15 October 2020

@qualcomm

Qualcomm

Transforming enterprise and industry with 5G private networks

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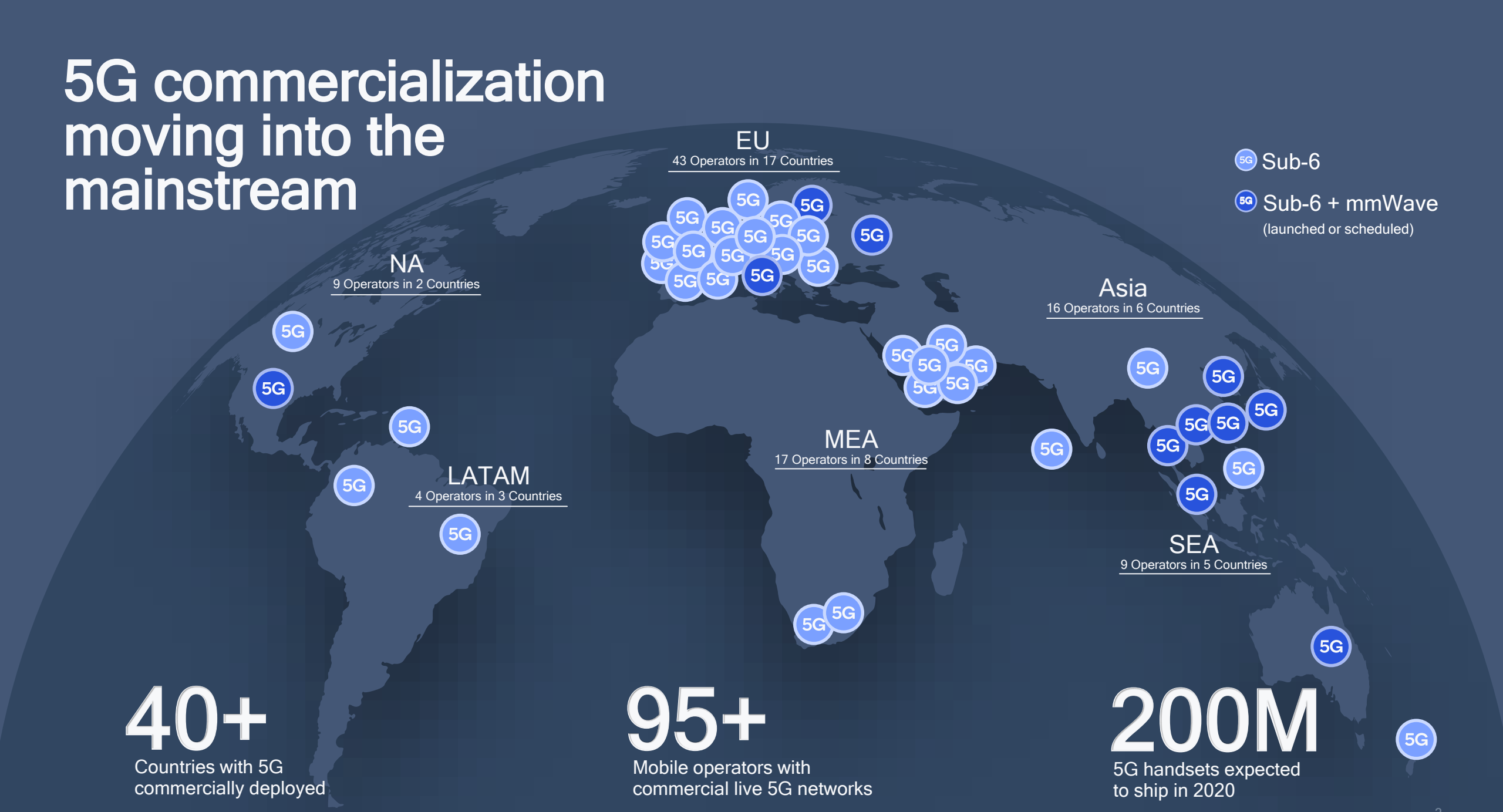
Qualcomm Technologies, Inc.

5G commercialization moving into the mainstream



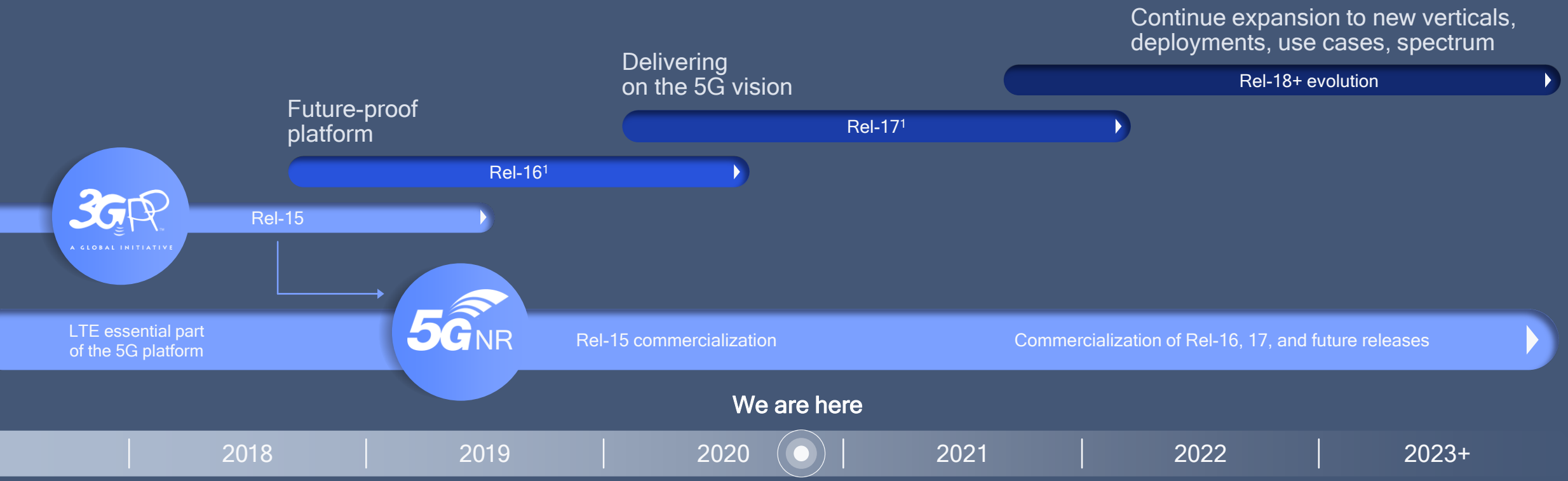
40+
Countries with 5G commercially deployed

95+
Mobile operators with commercial live 5G networks

200M
5G handsets expected to ship in 2020

Sources - GSA: 5G Market Snapshot Member Report - June 2020; Qualcomm estimates (2020 projection is at mid-point of guidance range), Nov. '19

Driving the 5G technology evolution



Rel-15 eMBB focus

- 5G NR foundation
- Smartphones, FWA, PC
- Expanding to venues, enterprises

Rel-16 industry expansion

- eURLLC and TSN for IIoT
- NR in unlicensed (NR-U)
- Positioning
- 5G V2X sidelink multicast
- In-band eMTC/NB-IoT

Rel-17+ long-term expansion

- Lower complexity NR-Light
- Boundless extended reality (XR)
- Higher precision positioning and more…

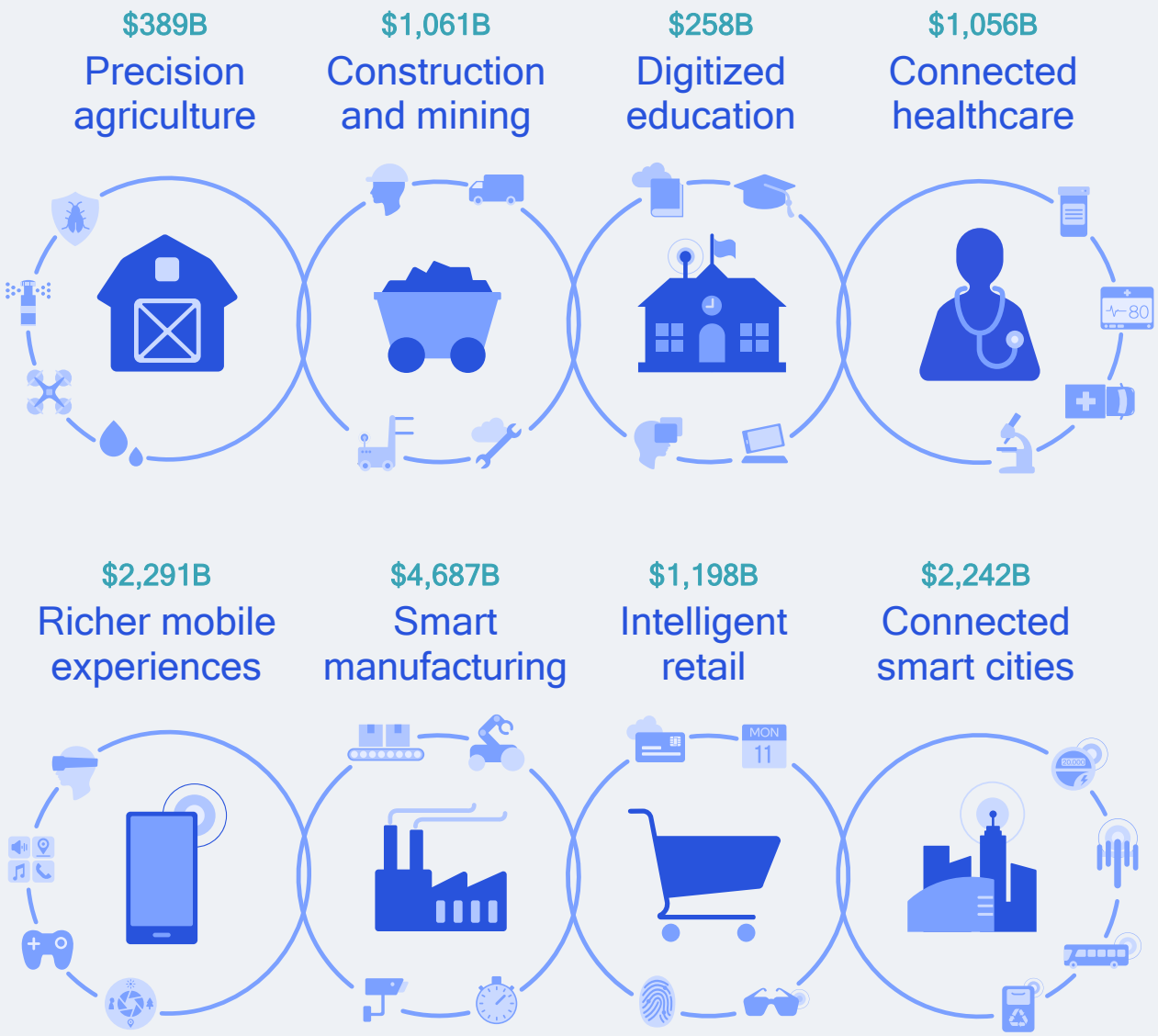
1 3GPP start date indicates approval of study package (study item → work item → specifications), previous release continues beyond start of next release with functional freezes and ASN.1

