Advancing 5G for a new decade

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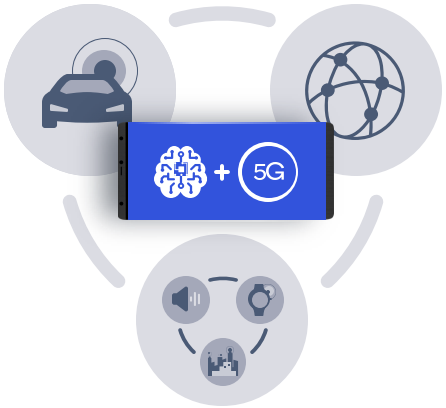
Leading mobile innovation for over 30 years

Digitized mobile communications

Analog to digital

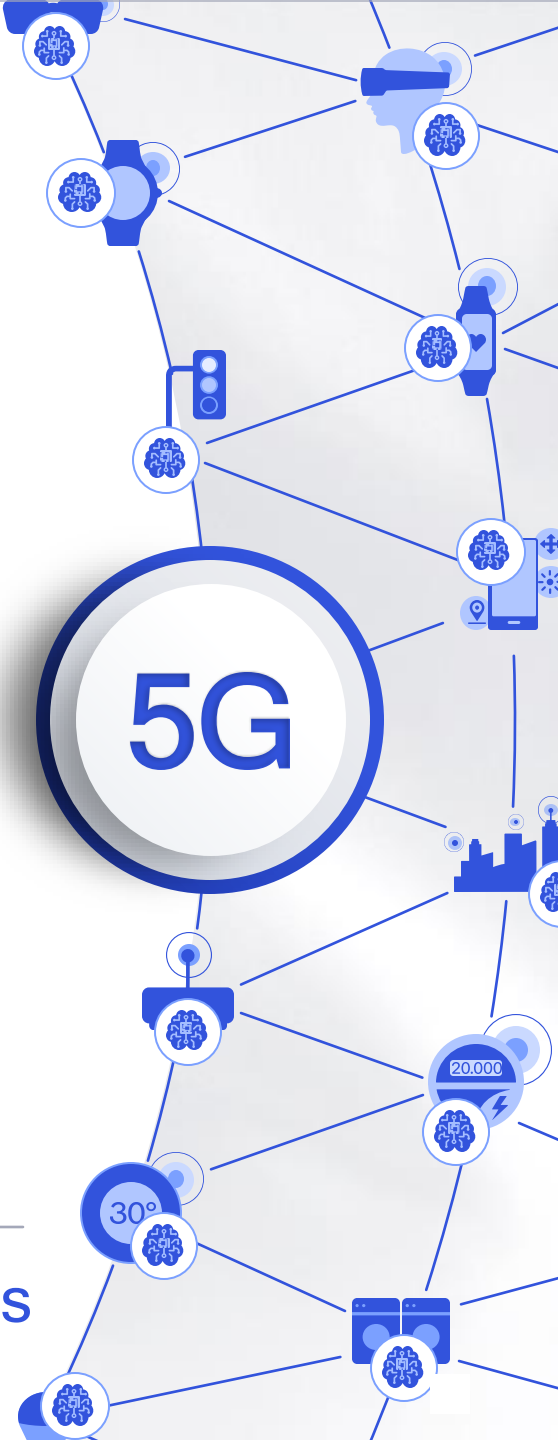
Redefined computing

Desktop to smartphones



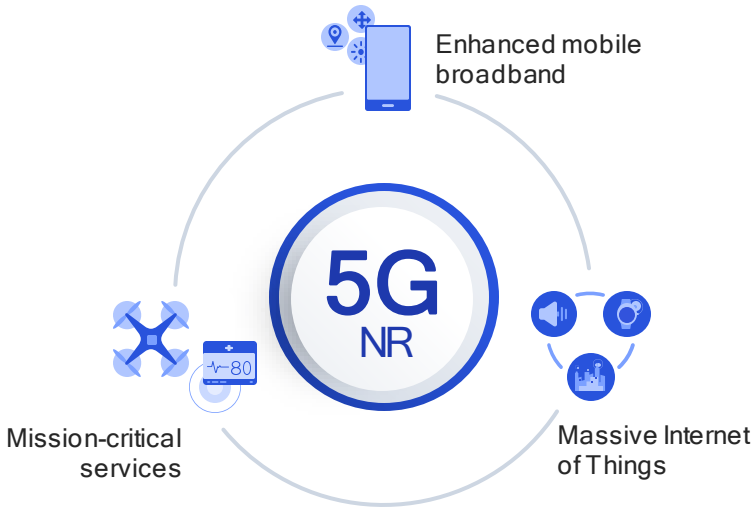
Transforming industries

Connecting virtually everything at the wireless edge

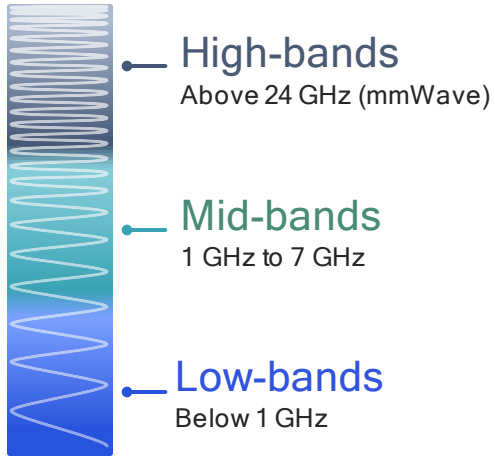


Transforming how the world connects, computes and communicates

5G NR is a unified, more capable wireless platform



Diverse services



Licensed/shared/unlicensed

Diverse spectrum

Diverse deployments

10x Decrease in end-to-end latency

10x Experienced throughput

3x Spectrum efficiency

100x Traffic capacity

100x Network efficiency

10x Connection density

Based on ITU vision for IMT-2020 compared to IMT-advanced; URLLC: Ultra Reliable Low Latency Communications; IAB: Integrated Access & Backhaul

