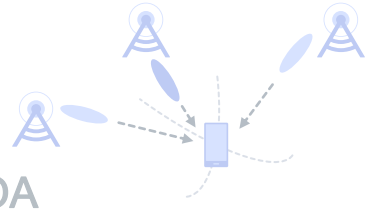

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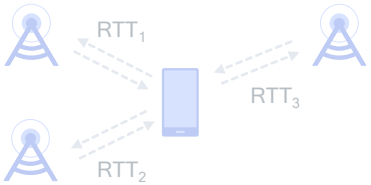

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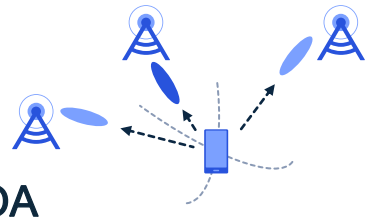

UL-RTOA

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Leveraging time of flight and angular resolution to deliver precise positioning

RF fingerprinting and ML-based algorithms further enhance accuracy

Pushing forward with the 5G positioning technologies

Release 16

Establishing foundation

Achieving accuracy of 3m/10m (indoor/outdoor) for 80% of time

Supporting RTT[1], AoA/AoD[2], TDOA[3], single-cell positioning

Including new evaluation scenarios, i.e., industrial IoT

Release 17

Enhancing performance

5G Positioning Evolution

Meeting centimeter-level absolute accuracy requirement of down to 0.3m

Reducing positioning latency to as low as 10 ms
Scaling to higher capacity for millions of simultaneous devices (e.g., IoT, automotive)

5G Advanced in Release 18+

Improving performance, expanding to new devices and deployments

Sidelink positioning and ranging

Defining reference signals, measurements, procedures for out-of-range, absolute and relative (e.g., ranging) sidelink positioning

Improved positioning performance

Specifying higher layer solutions for RAT[4] dependent positioning techniques, accuracy improvement based on PRS/SRS[5] bandwidth aggregation, carrier phase measurements, and positioning accuracy in heavy NLOS[6] with AI/ML

NR-Light[7] positioning

Setting performance requirements, evaluating performance for R17 positioning procedures, and identifying potential enhancements

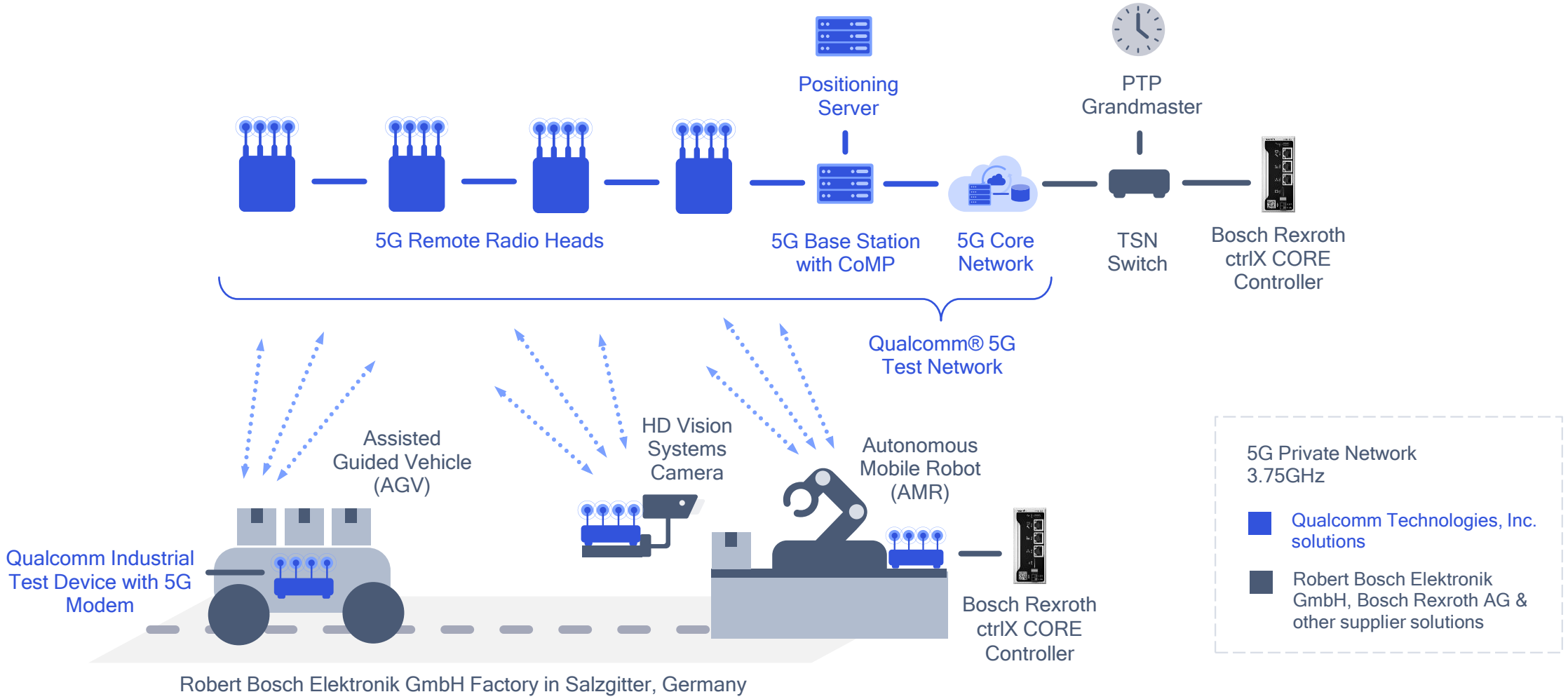
Source: RP-211660 Expanded and improved Positioning. 1. Roundtrip Time; 2. Angle of Arrival, Angle of Departure; 3. Time Difference of Arrival; 4. Radio Access Technology; 5. Positioning Reference Signal, Sounding Reference Signal; 6. Non-line of sight; 7. aka. RedCap