5G

5G will expand the mobile ecosystem to new industries

Powering the digital economy

$13.2 Trillion In global economic value by 2035*

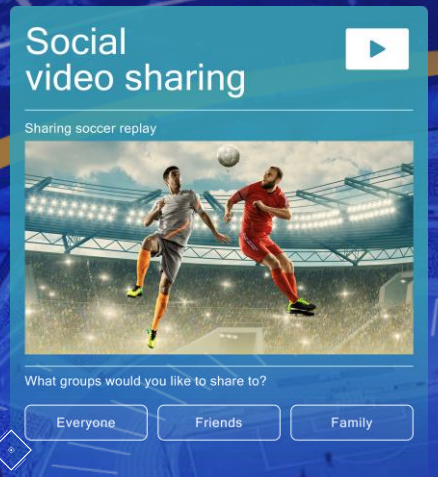


* The 5G Economy, an independent study from IHS Markit, Penn Schoen Berland and Berkeley Research Group, commissioned by Qualcomm


Enhanced mobile broadband
Computer vision
Head mounted display
Handheld terminal
Massive IoT
Sensors
Ultra-reliable low-latency
Automated guided vehicle (AGV)
Wireless edge analytics
Industrial robot

Emerging dedicated private networks for targeted needs

Delivering better customer venue experiences



Enhanced immersive audio

5G private network

Real-time traffic

UHD surveillance camera

Reliable and consistent mobile broadband

Personal concierge, e.g., smart ticketing

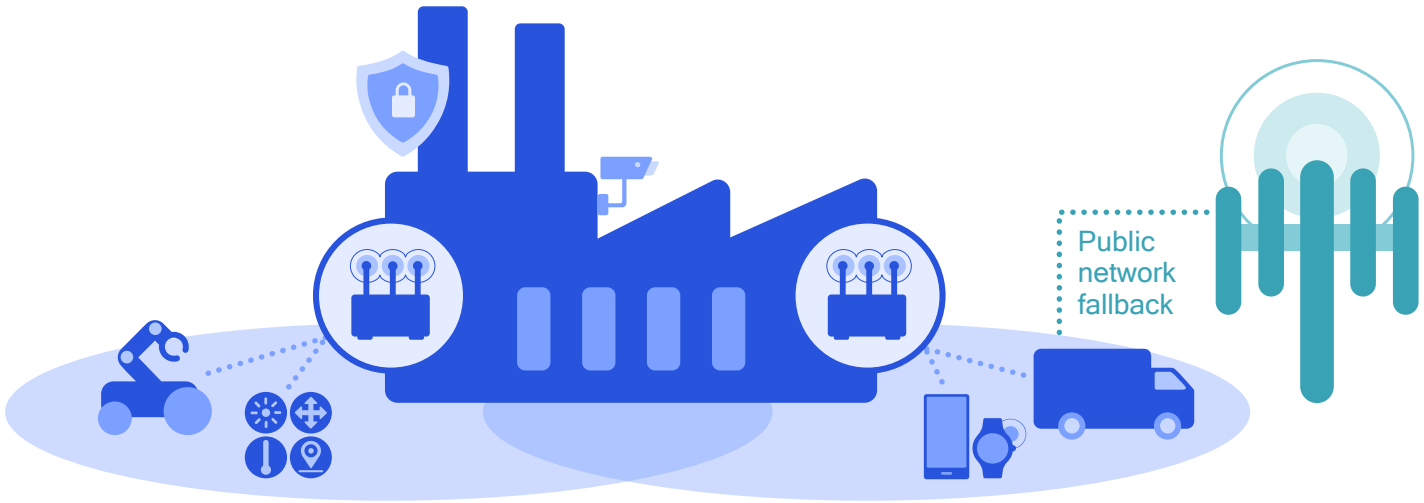
Autonomous ride share

Indoor seat navigation

Personalized in-seat concession

Real-time smart parking status

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-premise

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])

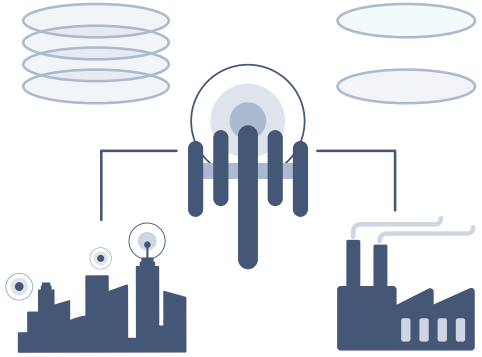
Interoperability

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

5G private networks: An opportunity for mobile operators

To deploy, manage, or offer as a service, both in licensed and unlicensed spectrum

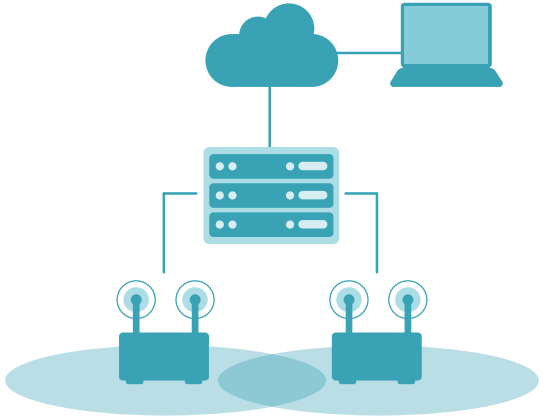


Licensed spectrum assets

Dedicate a portion for private networks

Spectrum may be under-utilized in industrial areas

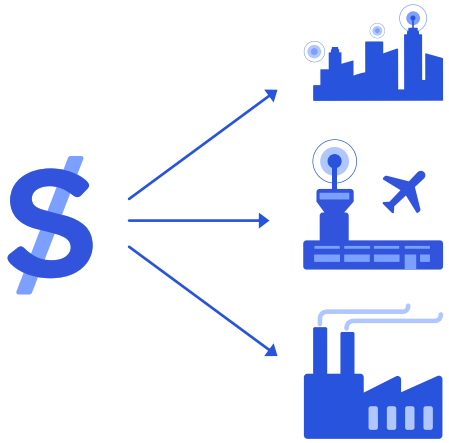
Reuse mmWave spectrum indoors, such as for private enterprise network