5G

accelerating globally

140+
Operators with 5G commercially deployed

305+
Additional operators investing in 5G

3.8B+
5G smartphones to ship between 2020 and 2024

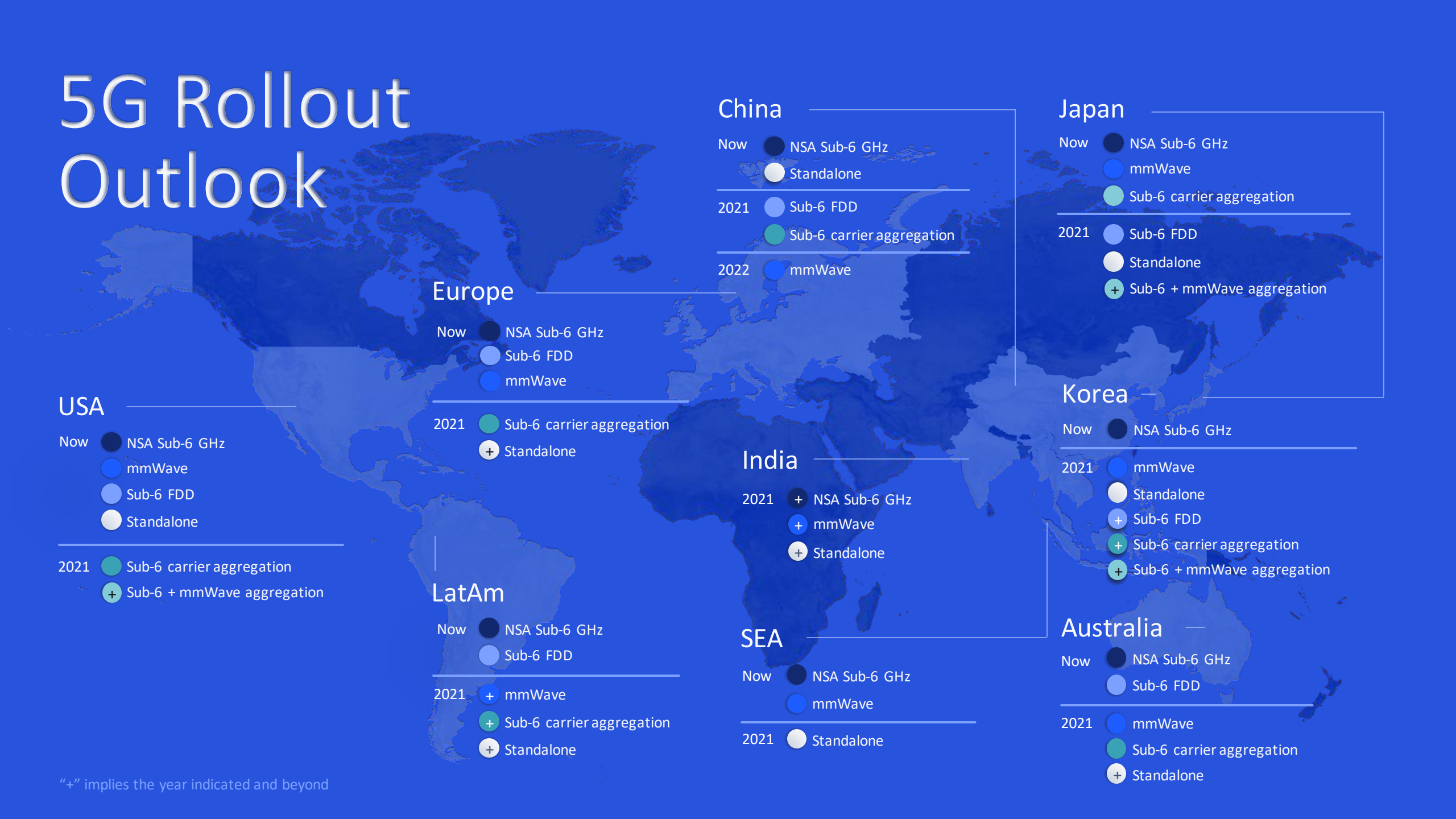
750M+
5G smartphones to ship in 2022

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

800+
5G designs launched or in development

Sources – 5G commercial networks: operator public announcements. Operators investing in 5G: GSA, Oct 2020. 5G device shipment projections: Qualcomm internal estimates, Nov 2020. 2023 5G connections: avg of ABI (Jun 2020), Ericsson (Jun 2020) and GSMA Intelligence (Oct 2020). Cumulative 5G smartphone shipments - avg of CCS Insight (Sep 2020), CounterPoint Research (Sep 2020), IDC (Aug 2020), Strategy Analytics (Oct 2020).

5G Rollout Outlook



China

- Now: NSA Sub-6 GHz
- Now: Standalone
- 2021: Sub-6 FDD
- 2021: Sub-6 carrier aggregation
- 2022: mmWave

Japan

- Now: NSA Sub-6 GHz
- Now: mmWave
- Now: Sub-6 carrier aggregation
- 2021: Sub-6 FDD
- 2021: Standalone
- 2021: Sub-6 + mmWave aggregation

Europe

- Now: NSA Sub-6 GHz
- Now: Sub-6 FDD
- Now: mmWave
- 2021: Sub-6 carrier aggregation
- 2021: Standalone

USA

- Now: NSA Sub-6 GHz
- Now: mmWave
- Now: Sub-6 FDD
- Now: Standalone
- 2021: Sub-6 carrier aggregation
- 2021: Sub-6 + mmWave aggregation

India

- 2021: NSA Sub-6 GHz
- 2021: mmWave
- 2021: Standalone

Korea

- Now: NSA Sub-6 GHz
- 2021: mmWave
- 2021: Standalone
- 2021: Sub-6 FDD
- 2021: Sub-6 carrier aggregation
- 2021: Sub-6 + mmWave aggregation

LatAm

- Now: NSA Sub-6 GHz
- Now: Sub-6 FDD
- 2021: mmWave
- 2021: Sub-6 carrier aggregation
- 2021: Standalone

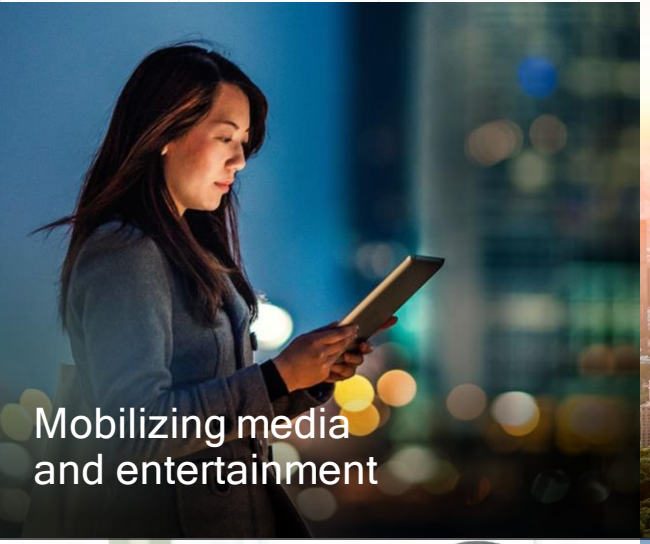
SEA

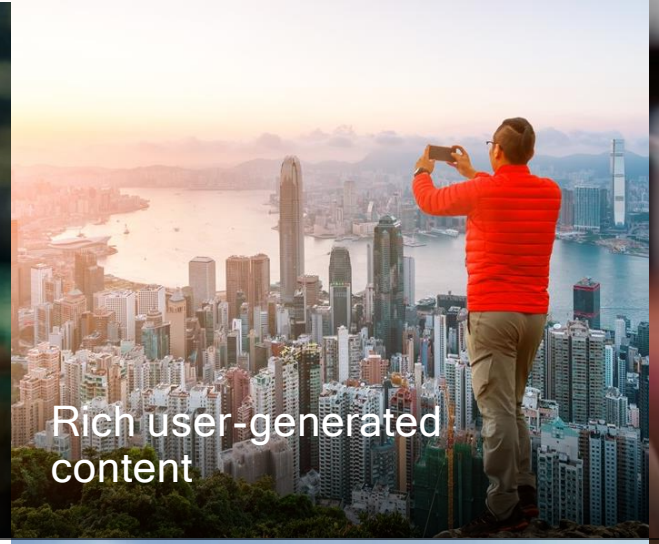
- Now: NSA Sub-6 GHz
- Now: mmWave
- 2021: Standalone

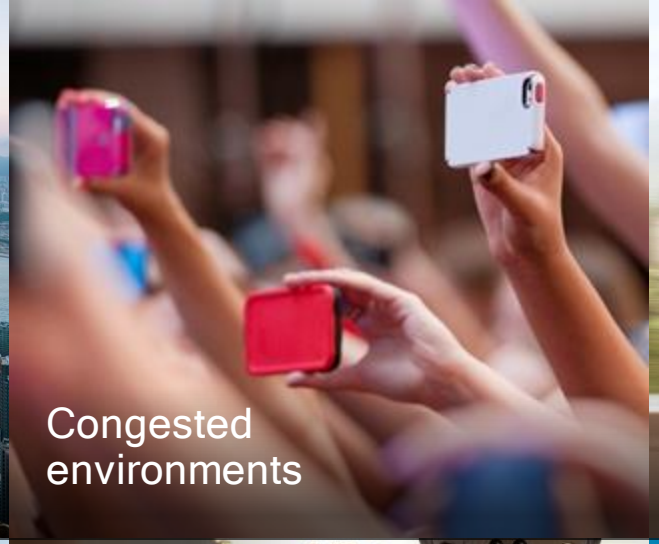
Australia

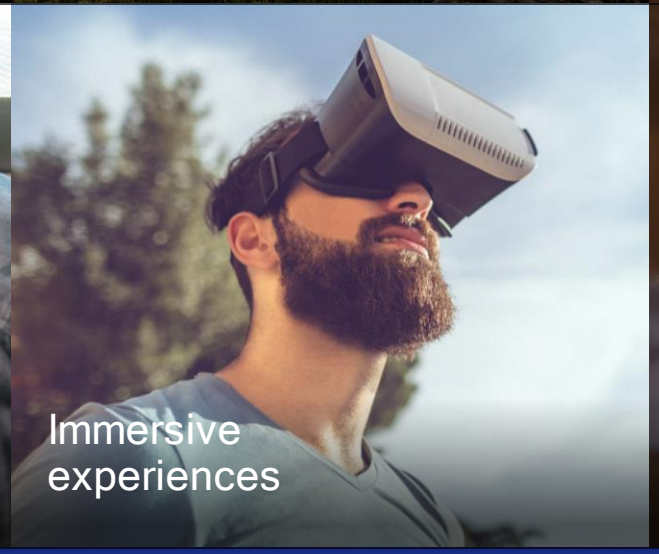
- Now: NSA Sub-6 GHz
- Now: Sub-6 FDD
- 2021: mmWave
- 2021: Sub-6 carrier aggregation
- 2021: Standalone