Qualcomm

rexroth A Bosch Company

BOSCH

Qualcomm Technologies, Inc. & Bosch Rexroth AG Showcase an End-to-End Industrial Solution for Time-Synchronized Applications. The Demo Installation at the Robert Bosch Elektronik GmbH Factory in Salzgitter, Germany, Showcases Ultra-Low Latency and Time-Synchronized Networking for an Autonomous Mobile Robot (AMR) and Positioning an Assisted Guided Vehicle (AGV) Over a Live 3.75GHz 5G Private Network.



Qualcomm | BOSCH | rexroth A Bosch Company

Mission-critical industrial automation over a live 5G private network

Click to watch the video

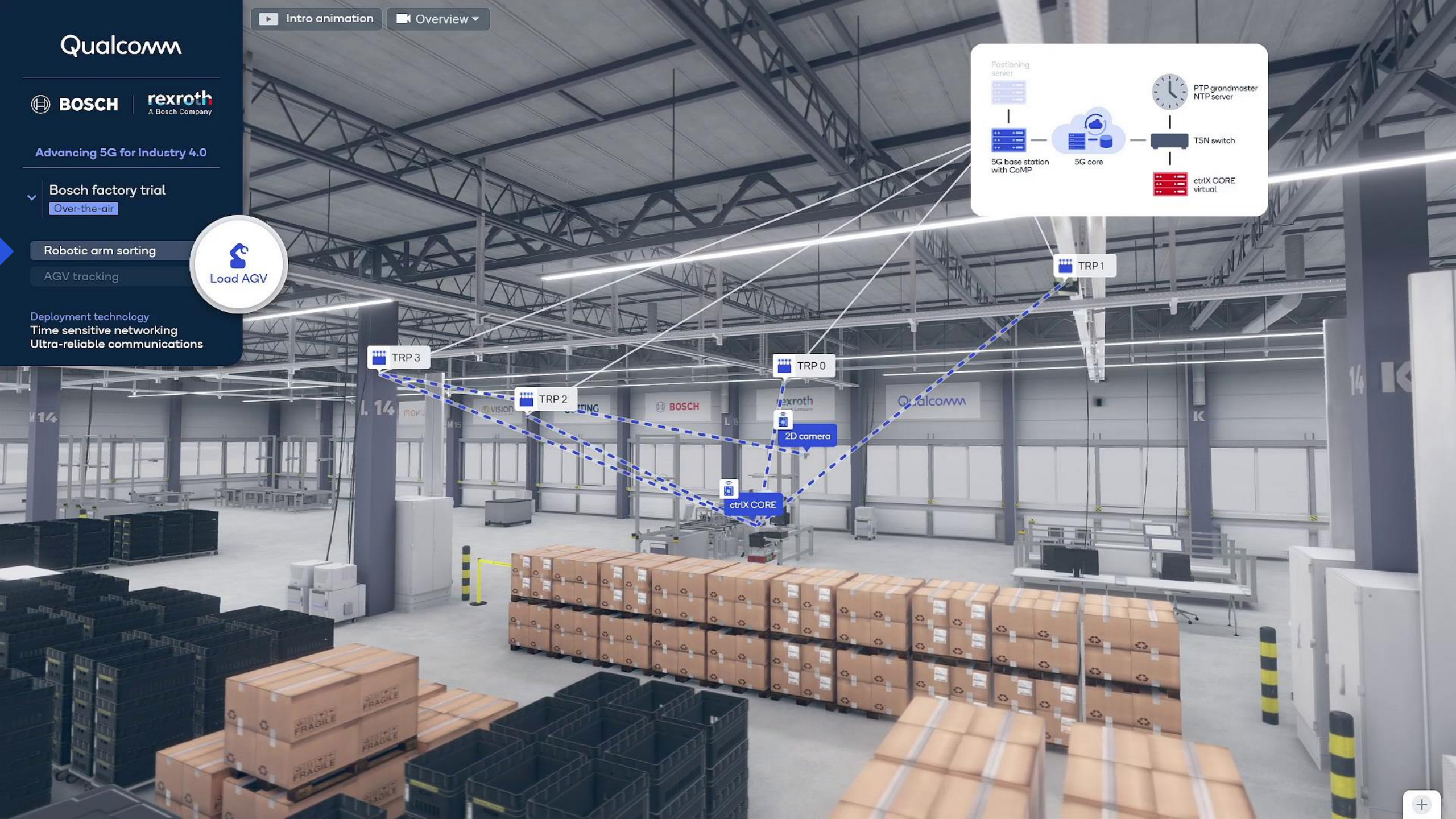
Robert Bosch Elektronik GmbH factory
Salzgitter, Germany

