
Qualcomm
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January 20, 2021
5G Revolution
Lola Awoniyi-Oteri, PhD
Principal Systems Engineer,
Qualcomm Technologies Inc.
5G

Agenda

1. 5G vision, services and requirements
2. 5G NR design and technologies
3. 5G NR Commercialization
4. 5G NR evolution and expansion

Cellular has revolutionized the way we communicate

From voice only to a plethora of new services that our lives depend on today (e.g., smartphone)

< Then

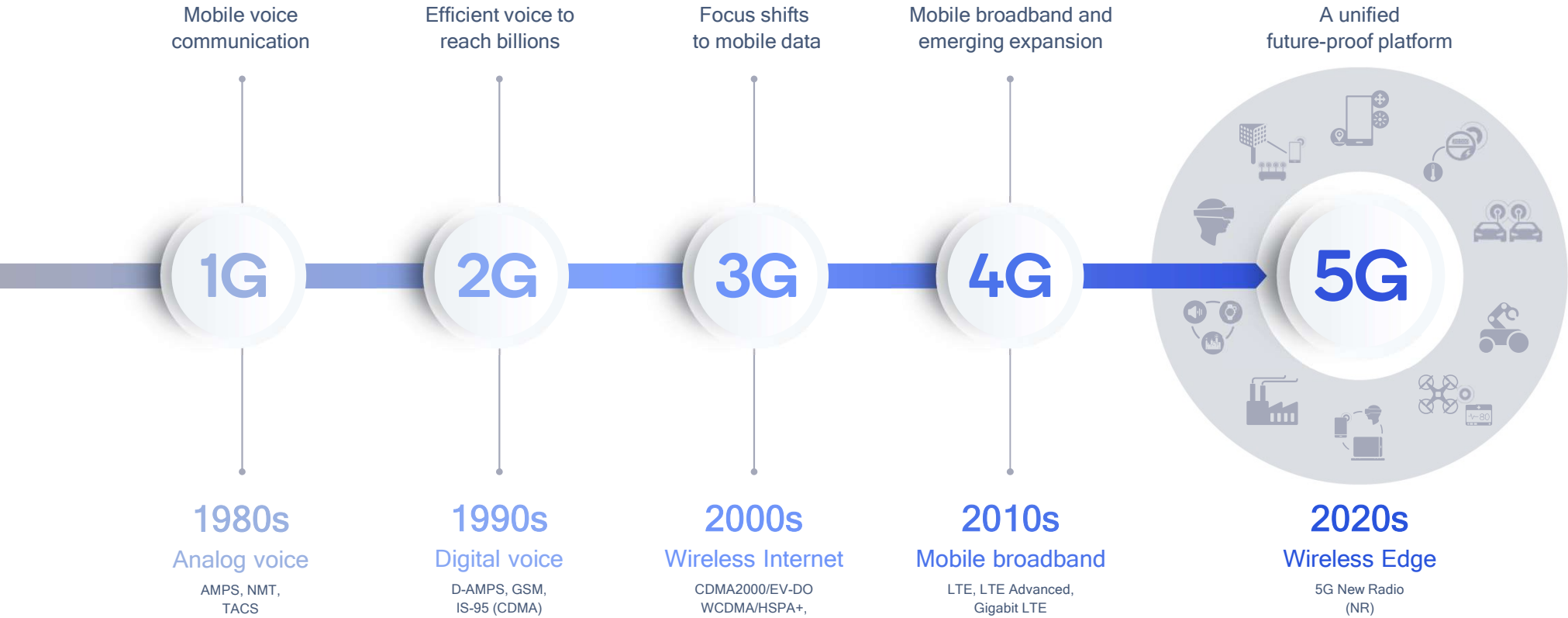
Now >

8.9B
mobile subscriptions
by 2025

Source: Ericsson Mobility Report, November, 2019

Mobile has made a leap every ~10 years

Continuous innovation between “G”