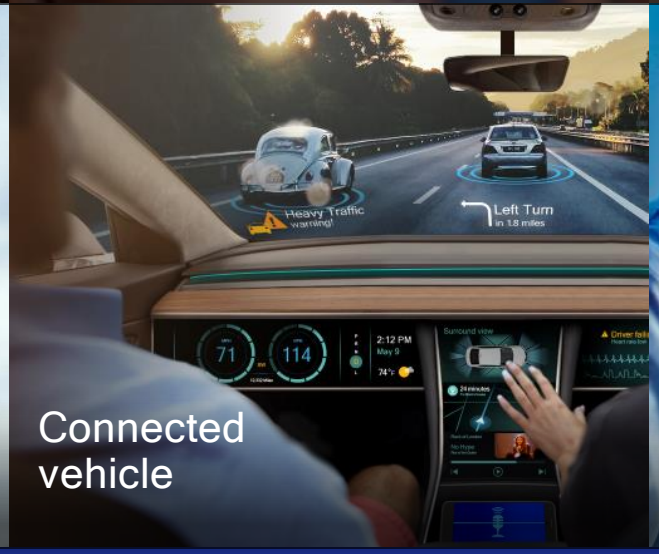
"+" implies the year indicated and beyond











5G

5G is essential for next generation mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- More consistent performance
- Massive capacity for unlimited data

Expanding the mobile ecosystem to new industries

Powering the digital economy

$13.1 Trillion

in global economic value by 2035*

Precision agriculture
$416B

Construction and mining
$984B

Digitized education
$264B

Connected healthcare
$1,083B

Richer mobile experiences
$2,224B

Smart manufacturing
$4,771B

Intelligent retail
$1,144B

Smart city
$2,213B

* The 5G Economy in a Post-COVID-19 Era – an independent study from IHS Markit, commissioned by Qualcomm Technologies, Inc.

Driving the next industrial revolution with flexible manufacturing

On-premise edge analytics and data storage

5G private network

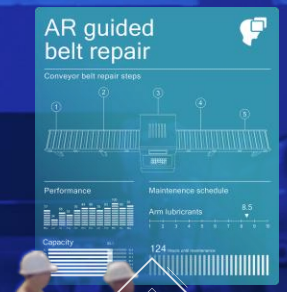
Process monitoring sensors

5G private network

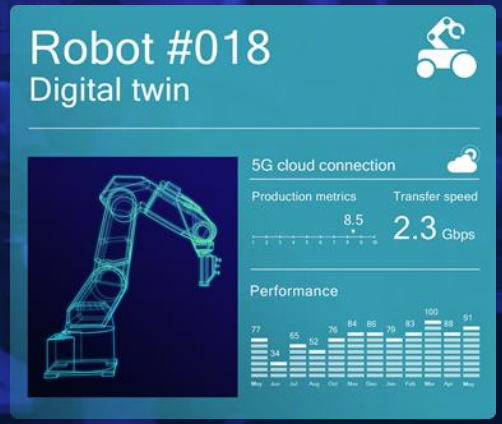
Smart UHD surveillance

Process monitoring sensors

Wireless modular equipment



HMI interface



Factory automation

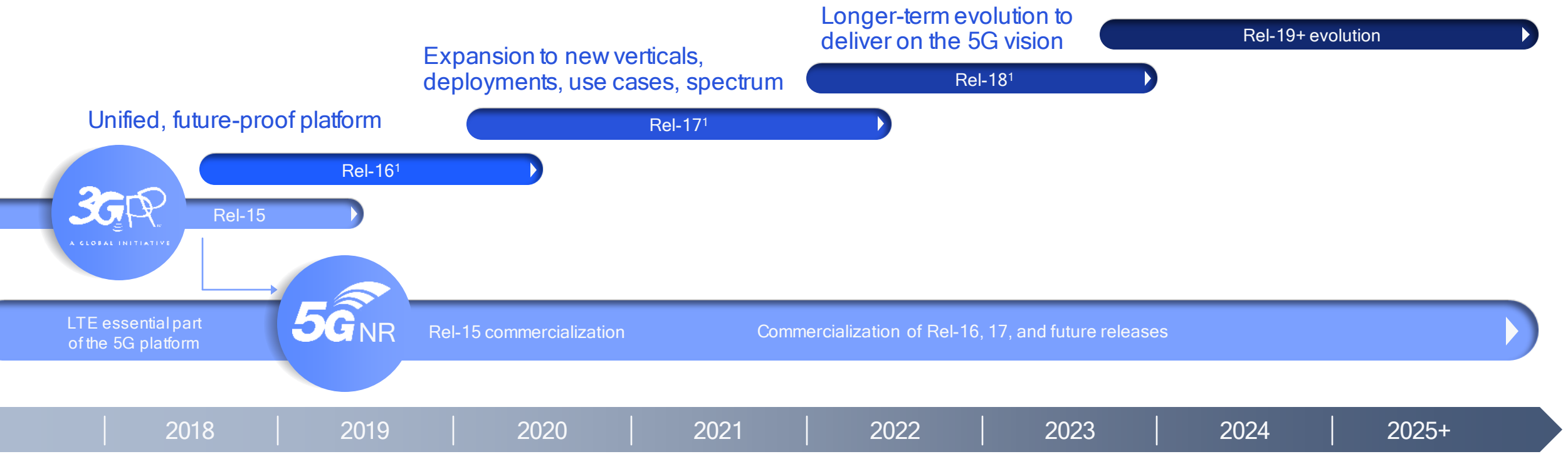
Autonomous guided vehicle

Predictive maintenance


5G
private network
Patient vital insights
Blood pressure
70/120
Patient X-ray
Medication alerts
Precise daily reading recording
Emergency contact 510 532 2423
Smart medicine dispenser
Diagnostic equipment (BP/ HR/ Oxygen)
Health wearable
Equipment tracking
Remote surgery
Patient location tracker
Remote patient care
Sylvia Brown
Female,
28yr, Seattle
Rx
1 capsule X 12 days
After meals
68 RPM 12
SYS 122 DIA 79
Upcoming appointment notification
MON
11
Drugs track and trace
Automated records and retrieval
Digitizing healthcare with IoT to bring better patient experiences

Connecting classrooms and remote learning

Driving the 5G technology evolution



Rel-15 eMBB focus

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

Rel-16 industry expansion

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

Rel-17 continued expansion

- Lower complexity NR-Light
- Higher precision positioning
- Improved IIoT, V2X, IAB, and more…

Rel-18+ longer-term evolution

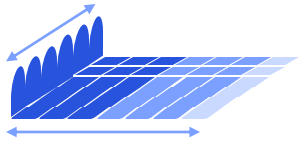
- Next set of 5G releases (i.e., 18, 19, 20, …)
- Potential projects in discussions
- Rel-18 expected to start in 2022

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

Our technology inventions drove 5G Rel-15 specifications

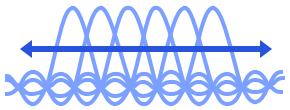
Flexible slot-based framework

For forward compatibility and ultra low-latency



Scalable OFDM-based air interface

For diverse services, spectrum, deployments

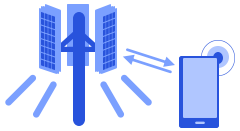


Advanced channel coding

For more efficient delivery of multi-Gbps throughput

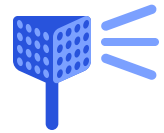
Massive MIMO

For increased network coverage and capacity



Mobile mmWave

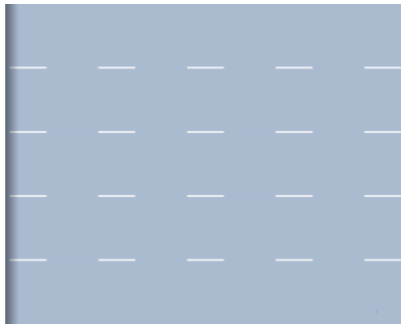
For extreme capacity and throughput



5G NR air interface foundation is analogous to new road and vehicle designs

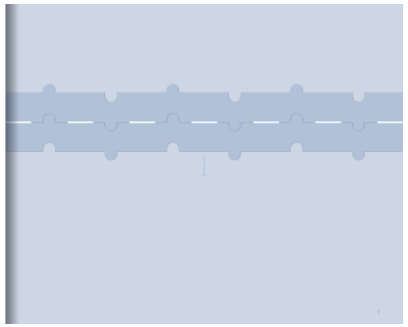
Flexible road framework

Dynamically and efficiently adapt to all traffic types and situations



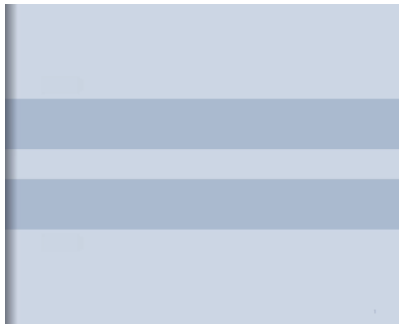
Modular road design

Exponentially scalable from single to multi-lane; common design for all configurations