Qualcomm | BOSCH | rexroth
A Bosch Company

Advancing 5G for Industry 4.0

(click to play)

Demo


Intro animation
Overview
Qualcomm
BOSCH
rexroth
A Bosch Company
Advancing 5G for Industry 4.0
Bosch factory trial
Over-the-air
Robotic arm sorting
AGV tracking
Load AGV
Deployment technology
Time sensitive networking
Ultra-reliable communications
Positioning server
PTP grandmaster
NTP server
TSN switch
5G base station with CoMP
5G core
ctrlX CORE virtual
TRP 1
TRP 2
TRP 3
TRP 0
2D camera
ctrlX CORE

Intro animation | Overview

Qualcomm

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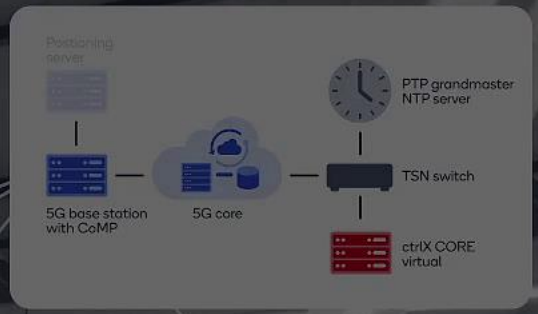


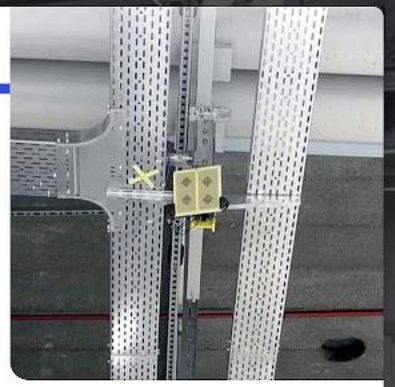
TRP 3

TRP 2

ctrlX CORE

5G TRP 1

- Directional antenna
- 4x4 MIMO capable
- 3.75 GHz frequency
- 100 MHz bandwidth



Intro animation

Qualcomm

BOSCH | rexroth A Bosch Company

Advancing 5G for Industry 4.0

Bosch factory trial

Over-the-air

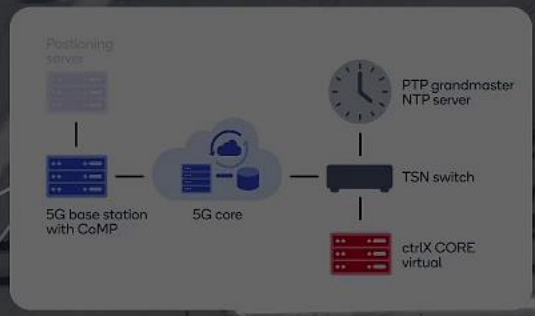
- Robotic arm sorting
- AGV tracking

Load AGV

Deployment technology
Time sensitive networking
Ultra-reliable communications

Robotic arm

- 6-axis industrial robot
- Low machine cycle time with movements reaching 11.1 m/s
- High-precision operation with ± 0.03 mm repeatability for up to 3.7 kg loads