5G will address the insatiable demand for mobile broadband

Over 60x growth in mobile data traffic from 2013 to 2024

~131B Gigabytes

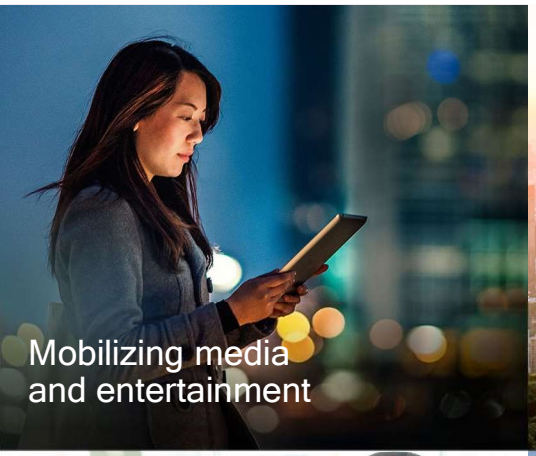
Monthly global mobile data traffic in 2024

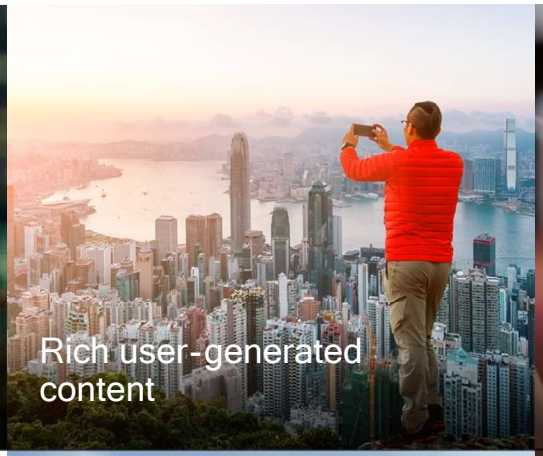
In 2024, ~75% of mobile data traffic from multi-media creation & consumption

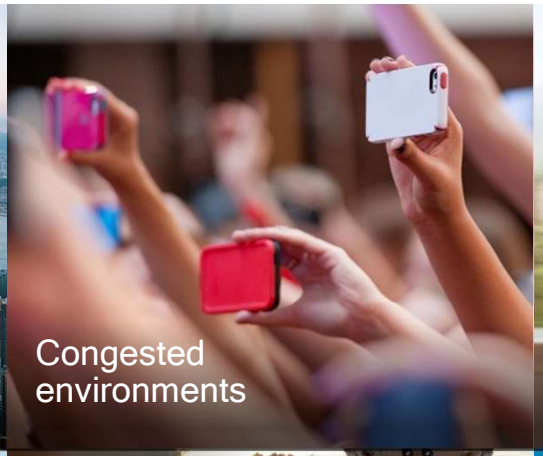
5G

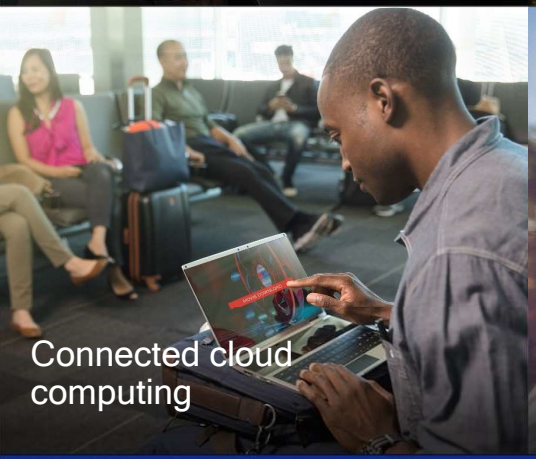
In 2024, 25% of mobile data traffic will be carried by 5G networks – 1.3x more than 4G/3G/2G traffic today

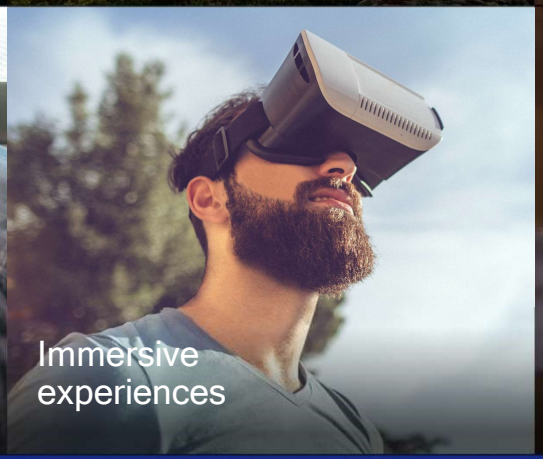
Source: Ericsson Mobility Report June 2019