Better engine efficiency

Ability to achieve high speeds with lower energy consumption

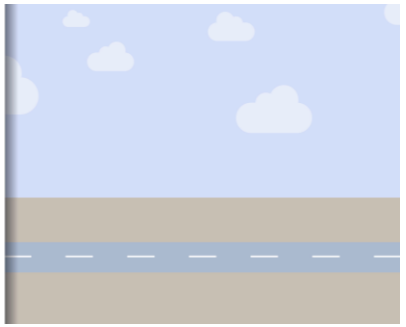


Multi-deck road

Stacking roads to allow more cars to travel faster

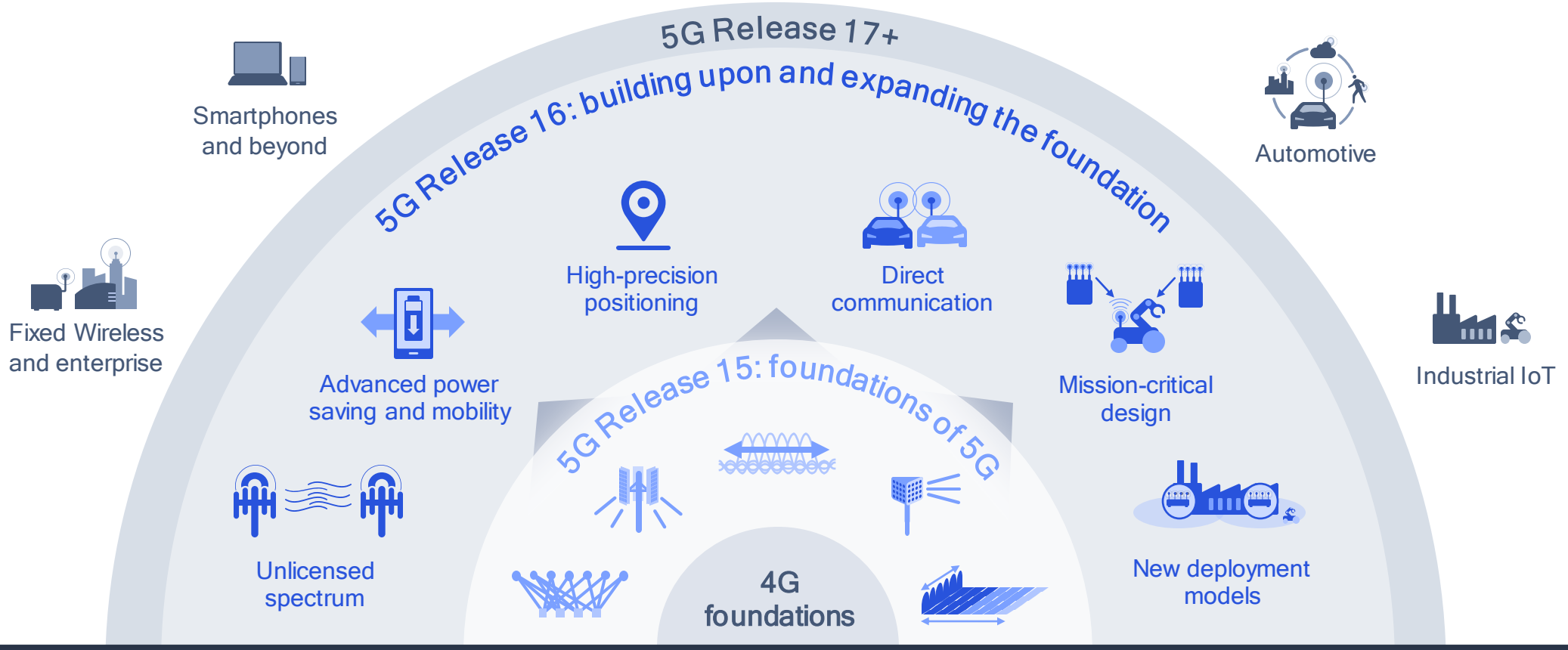
Roads in the sky

New types of high-speed roads based on resources that were previously thought unusable



Ongoing innovation through 5G releases

Enhancing broadband and enabling new verticals



Continuing pipeline of high value, foundational IP

5G

Advancing 5G for the new decade

Release 15

Established 5G NR technology foundation

- eMBB — enhanced mobile broadband services
- 5G core network
- Sub-6 GHz with massive MIMO
- Advanced channel coding
- Scalable OFDM-based air interface
- Mobile mmWave
- Flexible framework
- LTE integration

Release 16

Expanding to new use cases and industries

- 5G broadcast[1]
- In-band eMTC/NB-IoT & 5G Core[2]
- 5G NR IIoT with eURLLC
- Positioning across use cases
- eMBB evolution - improved power, mobility, more[3]
- 5G NR Cellular V2X
- Better coverage with IAB, uplink MIMO
- 5G NR in unlicensed spectrum
- IAB — integrated access/backhaul
- Private Networks, SON, satellites[4]

Release 17

Continued expansion and enhancements

- Enhanced DL/UL MIMO, multiple transmission points[5]
- NR-Light for wearables, industrial sensors
- Unlicensed spectrum across all use-cases
- More capable, flexible IAB
- New spectrum above 52.6 GHz
- Centimeter accuracy IIoT with mmWave
- Expand sidelink for V2X reliability, P2V, IoT relay
- Enhancements to 5G NR Industrial IoT
- Continued eMBB enhancements, XR, others[4]
- Rel-15 deployment learning, XR, drones, others[6]

Release 18

Potential projects (nominal work expected to start in 2022)

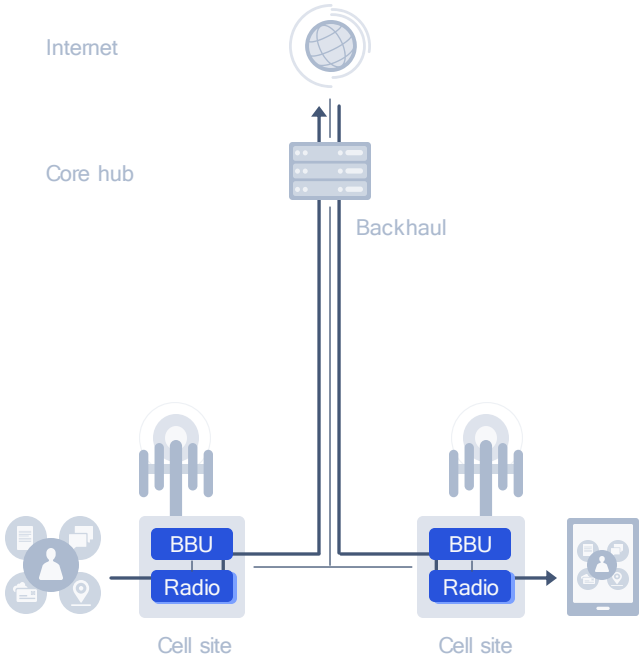
- Further eMBB enhancements
- Full-duplex MIMO
- Extended reality
- Higher mmWave frequencies
- Automotive & NR V2X enhancements
- Non-terrestrial acces
- 5G NR-Light expansion for IoT
- AI/ML data-driven designs
- Broadcast enhancements
- Sidelink in unlicensed spectrum

1. Enhancing Rel-14 LTE enTV to meet 5G requirements; 2. eMTC/NB-IOT in-band 5G NR and connected to 5G core; 3. MIMO, power consumption, mobility, MR DC/CA, interference management and more; 4. Non-terrestrial networks, non-public networks (private networks), NR SON/MDT and more; 5. further improvements to capacity, coverage, mobility, power consumption, spectral efficiency; 6. mixed-mode multicast, small data transmission, multi-SIM, satellite, multimedia