Expertise in mobile networks

Relevant expertise in deploying, optimizing, operating mobile networks

Existing ecosystem relationships

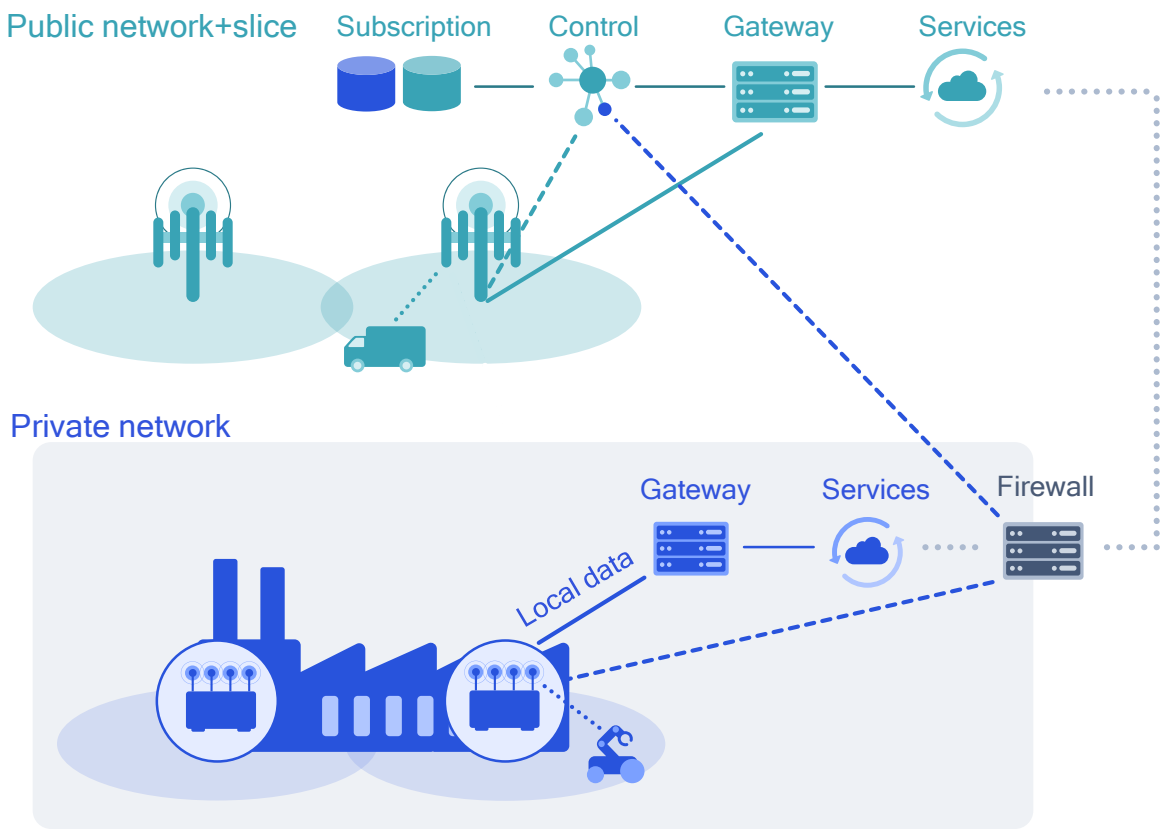


Existing sales channels

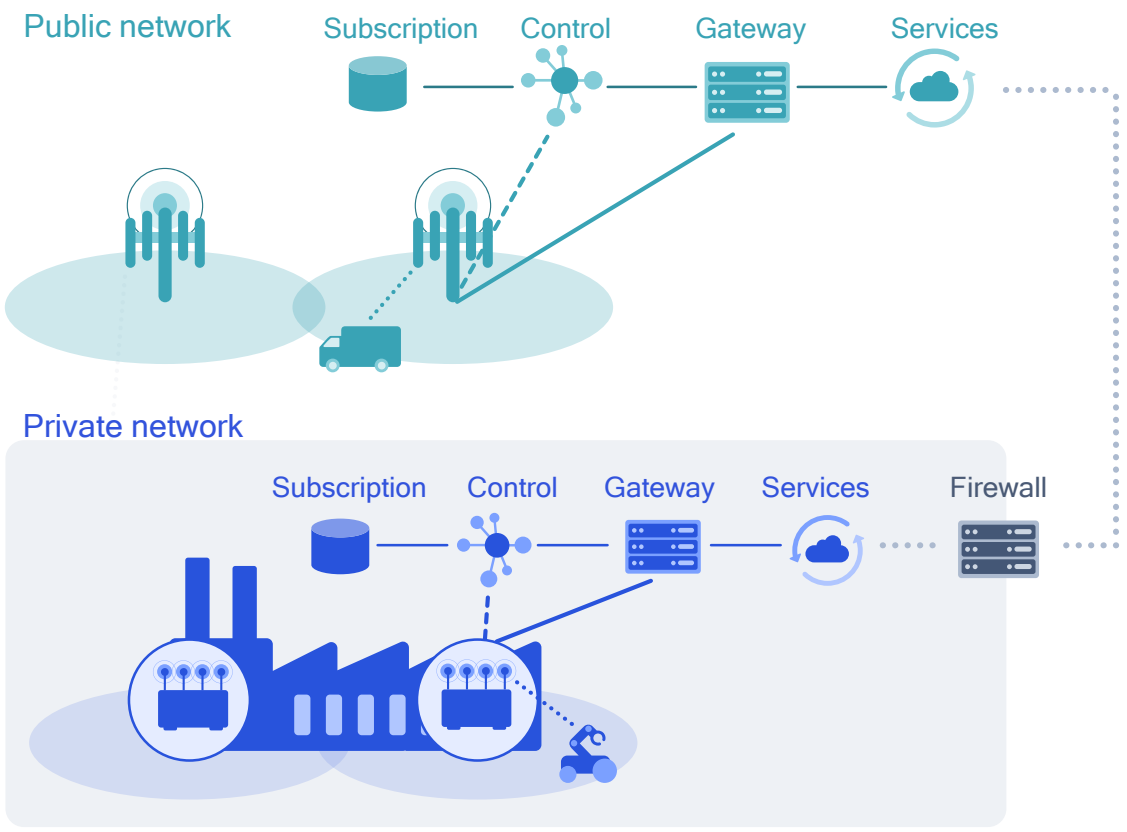
Already provide services to many industrial and enterprise customers

Multiple business opportunities, from deploy to offer private network as a service

Integrated private network



Independent private network[1]



1) Mobility between private and public networks can still be supported via dual subscriptions

Multiple private network architectures for flexible deployments

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

Verizon
22 Jun. 2020

Verizon Taps Partners to Build 5G Private Networks

https://www.eetimes.com/verizon-taps-partners-to-build-5g-private-networks/

Lufthansa
27 Feb. 2020

Lufthansa Technik and Vodafone Business have built a standalone private 5G campus network at the 8,500 square meters Lufthansa base at Hamburg Airport

https://www.vodafone.com/business/news-and-insights/company-news/lufthansa-technik-and-vodafone-business-launch-5g-private-network

Yangquan Coal Industry
3 Jun. 2020

China goes deep, with 5G network in coal mine

http://www.chinadaily.com.cn/a/202006/03/WS5ed78e2da310a8b24115aad1.html

Toyota
23 Jun. 2020

Toyota to assess 5G private network in Japanese manufacturing center

https://www.lightreading.com/private-networks/toyota-to-assess-5g-private-network-in-japanese-manufacturing-center/d/d-id/761904

Ford
25 Jun. 2020

How Ford and Vodafone are creating the 5G 'factory of the future'

https://newscentre.vodafone.co.uk/news/how-ford-and-vodafone-are-creating-the-5g-factory-of-the-future/

Group ADP, Hub One & Air France
10 Jul. 2020

ADP Group company Hub One, gets 10 year licence to operate 4 &5G mobile network covering Paris-Charles de Gaulle, Paris-Orly and Paris-Le Bourget airports.

https://www.air101.co.uk/2020/02/adp-group-company-hub-one-gets-10-year.html

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

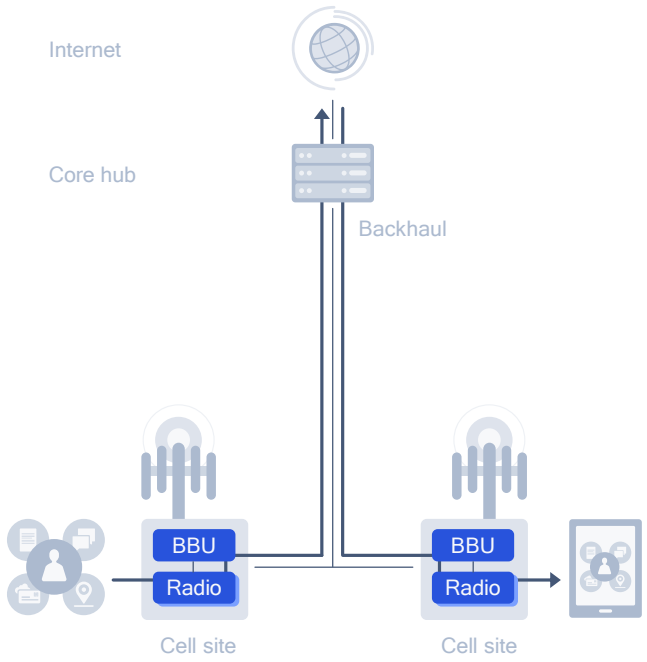
Manufacturing and process operators	Technology providers	Network operators	Spectrum advocacy	Collaboration with global industry bodies

https://www.5g-acia.org/

Evolving the 5G network

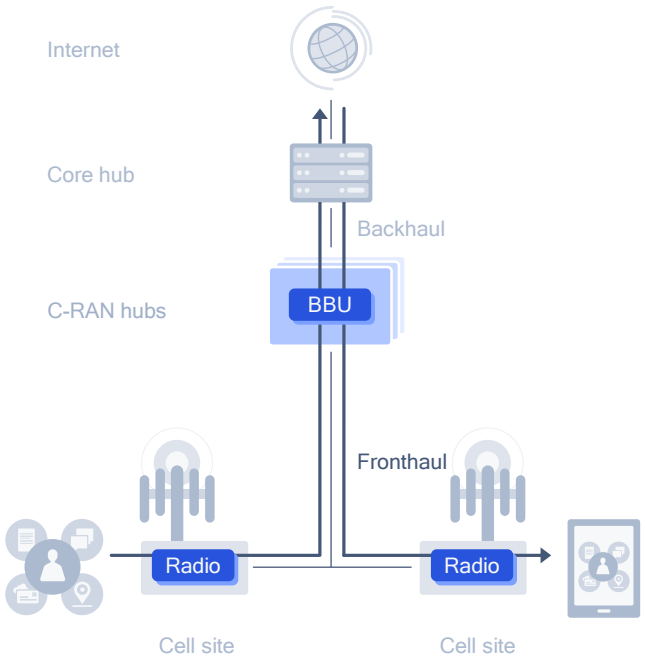
Traditional RAN

Combined baseband processing unit + Radio unit



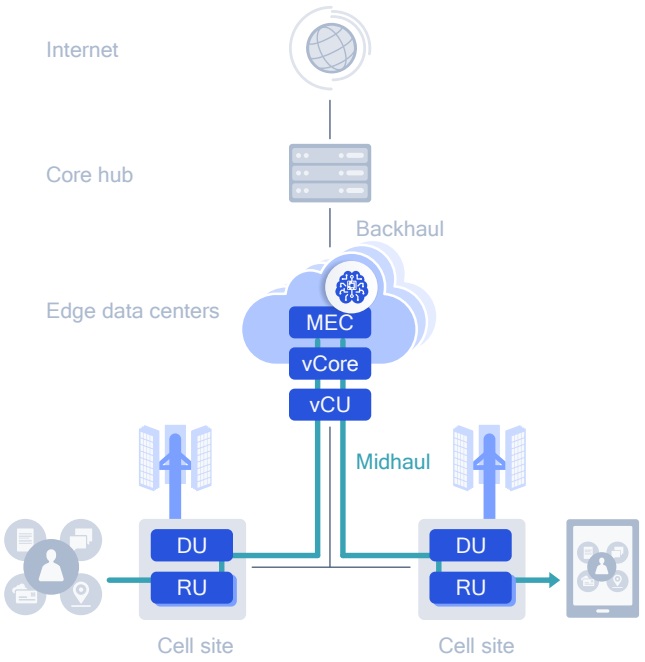
Centralized RAN (C-RAN)