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

5G NR Services

To meet an extreme variation of 5G NR requirements

Mission-critical services

Enhanced mobile broadband

Massive Internet of Things

10x	10x	3x	100x	100x	10x
Decrease in end-to-end latency	Experienced throughput	Spectrum efficiency	Traffic capacity	Network efficiency	Connection density

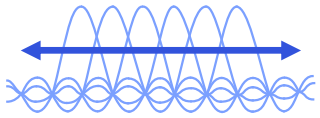
Based on ITU vision for IMT-2020 compared to IMT-advanced; URLLC: Ultra Reliable Low Latency Communications;

5G NR Key Technologies

Release 15

Key Technologies driving Rel-15 specifications

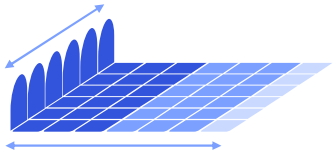
Scalable OFDM-based air interface



Scalable OFDM numerology

Address diverse services, spectrum, deployments

Flexible slot-based framework



Self-contained slot structure

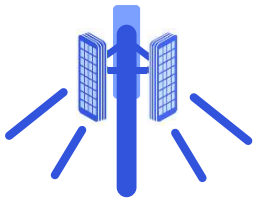
Low latency, URLLC, forward compatibility