Evolving the 5G network

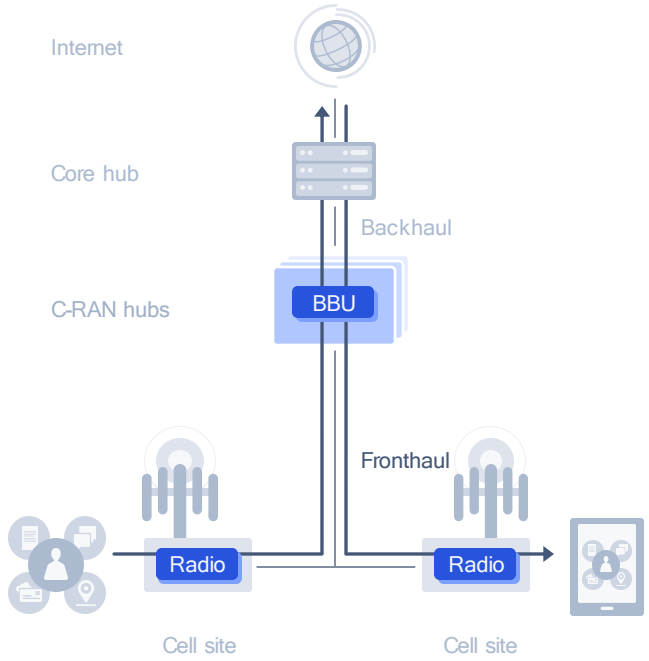
Traditional RAN

Combined baseband processing unit + Radio unit



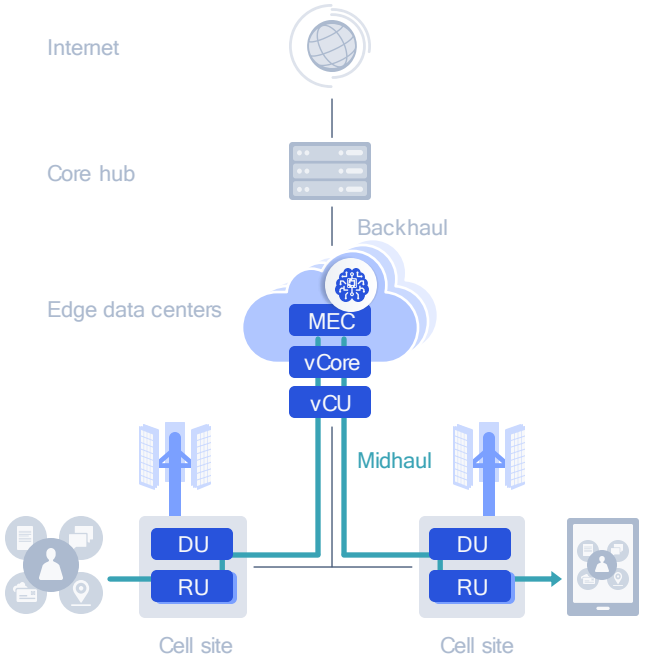
Centralized RAN (C-RAN)

Centralized baseband processing unit



Virtual RAN (vRAN) + MEC

Virtualized baseband processing unit with disaggregation

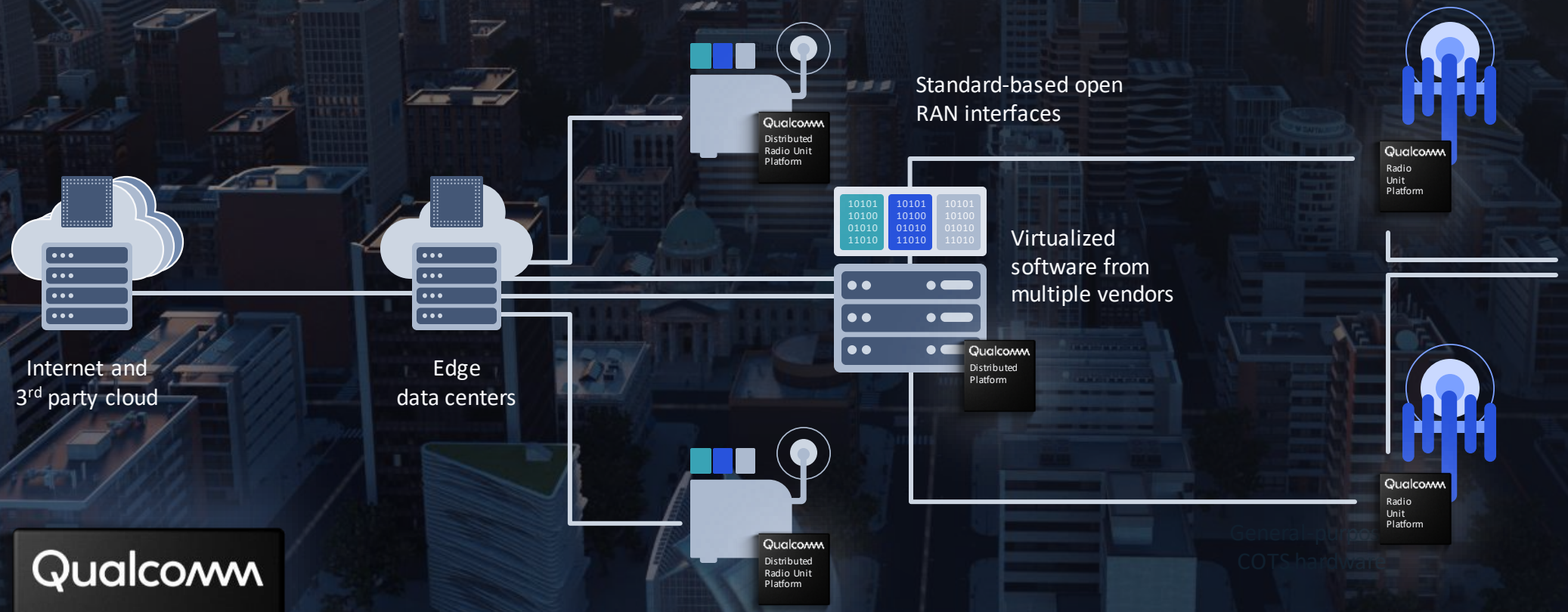


For better coordination, scalable capacity, faster deployments, lower latency, and new use cases

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

Transitioning to Infrastructure 2.0

Powered by extended portfolio of Qualcomm® 5G RAN platforms



Qualcomm

5G RAN Platforms

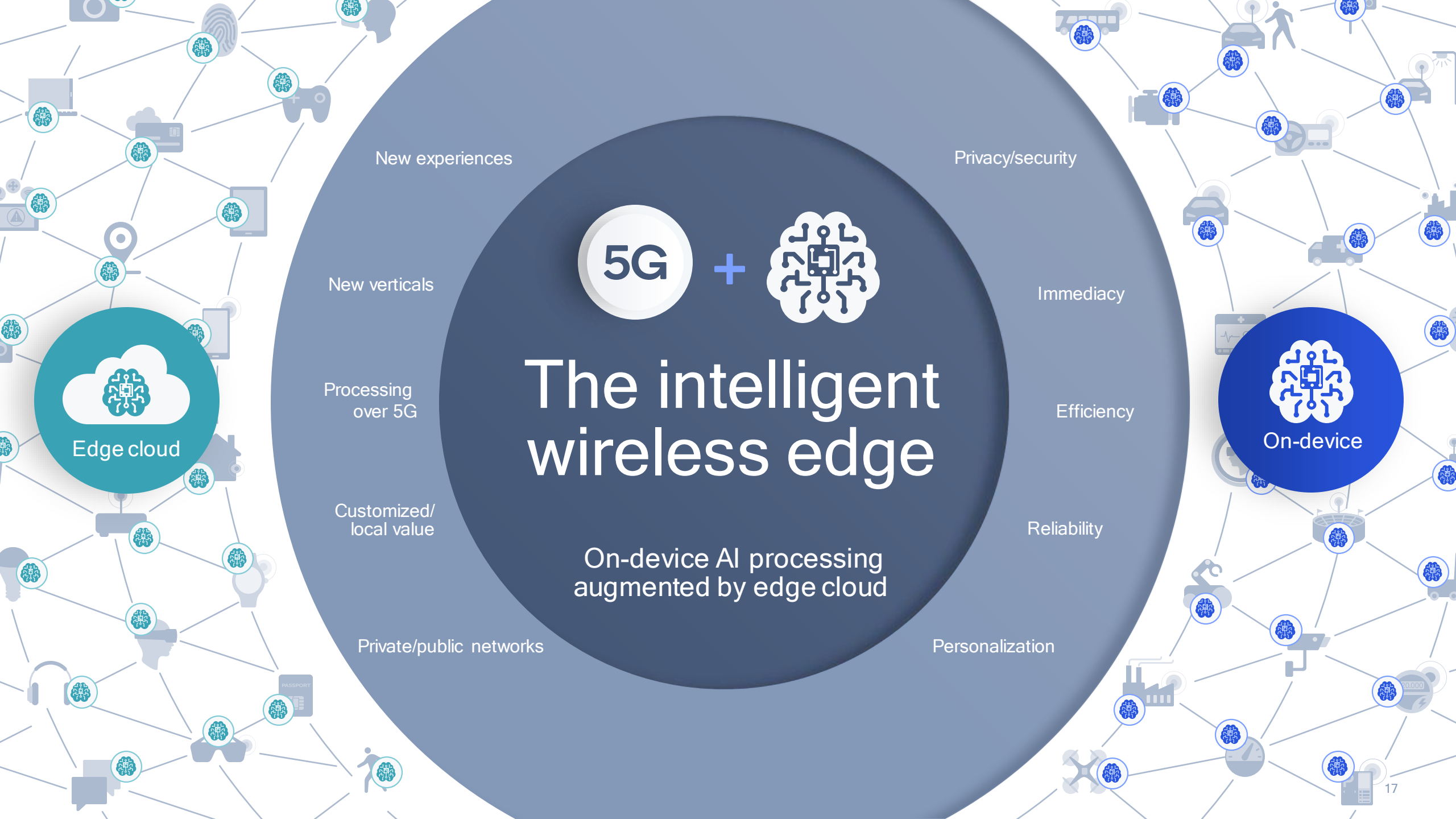
High performance Modem-RF

Virtualization with hardware acceleration

Flexible, scalable, O-RAN compatible

From Macro to Small Cells

Integrated Sub-6 and mmWave solution


New experiences
Privacy/security
New verticals
Immediacy
Processing over 5G
Efficiency
Customized/ local value
Reliability
Private/public networks
Personalization
5G
+
The intelligent wireless edge
On-device AI processing augmented by edge cloud
Edge cloud
On-device