Centralized baseband processing unit



Virtual RAN (vRAN) + MEC

Virtualized baseband processing unit with disaggregation



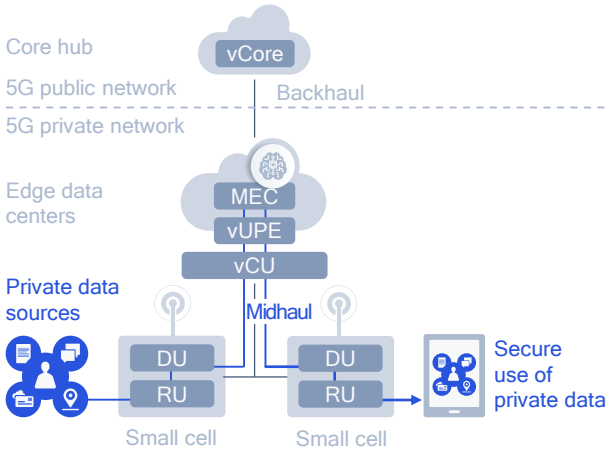
For better coordination, scalable capacity, faster deployments, lower latency, and new use cases

BBU: Baseband unit; DU: Distributed unit; vBBU: Virtual baseband unit; vCore: Virtual core network; vCU: Virtual central unit; MEC: Multi-access Edge Computing

Transform industry and enterprise with 5G, vRAN and MEC

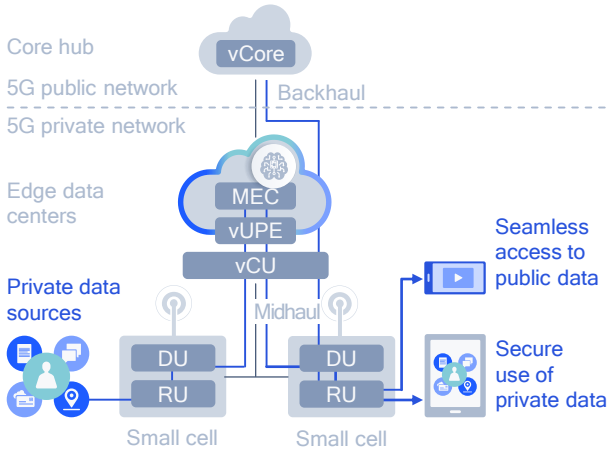
Reduce end-to-end latency

with 5G and MEC for industrial IoT and delay-sensitive applications, e.g. Boundless XR



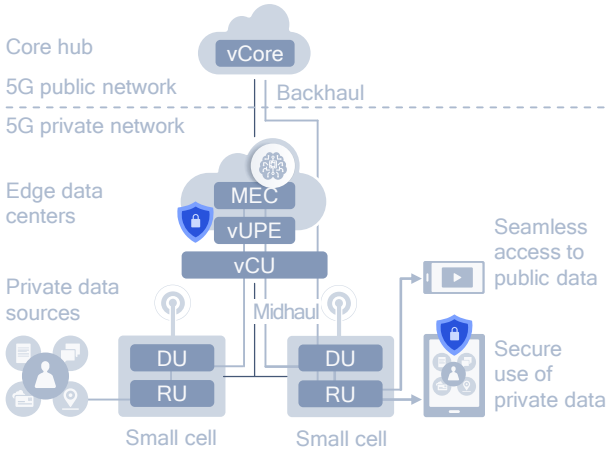
Support multiple services

by deploying network and compute resources opportunistically for various latency, throughput and reliability needs



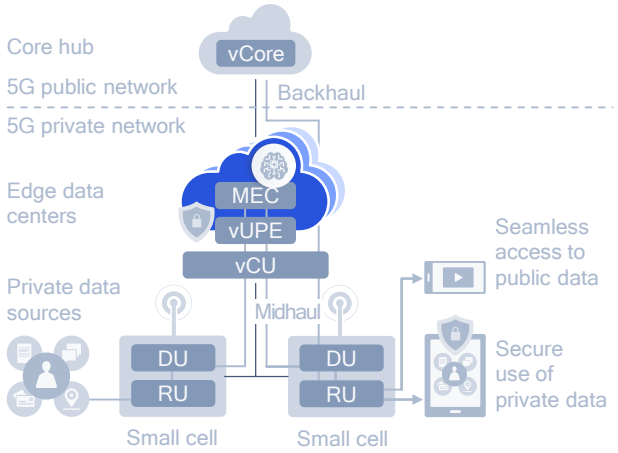
Increase data security and privacy

by keeping data local and physically secure



Increase availability and scalability

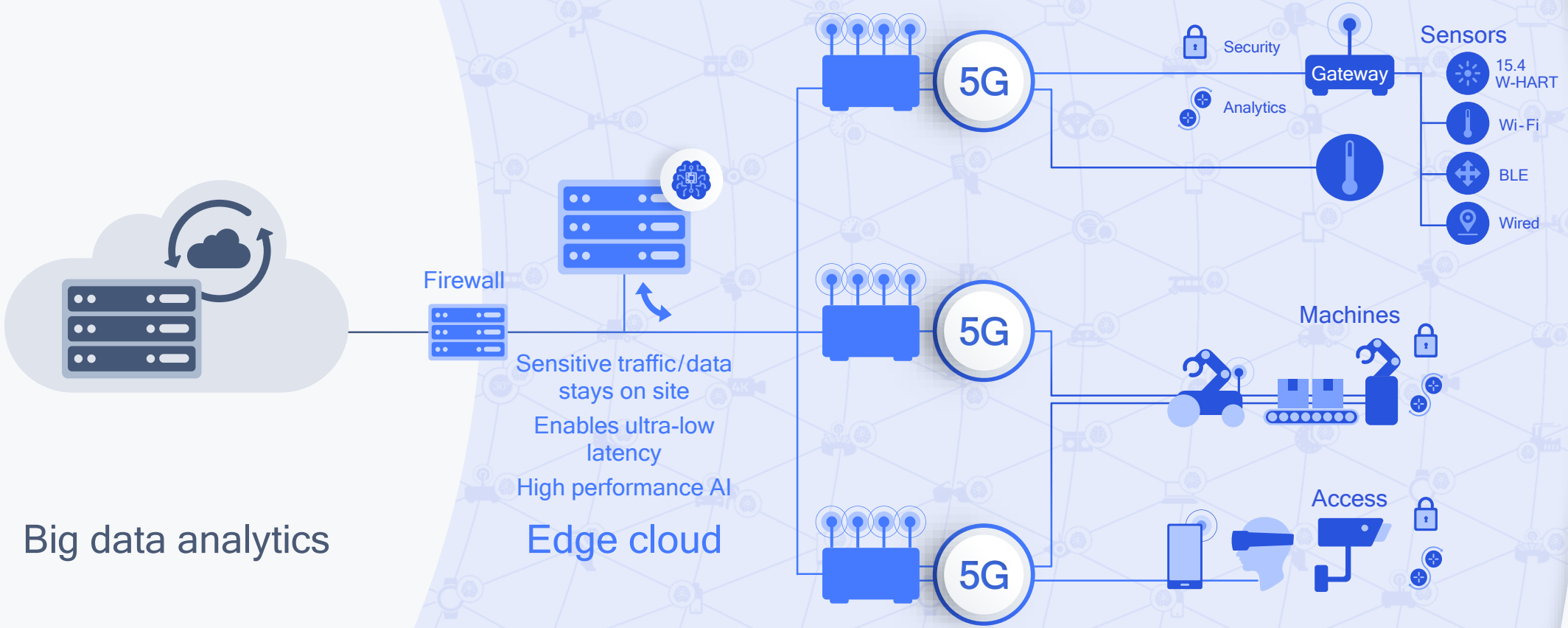
- by using common edge compute resources for both vRAN and MEC
- by independently scaling resources for control plane and user plane traffic



DU: Distributed unit; MEC: Multi-access edge compute; PHY: Physical layer; RU: Radio unit; vCore: Virtual core network; vCU: Virtual central unit; vRAN: Virtual radio access network; vUPF: Virtual user plane function


Distributed autonomy
Privacy/security
New experiences
Immediacy
Processing over 5G
Efficiency
Customized/local value
Reliability
Private/public networks
Personalization
5G
+
The intelligent wireless edge
On-device AI, processing, sensing, vision,... augmented by edge cloud
Process data closest to the source to scale for massive amount of data and connected things
Edge cloud
On-device