Advanced channel coding

Multi-Edge LDPC and CRC-Aided Polar

Support large data blocks, reliable control channel

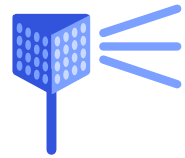
Massive MIMO



Reciprocity-based MU-MIMO

Large # of antennas to increase coverage/capacity

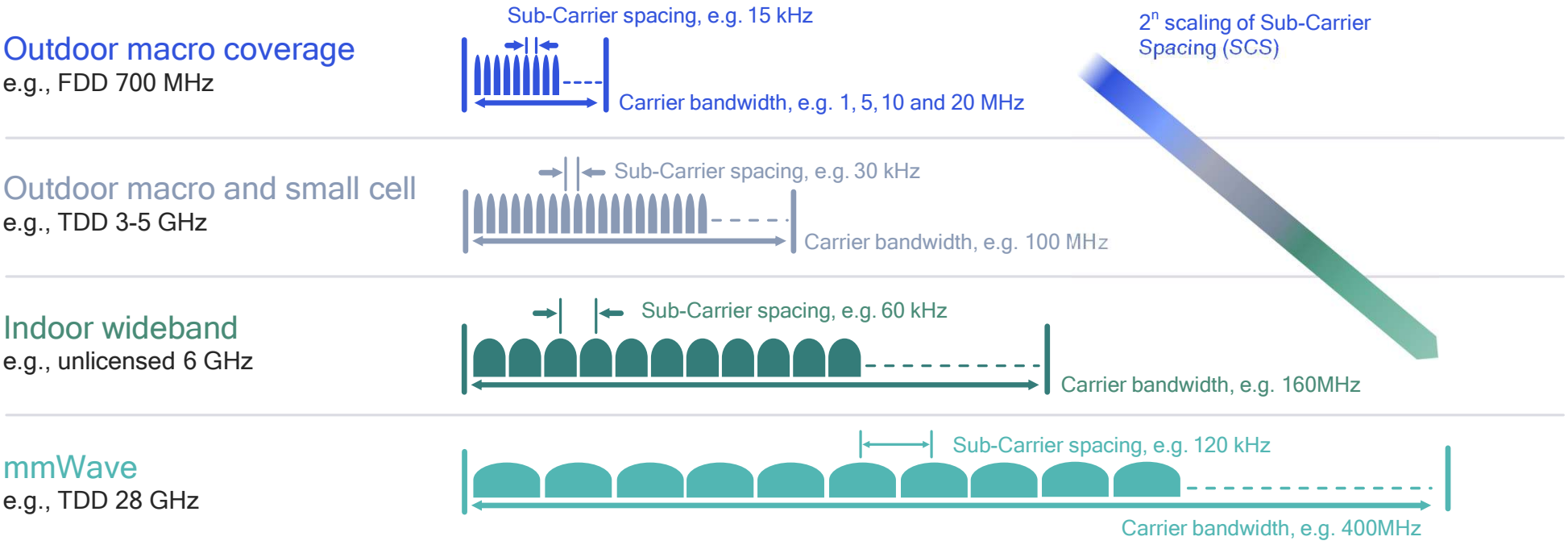
Mobile mmWave



Beamforming and beam-tracking

For extreme capacity and throughput

Scalable 5G NR OFDM numerology–examples



Efficiently address 5G diverse spectrum, deployments and services

Scaling reduces FFT processing complexity for wider bandwidths with reusable hardware

Flexible slot-based 5G NR framework

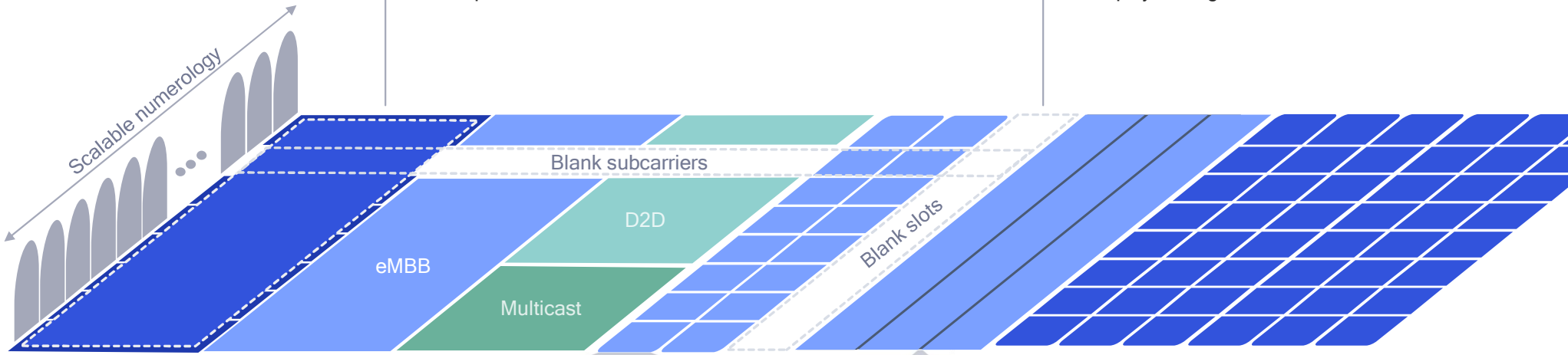
Efficiently multiplex envisioned and future 5G services on the same frequency

Scalable slot duration

Efficient multiplexing of diverse latency and QoS requirements

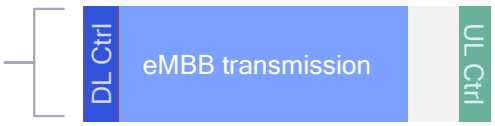
Forward compatibility

Transmissions well-confined in time/frequency to simplify adding new features in future