Enriched user experiences, new use case, new verticals

Distributed functionality

5G

Longer latency
Big data/aggregated value
Content/storage/AI/processing

5G low latency
Customized/local value
Content/storage/AI/processing

Compute, vision, sensing
AI powered use cases
Internal AI optimizations

On-premise control for ultra-low latency

On-device intelligence assisted by cloud

Distributed processing, like boundless XR

New services

Cloud computing, storage, instant access

Low-latency gaming

Real time assisted services like voice UI


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

Elevating 5G NR capabilities for mission-critical designs

- 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)

Time Sensitive Networking (TSN)

Positioning

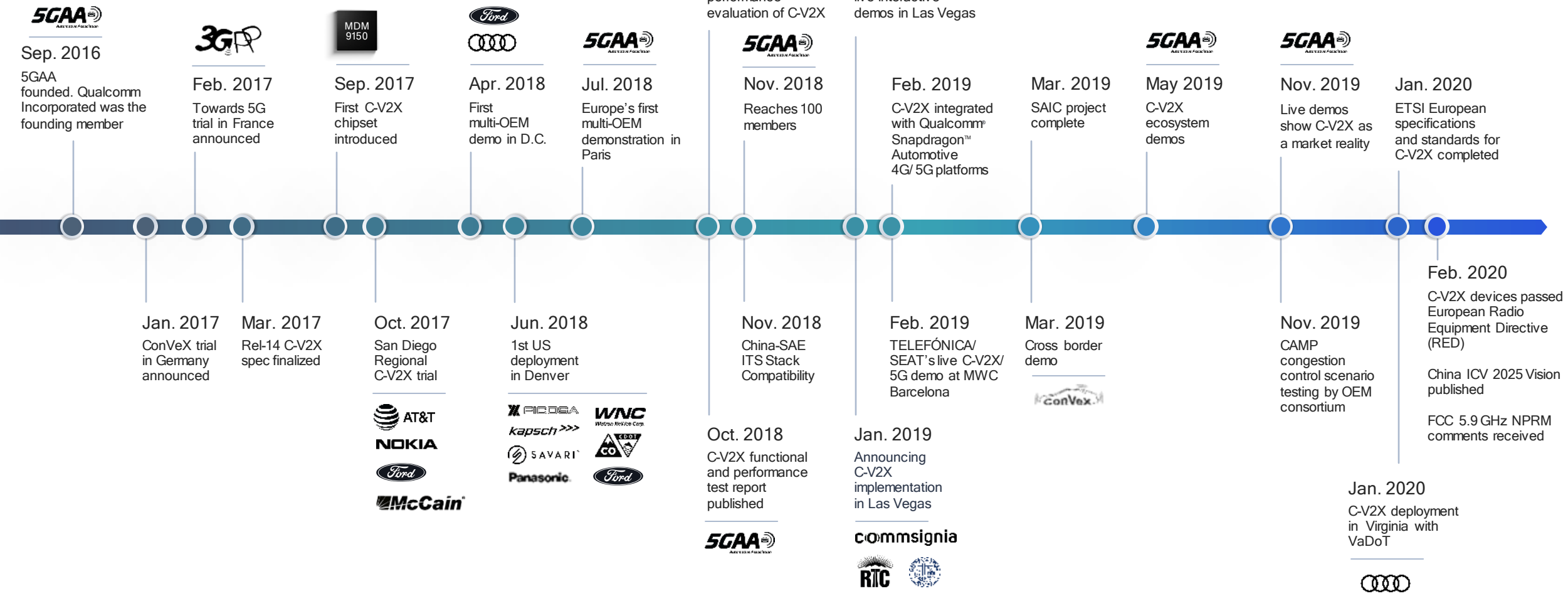
C-V2X

Rel 14/15 C-V2X established basic safety

Rel 16 5G V2X saw continued evolution for advanced safety use cases

- Release 14/15 C-V2X standards completed
- Broad industry support with 5GAA
- Global trials started in 2017; first commercial deployment expected in 2020
- Qualcomm® 9150 C-V2X chipset announced in September 2017
- Integration of C-V2X into the Qualcomm® Snapdragon™ Automotive 4G and 5G Platforms announced in February 2019

Strong C-V2X momentum globally



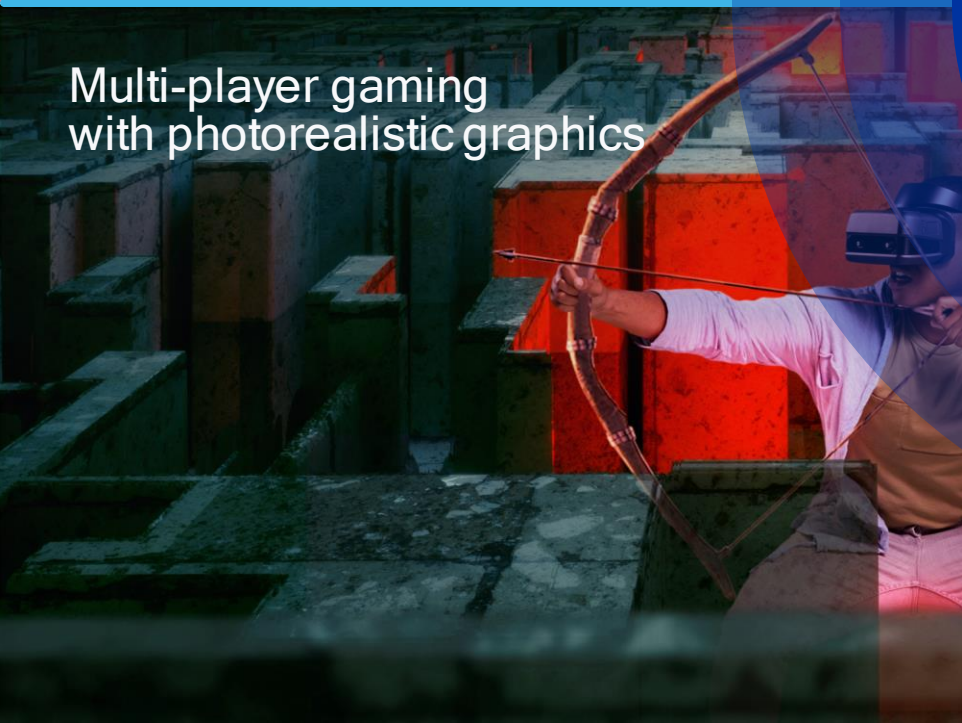
Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.