Keep data and AI local for privacy and responsiveness



Sensor fusion

Computer vision

On-device intelligence

Low-power processing

Cloud services

Cloud analytics and virtualized core network functions

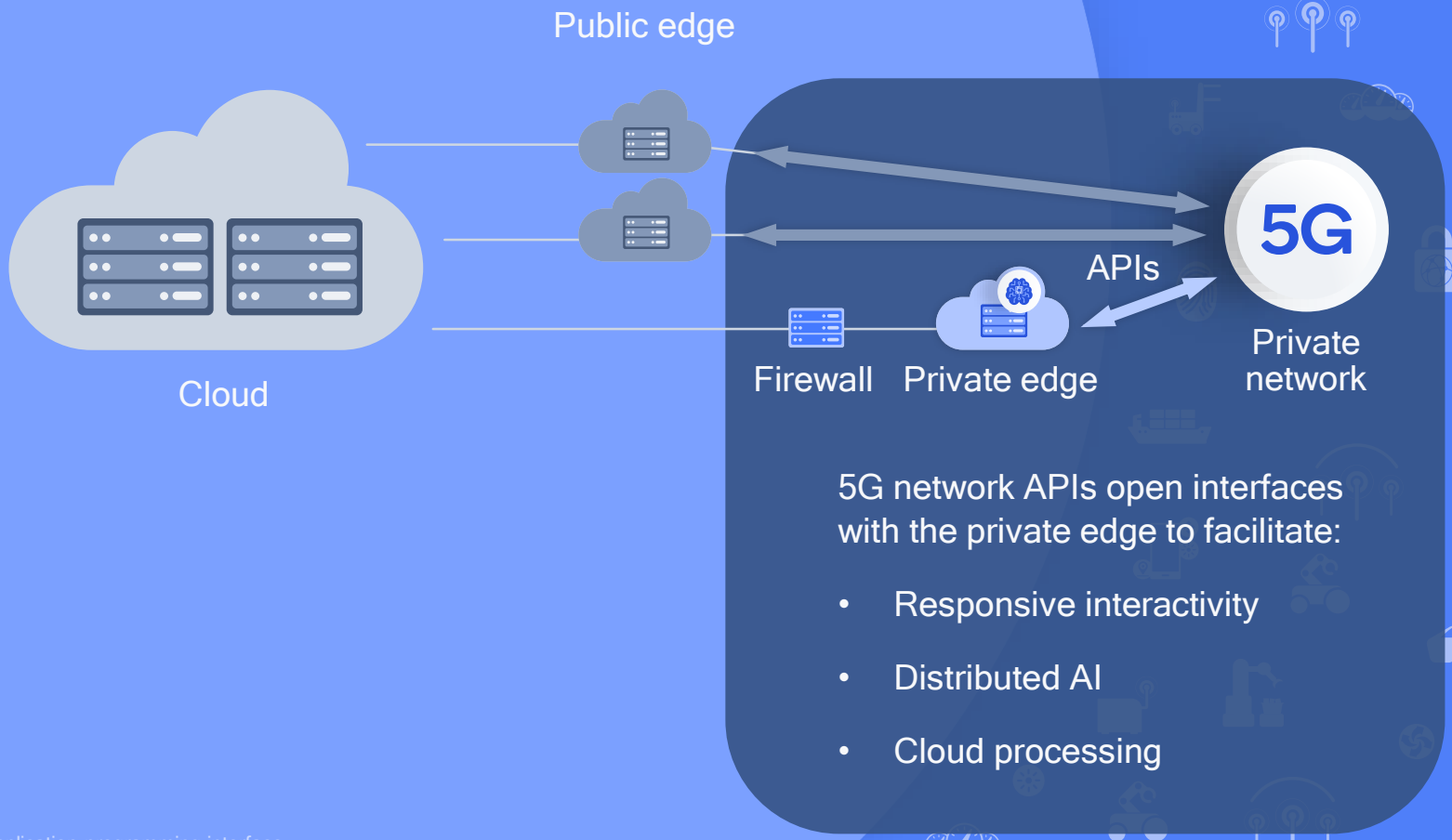
Local network

Local gateway and/or local core network functions

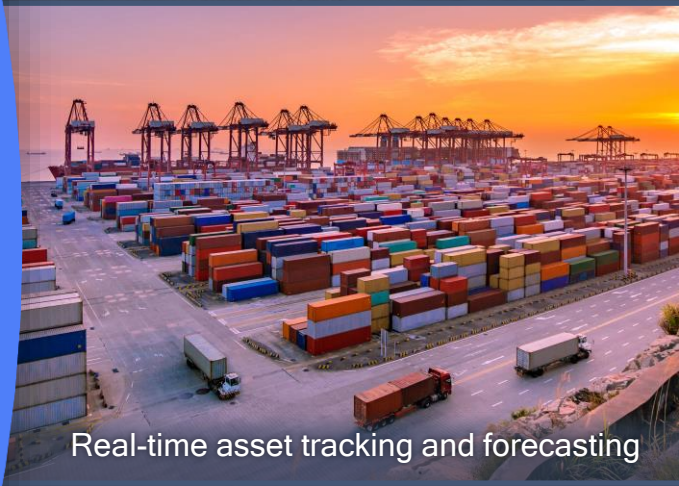
On-device

Various degree of on-devices capabilities

Drive new efficiencies and innovation with an integrated 5G private network and edge



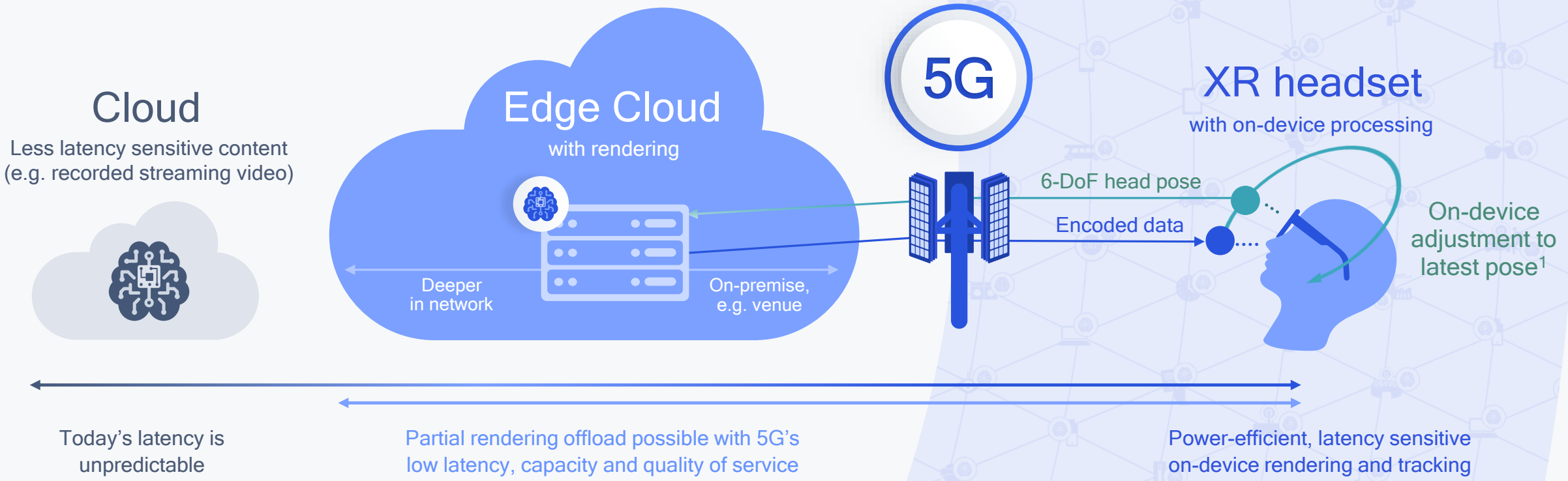

Untethered collaboration with low latency


Real-time asset tracking and forecasting


Digital twins for predictive maintenance

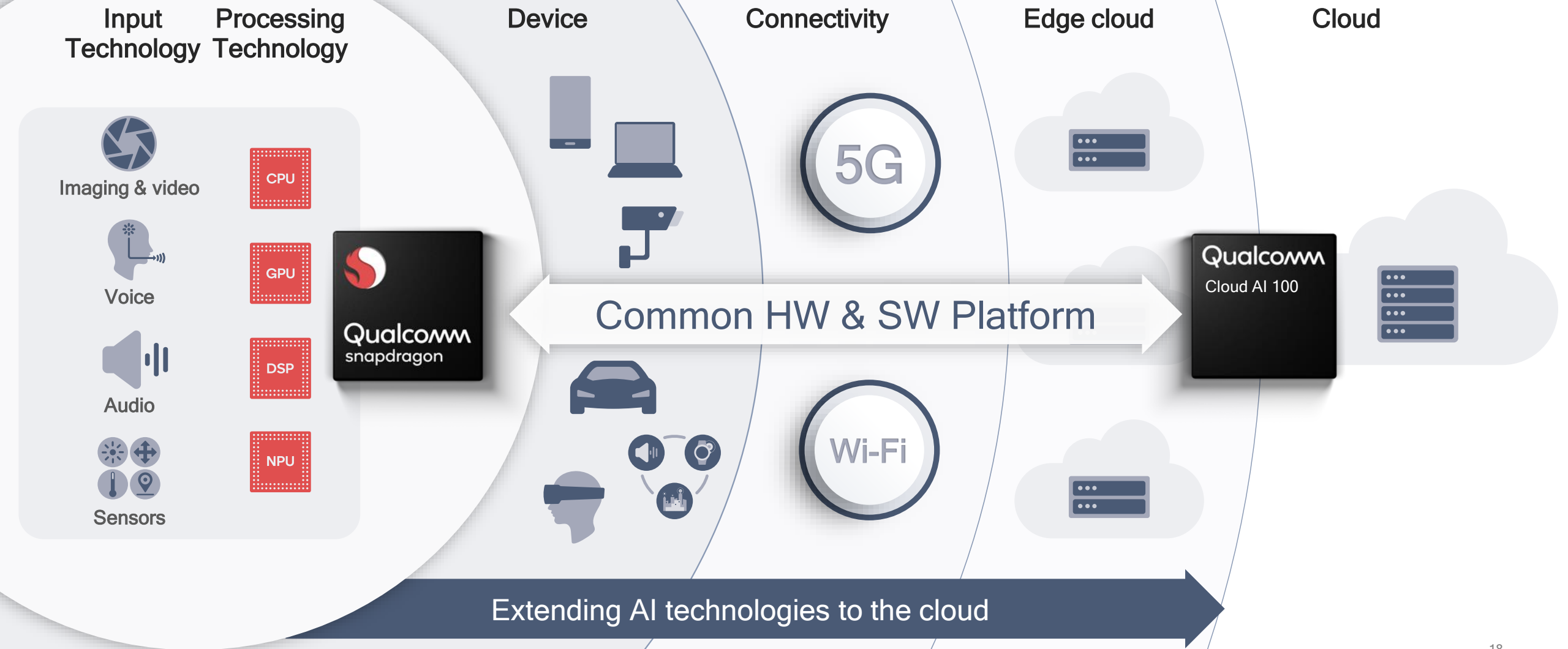
API: Application programming interface

Augment on-device processing for boundless photorealistic mobile XR



1. Asynchronous time warp reduces Motion to Photon (MTP) latency by using on-device processing based on the latest available pose. MTP below 20 ms generally avoids discomfort – has to be processed on the device

AI + 5G strategy to enable distributed intelligence at scale



USA

- 3.5 GHz CBRS, exclusive & shared licenses, deployments in 2H19
- 37 - 37.6 GHz shared spectrum/local licenses, under evaluation

Germany

- 3.7 – 3.8 GHz
- 24.25 - 27.5 GHz, local licenses, under consultation
- Local licenses. Assignment complete; available 2H 2019

U.K.