Self-contained slot structure

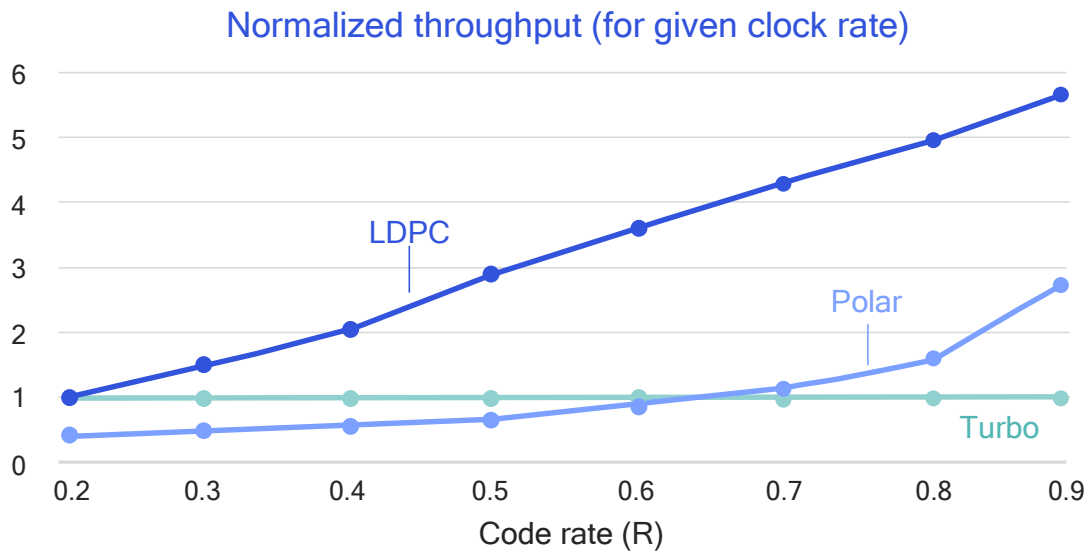
Ability to independently decode slots and avoid static timing relationships across slots



Nominal traffic puncturing

To enable URLCC transmissions to occur at any time using mini-slots

Advanced ME-LDPC[1] channel coding is more efficient than LTE Turbo code at higher data rates



High efficiency

Significant gains over LTE Turbo–particularly for large block sizes suitable for MBB

Low complexity

Easily parallelizable decoder scales to achieve high throughput at low complexity

Low latency

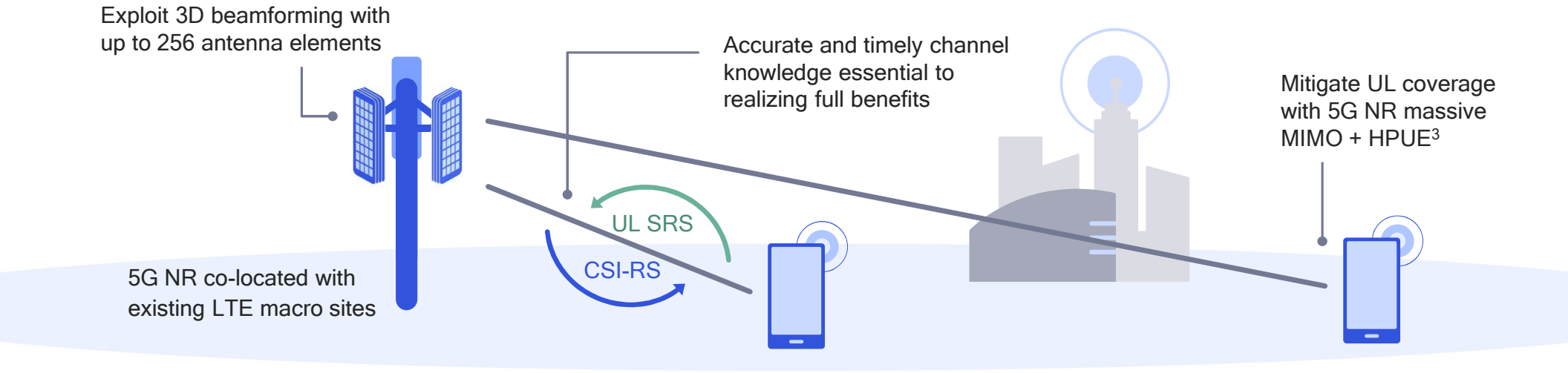
Efficient encoding/decoding enables shorter transmission time at high throughput

1. Multi-Edge Low-Density Parity-Check

Selected as 5G NR eMBB data channel as part of 3GPP Release-15

5G NR optimized design for massive MIMO

Key enabler for using higher spectrum bands, e.g. 4 GHz, with existing LTE sites



Enabled through an advanced 5G NR end-to-end Massive MIMO design (network and device)