Real-time interactive collaboration

Shopping like never before

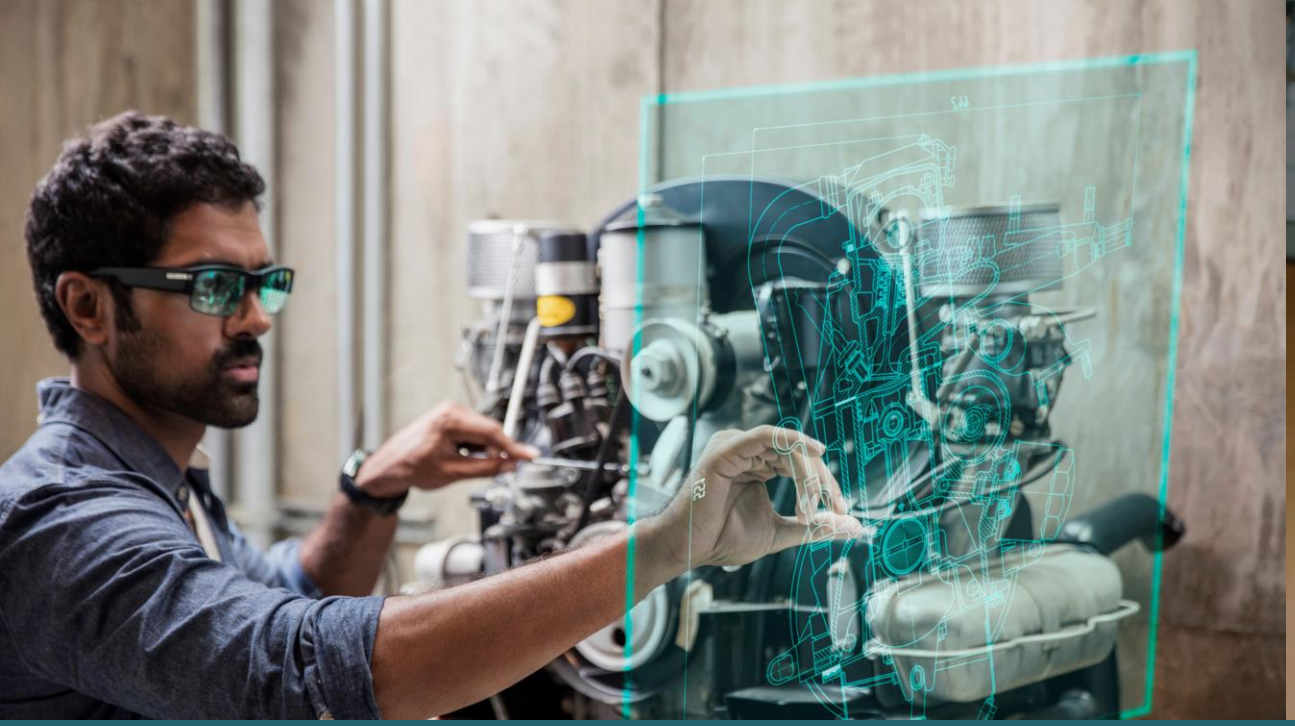
Boundless XR platform is ready for trials

Rel.16-18 features will pave the way for low-power split-AR solution



Multi-player gaming with photorealistic graphics

Our mobile office or living room, virtually anywhere



Smart viewer benefits

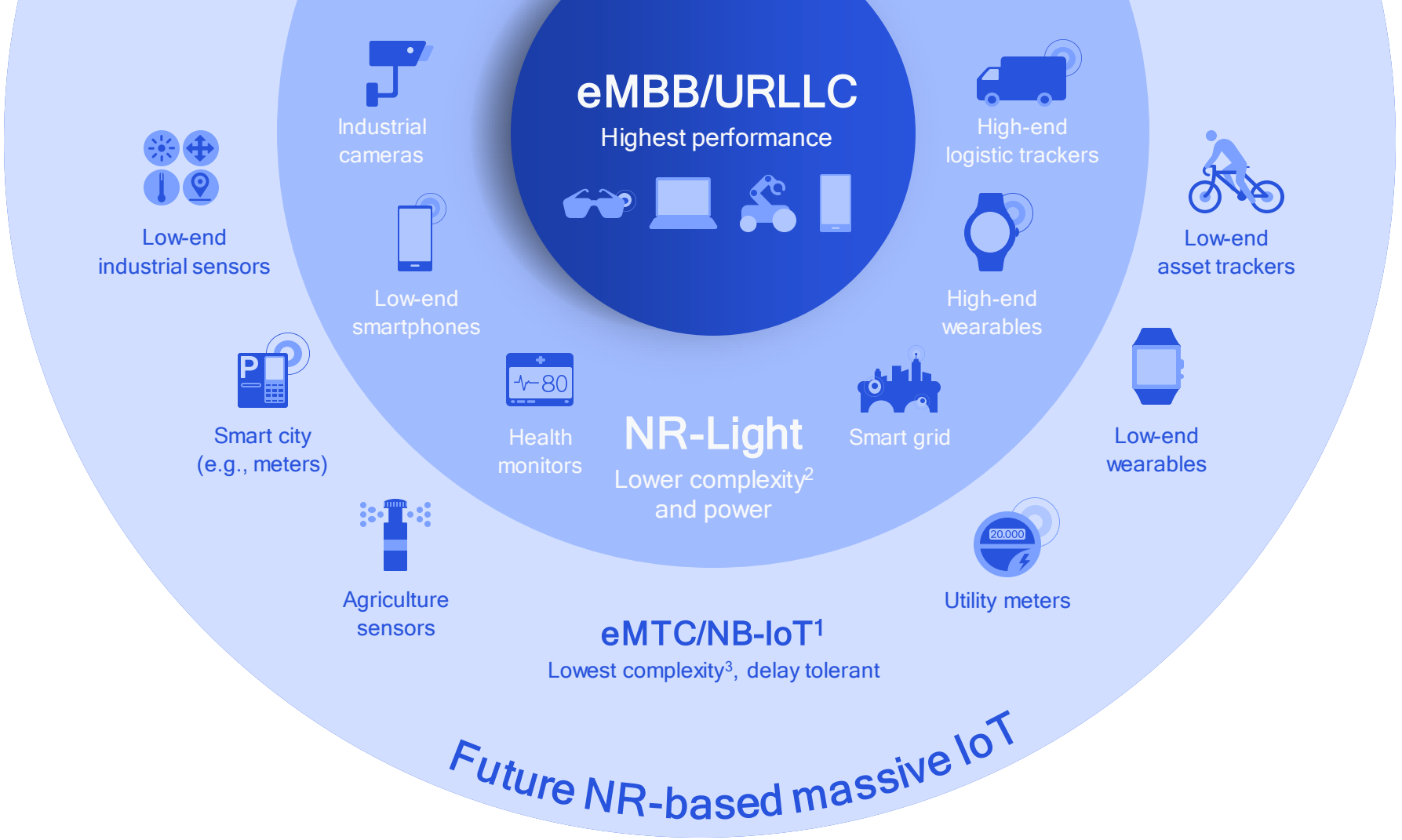
Interaction beyond reality

See and run multiple programs and tasks simultaneously

Low-latency

Impressive power efficiency

Perfect for immersive collaboration and streaming

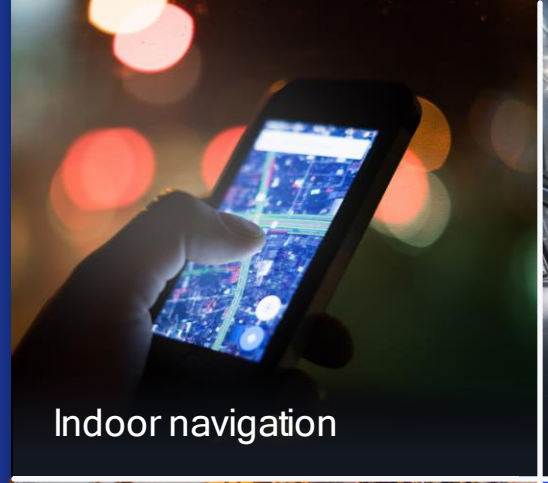


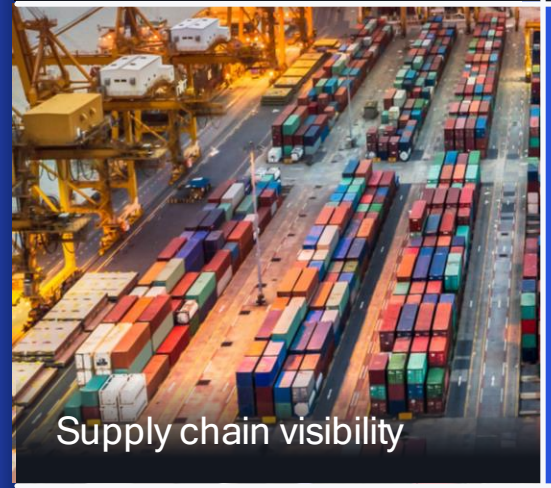
5G NR: A unified, scalable air interface allowing coexistence of a wide range of 5G device classes

1 Also including satellite access; 2 Data rate of 150 Mbps DL / 50 Mbps UL, latency of 10-30 ms, 10-3 to 10-5 reliability, coverage MCL of 143 dB; 3 Data rate of 1Mbps, MCL of 155.7 dB (eMTC) and 164 dB (NB-IoT)