TRP 1

TRP 0

Automation controller

Bosch Rexroth ctrlX CORE

- Ultra-compact Linux-based industrial control system
- Flexible and secure software scalability with apps
- Control system also capable of running as a virtualized software on server hardware

5G device

Qualcomm 5G R&D prototype

- Supports internal and external antennas
- 4 TRX antennas
- 4x4 MIMO capable
- 100 MHz bandwidth

Intro animation | Overview

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Advancing 5G for Industry 4.0

Bosch factory trial

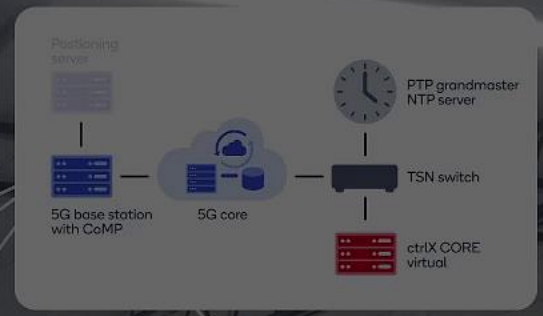
Over-the-air

Robotic arm sorting

AGV tracking

Load AGV

Deployment technology
Time sensitive networking
Ultra-reliable communications



2D camera

- 5.0 MP resolution 2D camera for industrial applications
- HD Vision Systems image processing app on ctrlX AUTOMATION to perform automatic optical inspection
- GigE Vision Control Protocol (GVCP) with PTP used to control camera and image server

TRP 1

5G device

Qualcomm 5G R&D prototype

- Supports internal and external antennas
- 4 TRX antennas
- 4x4 MIMO capable
- 100 MHz bandwidth

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Advancing 5G for Industry 4.0

Bosch factory trial

Over-the-air

- Robotic arm sorting
- AGV tracking

Deployment technology

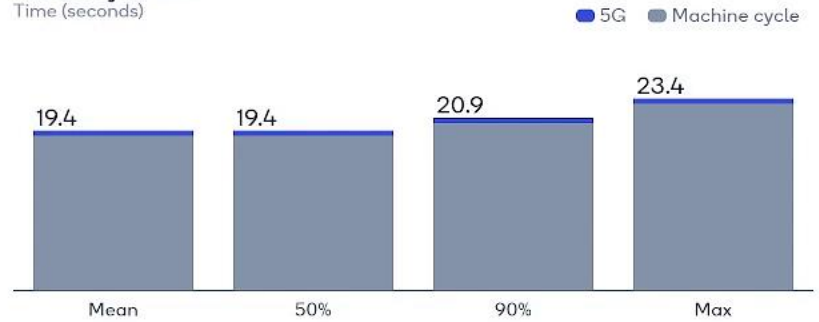
Time sensitive networking

Ultra-reliable communications

Intro animation | Robot arm

Process cycle time

Time (seconds)



Ultra-reliability

	Total packet errors	Total packet count
Uplink	0	24,000
Downlink	0	4,885

PTP time synchronization accuracy

Microseconds


Intro animation
Overview
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Robotic arm sorting
AGV tracking
Start AGV
Deployment technology
UL-TDOA 5G positioning
Postioning server
PTP grandmaster
NTP server
TSN switch
5G base station with CoMP
5G core
ctrlX CORE virtual
TRP 2
TRP 3
TRP 0
TRP 5
TRP 4
TRP 1
5G device