- 3.8 - 4.2 GHz
- 24.25 - 26.5 GHz, local licenses, applications open since end of 2019
- Local licenses (50 meters square); regulator database; decision formalized; applications invited from end 2019

Sweden

- 3.72 - 3.8 GHz, in consultations

Finland

- Sub-licensing of 3.4 - 3.8 GHz
- Local permission via operator lease; assignment complete

Netherland

- 3.5 GHz for local industrial use; 3.7 - 3.8 GHz (in consultations); 2.3 - 2.4 GHz (licensed shared access online booking system)
- 3.5 GHz for local industrial use; however users may need to move to 3.7 - 3.8 GHz, if allocated; 2.3 GHz approved for PMSE

France

- 2.6 GHz, regulator database & approval. Up to 40 MHz approved for Professional Mobile Radio

Czech Republic

- 3.4 - 3.44 GHz for private networks

Brazil

- 3.7 – 3.8 GHz, under consideration
- 27.5 – 27.9 GHz, allocation completed

Chile

- 3.75 – 3.8 GHz, allocation completed at end of 2019

Australia

- 24.25 - 27.5 GHz and 27.5 – 29.5 for final consultation in 1H20

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 will be allowed to acquire 800 MHz of 26/28 GHz spectrum to deploy local networks

Hong Kong

- 24.25 - 28.35 (400 MHz), local licenses; regulator approval. Approved; available 3Q19

Japan

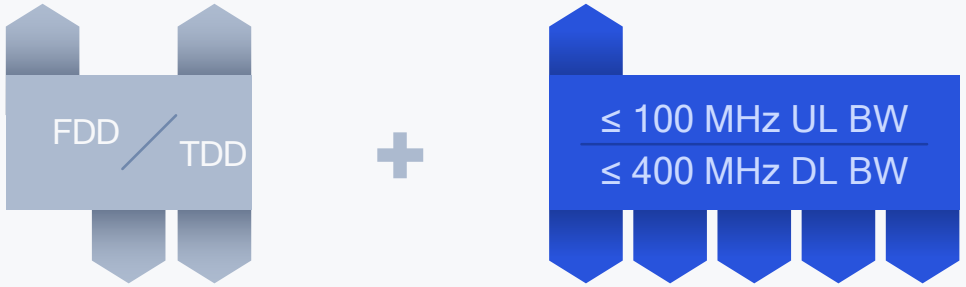
- Phase 1: 2,575 - 2,595 MHz (NSA anchor) and 28.2 - 28.3 GHz; local licenses, legislated in December 2019
- Phase 2: 1888.5 - 1916.6 MHz (NSA anchor), 4.6 - 4.9 GHz (4.6 - 4.8 GHz indoor only, 4.8 - 4.9 GHz outdoor possible) & 28.3 - 29.1 GHz (150 MHz outdoor use; total 250 MHz range 28.2 – 28.45 MHz); local license. Consultation 3Q20, legislation 4Q20. Uplink heavy TDD config. using semi-sync is allowed in sub-6 & 28 GHz

Global snapshot of spectrum optimized for private network use – local licensing or sharing

Rel-16 introduces NR in unlicensed spectrum

Anchored NR-U

Unlicensed spectrum is combined with other licensed or shared spectrum as anchor



Licensed or shared anchor spectrum

Unlicensed NR-U spectrum

Standalone NR-U

Only unlicensed spectrum is used

Unlicensed NR-U spectrum

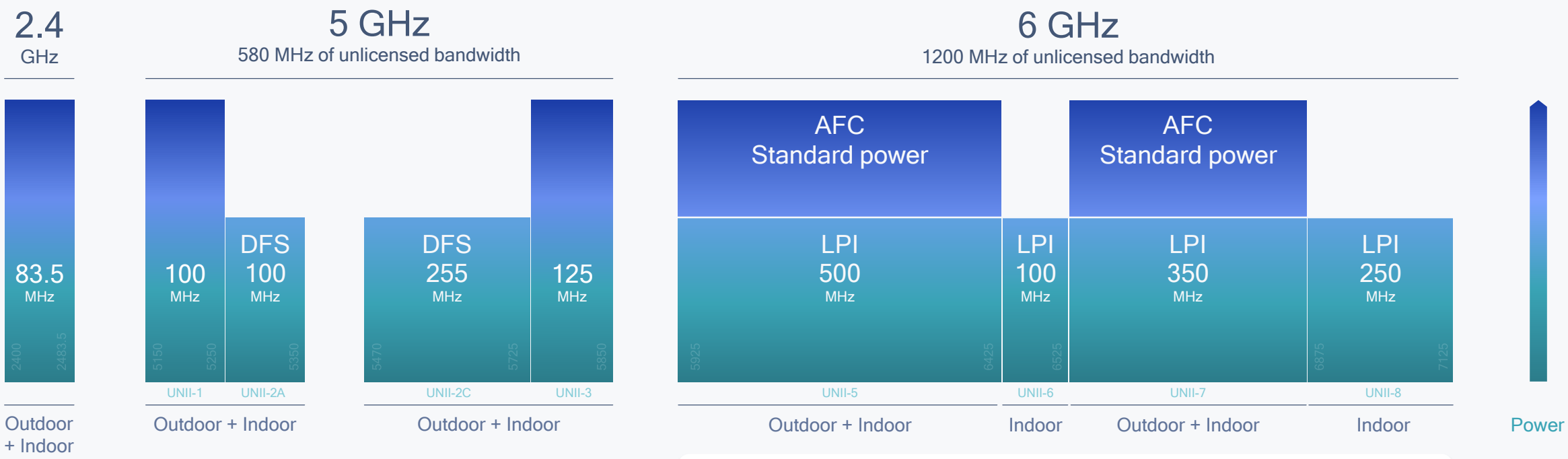
Unlock more spectrum globally

New markets and verticals

New deployment scenarios

6 GHz brings new unlicensed bandwidth for Wi-Fi and 5G

United States



1200 MHz

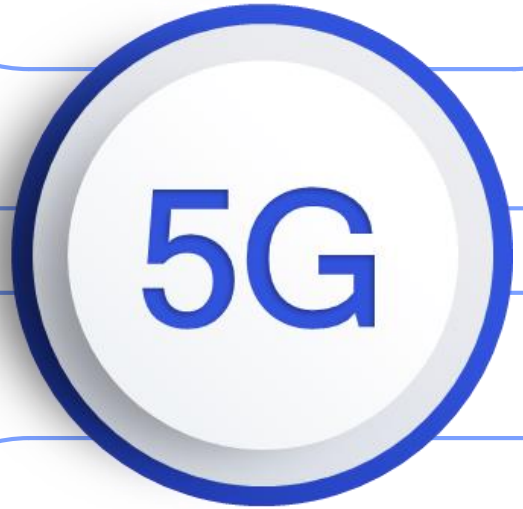
A massive amount of new unlicensed spectrum is now available in the U.S. for Wi-Fi 6E and 5G

AFC= Automated frequency control, DFS= Dynamic Frequency Selection, LPI= Low power indoor

Dedicated and reliable networks optimized for local services

Scalable wireless connectivity on a future proof platform

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



Private 5G network

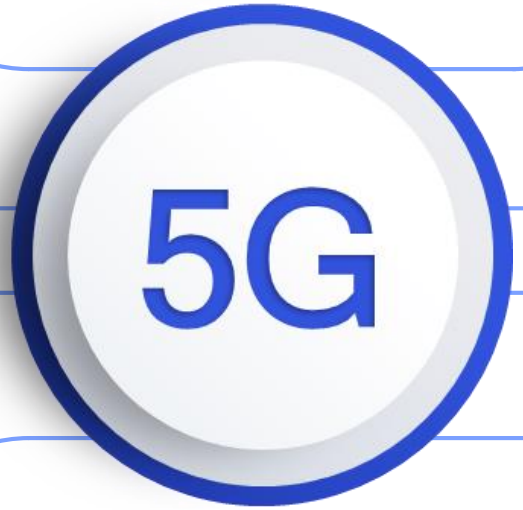
Licensed, shared and unlicensed Spectrum

Ultra Reliable Low Latency Communication (URLLC)

Ethernet and Time Sensitive Networking (TSN)

Positioning

Designing 5G to meet industrial IoT requirements



Private 5G network

- Unique network ID
- Integrated and independent architectures
- Seamless fallback to public networks

Spectrum

With NR-U, 5G NR will support:

- Licensed spectrum
- Shared spectrum
- Unlicensed spectrum

URLLC

- Low latency
- Ultra-reliability
- CoMP multi-TRP
- Service multiplexing
- Enhanced mobility

Ethernet and TSN

- Ethernet over 5G with PDU session support
- Deterministic networking
- Device time synch.