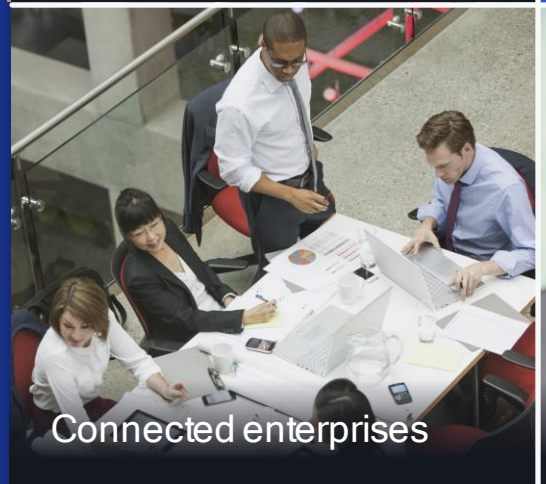
Supporting a wide range of new vertical use cases

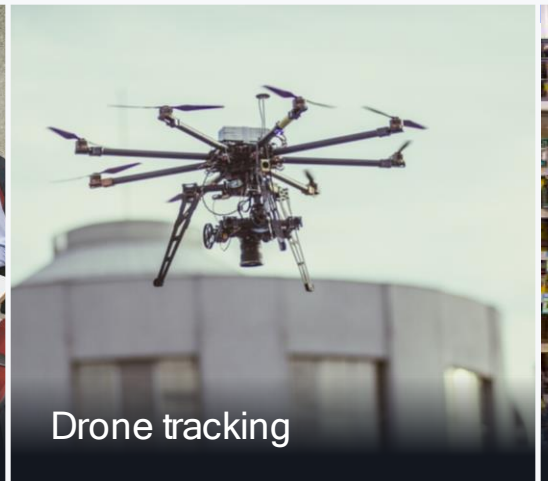
- For both indoor & outdoor positioning
- Complementing existing positioning technologies, such as GNSS[1], beacons, sensors, Wi-Fi/Bluetooth
- Targeting accuracy and latency that meet diverse service requirements[2]

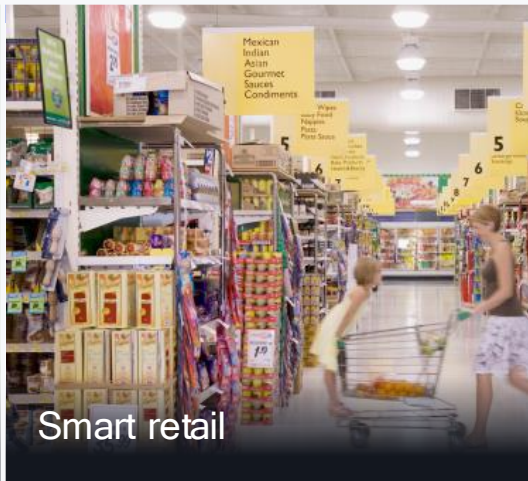




5G NR Positioning







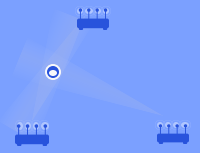
Evolving 5G NR positioning to fully meet 5G requirements[1]

Rel-17 will expand on the LTE and 5G NR Rel-16 foundation

Release 16

Meeting initial accuracy requirements of 3m (indoor) to 10m (outdoors) for 80% of time

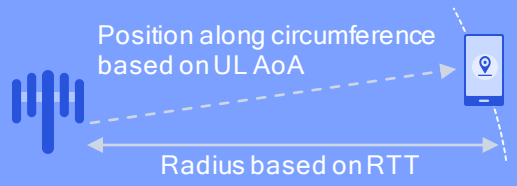
Roundtrip time (RTT)



Angel of arrival / departure (AoA/AoD)

Time difference of arrival (TDOA)

Single-cell positioning



Release 17

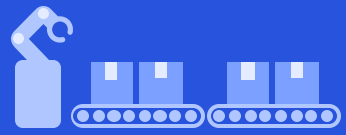
Enhancing capability and performance for a wide range of use cases

Centimeter level accuracy

Meeting absolute accuracy requirements[1] of down to 0.3m

Lower latency

Reducing positioning latency to as low as 10 ms[3]

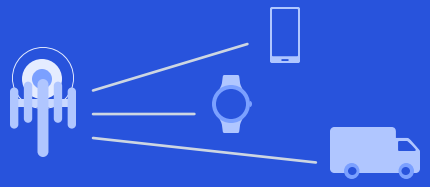


New evaluation scenarios

Supporting new channel models for industrial IoT environment

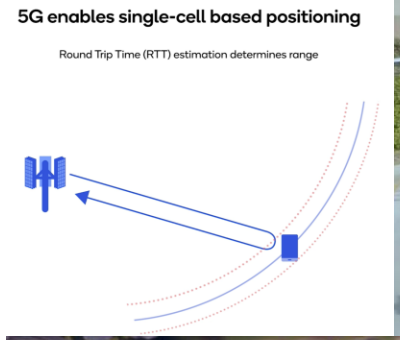
Higher capacity

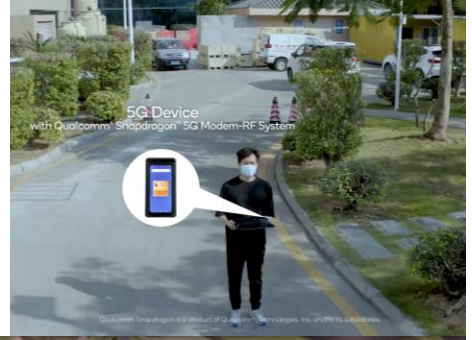
Scaling to millions of simultaneous devices for e.g., IoT, automotive



Accelerating innovations with 5G end-to-end system prototypes

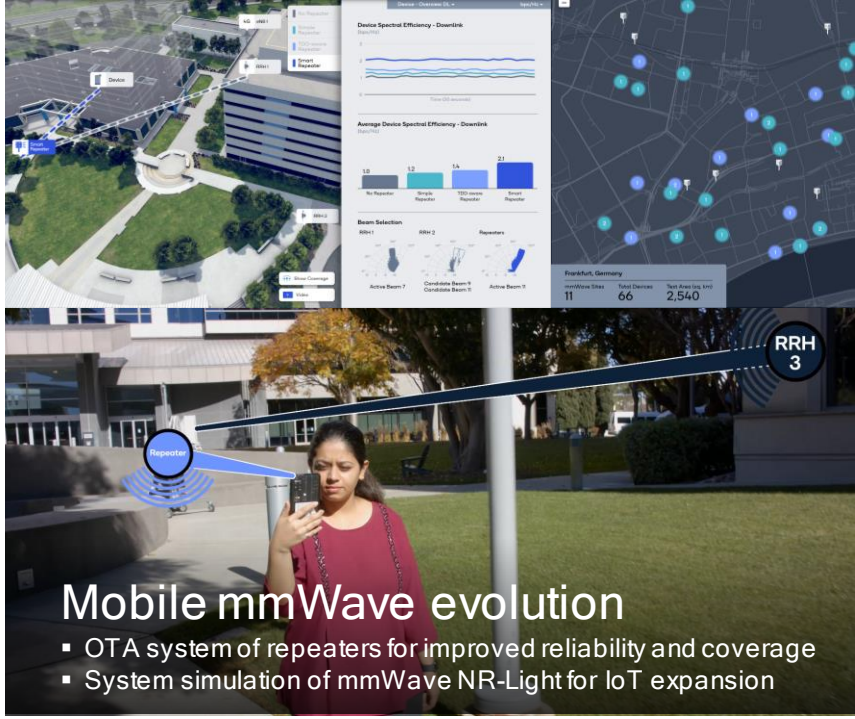
- Validate our advanced system designs and drive standardization
- Refine 5G algorithms to further improve performance and efficiency
- Demonstrate future system capabilities that expand 5G to new use cases





Wide-area 5G evolution

- OTA system of subband half duplex flexible service multiplexing
- OTA trial with ZTE of single-cell positioning using RTT/AoA



Mobile mmWave evolution

- OTA system of repeaters for improved reliability and coverage
- System simulation of mmWave NR-Light for IoT expansion

Industrial IoT expansion

- OTA system supporting ultra-high reliability, TSN, and sidelink

Advanced 5G V2X use cases

- OTA system of sidelink supporting navigation based on high-resolution 3D maps, provided by local roadside units (RSUs)

Boundless XR over 5G

- OTA mmWave system of multi-user, immersive boundless VR experience enabled by end-to-end optimizations

Intelligently connecting

our world in the 5G era

A unified connectivity fabric for this decade

5G

Continued evolution

Rel-15
eMBB focus

Rel-16 and 17
Expanding to new industries

Rel-18, 19, 20 and beyond
Continued 5G proliferation

6G

Next technology leap for new capabilities and efficiencies

Historically 10 years between generations

Strong 5G momentum sets the stage for the global expansion

Qualcomm

Thank you

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