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UL-TDOA 5G positioning

Intro animation | AGV route

5G device

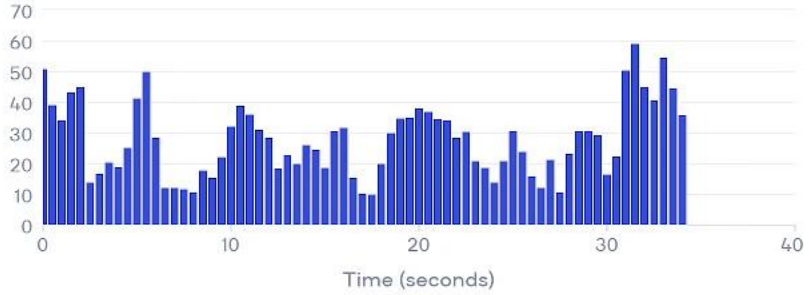
Ground truth

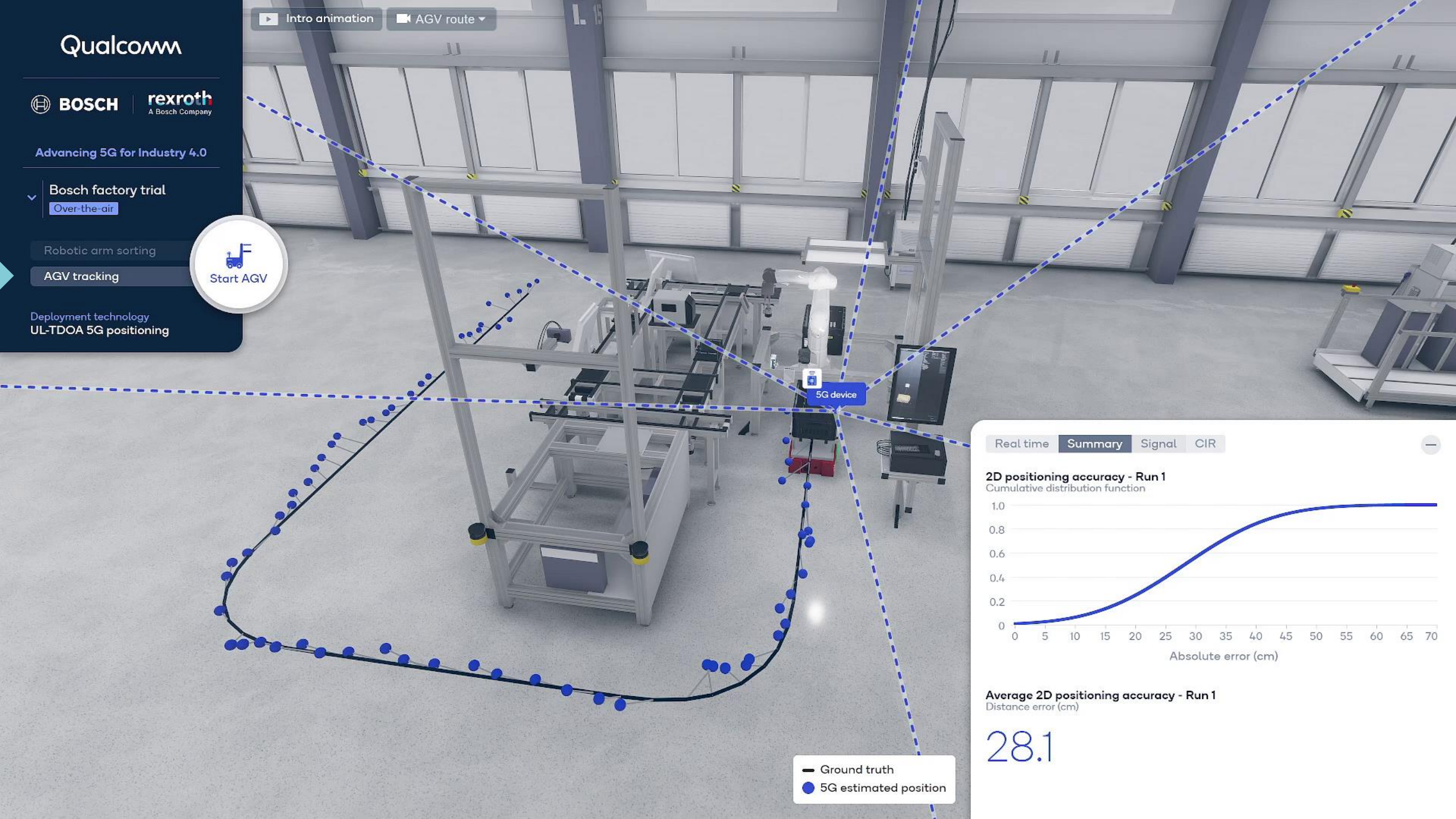
5G estimated position

Real time | Summary | Signal | CIR

2D positioning accuracy - Run 1

Distance error (cm)




Intro animation
AGV route
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Real time
Summary
Signal
CIR
2D positioning accuracy - Run 1
Cumulative distribution function
1.0
0.8
0.6
0.4
0.2
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Absolute error (cm)
Average 2D positioning accuracy - Run 1
Distance error (cm)
28.1
Ground truth
5G estimated position

Precise positioning in 60 GHz

Empowering industry and enterprise
around the world

- Better resolution in mmWave frequencies
- Ease of deployment in an unlicensed frequency band
- Common solution for high-performance connectivity and positioning

5G mmwave

Thank you

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