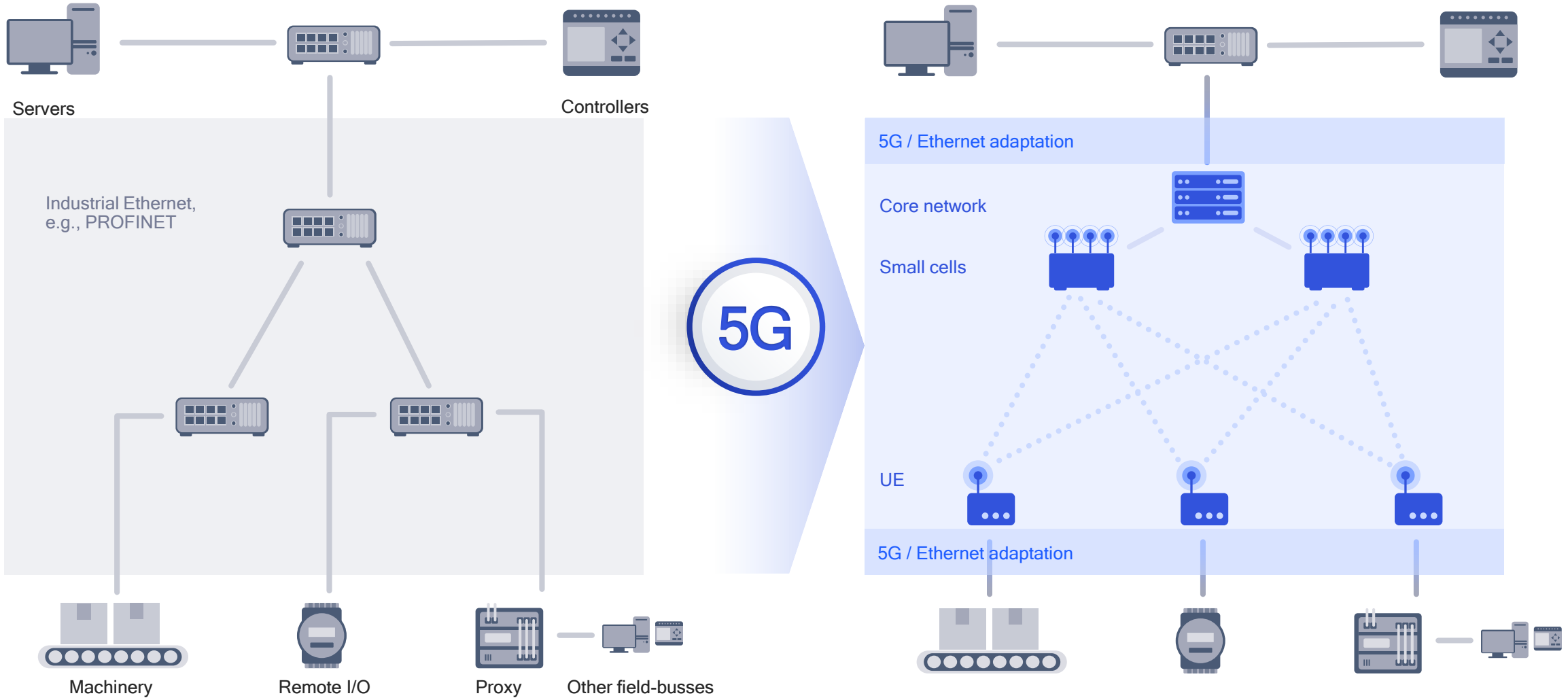
Positioning

- Network & device based
- Industrial IoT requirements

5G NR supports many industrial IoT use cases today

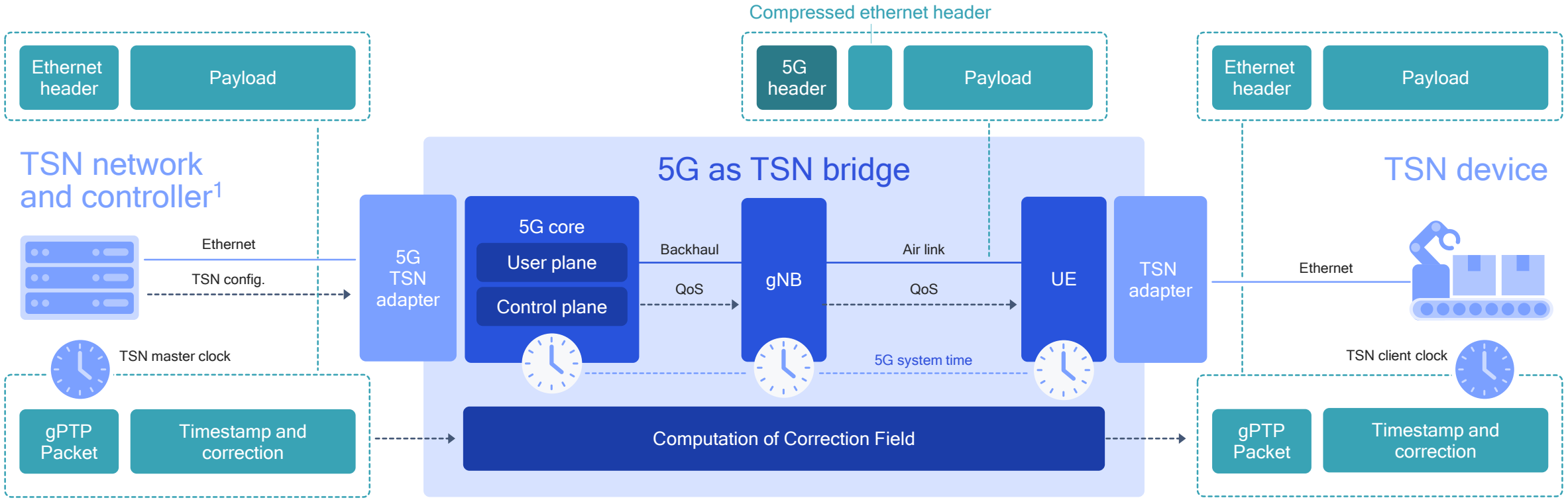
3GPP Rel-16 brings additional capabilities

Upgrading existing industrial networks with wireless 5G



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.

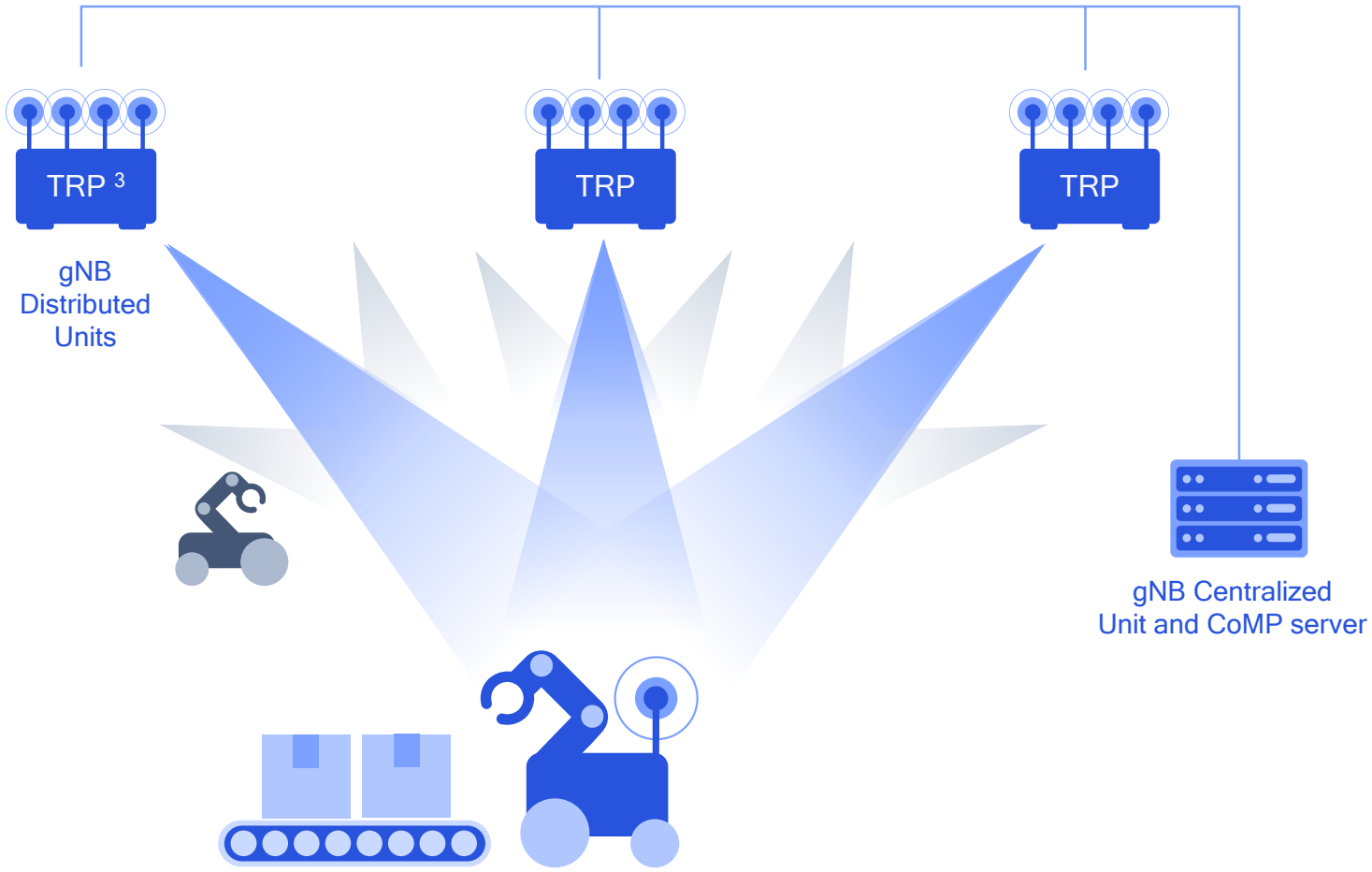
5G TSN adapters allow the 5G system to act as a TSN bridge with Ethernet connectivity

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

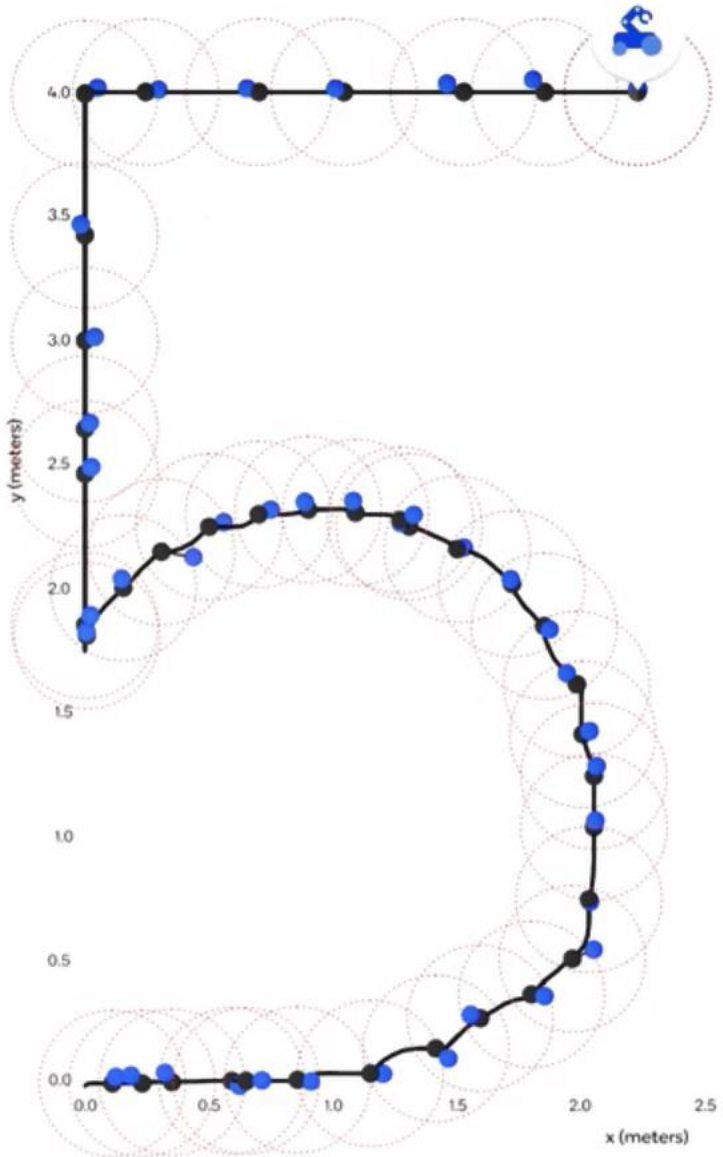
- Other diversity methods such as frequency and time diversity are not sufficient for URLLC
- CoMP is facilitated by denser deployment of small cells with high bandwidth backhaul

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

Qualcomm 5G | **Indoor Precise Positioning**

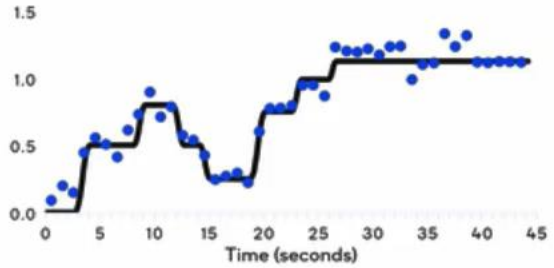
Use Case Animation | Network Layout | **Indoor Precise Positioning Test**

Ground Truth
5G



Vertical Ground Truth Comparison

Height (meters)



3D View | 2D View

Gantry Controls

Route "5" | Route "G" | 8 Corners

Start

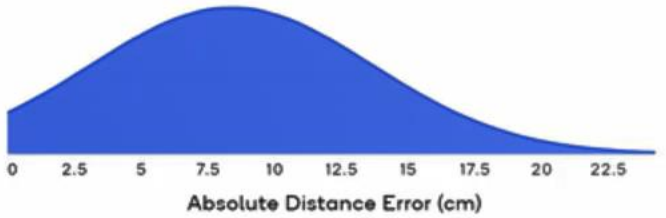
Status: Complete - Select Route

Video Feed | **Summary Results**

3D Positioning Accuracy (x,y,z)

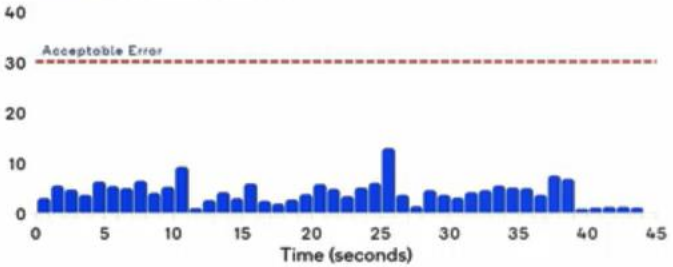
PDF | CDF | CCDF

Probability Density Function



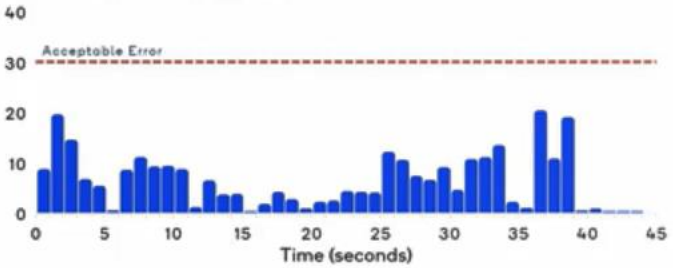
Horizontal Plane Accuracy (x,y)

Absolute Distance Error (cm)



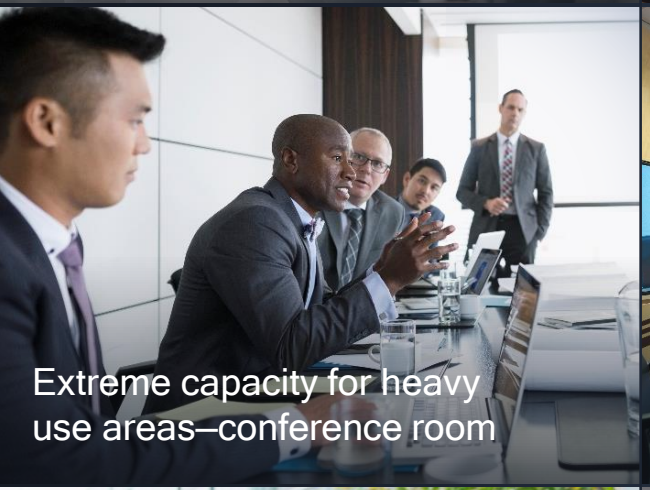
Vertical Plane Accuracy (z)

Absolute Distance Error (cm)

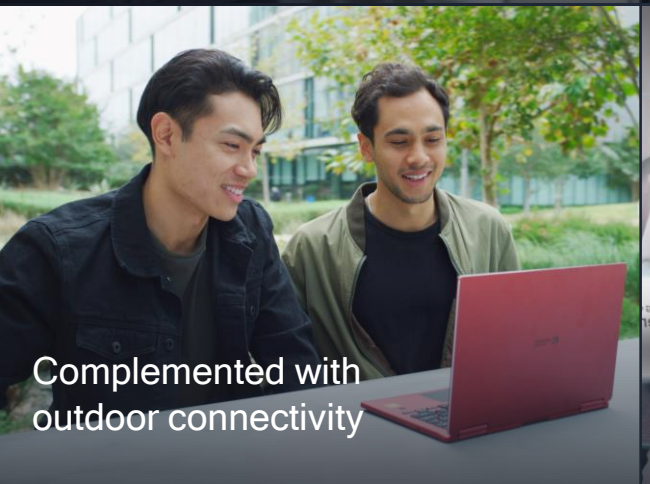



Next level of untethering –
the mobile office of future


Instant cloud applications,
instant cloud storage access


Extreme capacity for heavy
use areas–conference room


Connect to projectors/screens
with immersive content


Complemented with
outdoor connectivity


Beyond laptops:
Augmented and virtual reality (XR)

Boosting enterprise productivity with 5G private networks

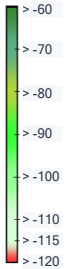
Complement Wi-Fi with mmWave

- Multi-Gigabit speeds with virtually unlimited capacity
- Seamless inside-out mobility
- Reuse licensed spectrum with inside-out mmWave isolation
- Private 5G NR indoor network with cellular grade security
- Commercially available ACPCs and smartphones, and soon 5G xR glasses

ACPC: Always-connected personal computer

Total area:
~27.6k ft²

Path loss (dB)



Existing Wi-Fi access point locations – co-sited with 5G NR mmWave antenna locations (each 128x2 elements & 16 horizontal beams)

5G NR mmWave for higher-density indoor enterprise

Co-siting 5G NR mmWave gNodeB antennas with existing Wi-Fi access points

Existing Wi-Fi access points on ceiling

Achieving significant coverage at 28 GHz[1]

- Downlink coverage of **~98%** with 115 dB MAPL[2]
- Uplink coverage of **~99%** with 117 dB MAPL[2]

For always-connected enterprise use cases

- Downlink median burst rate[3] of **5 Gbps**
- Extreme capacity for virtually unlimited data access fueling laptops, tablets, smartphones, and more

1 Coverage simulation based on MAPL (maximum allowable path loss) analysis with ray tracer propagation model and measured material and propagation loss; minimum 0.4/0.1 bps/Hz for downlink/uplink data and control; 2 Maximum Allowable Path Loss; 3 Using 800 MHz DI bandwidth and 100 MHz uplink bandwidth with 7:1 DL:UL TDD

Qualcomm

Thank you

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