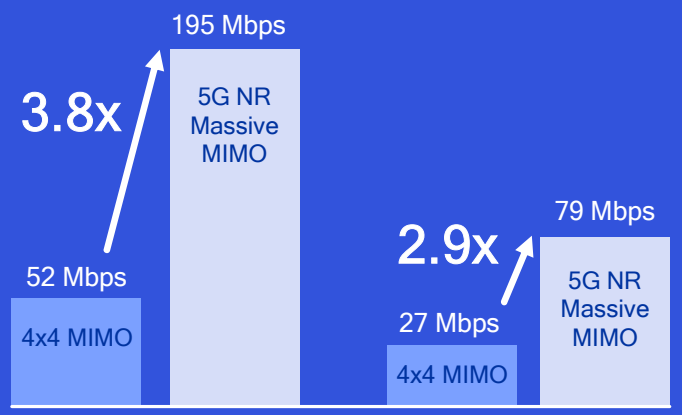
- Optimized design for TDD reciprocity procedures utilizing UL SRS[1]
- Enhanced CSI-RS[2] design and reporting mechanism
- Advanced, high-spatial resolution codebook supporting up to 256 antennas
- New features, such as distributed MIMO

C1. Sounding Reference Signal. 2. Channel State Information Reference Signal; 3. High-Power User Equipment (HPUE) Tx power gains

Qualcomm | 5G NR Massive MIMO

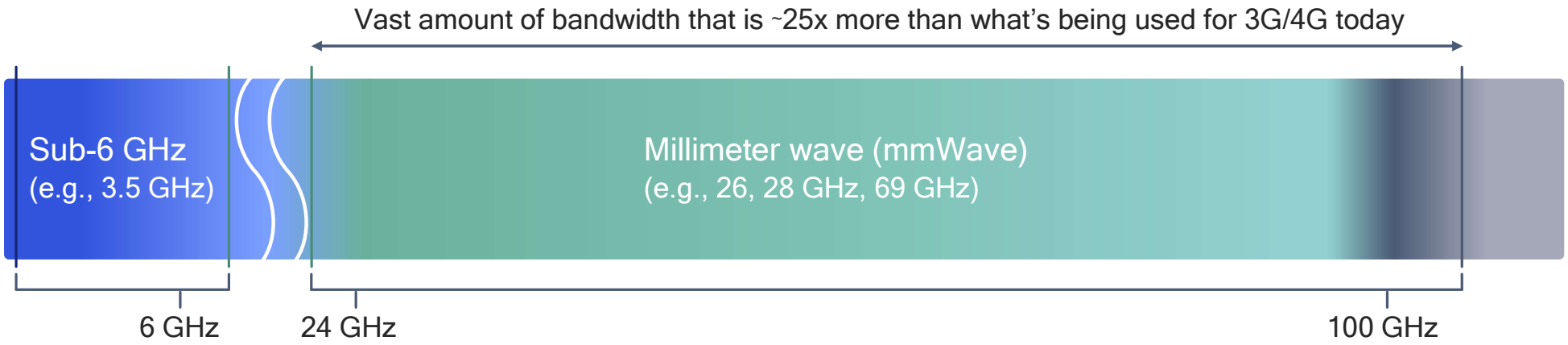
5G NR massive MIMO increases coverage & capacity

Faster, more uniform data rates throughout cell



Assumptions: carrier frequency 4GHz; 200m ISD, 200MHz total bandwidth; base station: 256 antenna elements (x-pol), 48dBm Tx power; UE: 4 Tx/Rx antenna elements, 23dBm max. Tx power; full buffer traffic model, 80% indoor and 20% outdoor UEs.

New frontier of mobile broadband – mobilizing mmWave



Multi-Gbps data rates
With large bandwidths (100s of MHz)

Much more capacity
With dense spatial reuse

Lower latency
Bringing new opportunities

Overcoming the mobile mmWave challenge

Proving the skeptics wrong about mmWave can never be used for mobile

Limited coverage and too costly

Significant path loss means coverage limited to just a few hundred feet, thus requiring too many small cells

Significant coverage with co-siting

Analog beamforming w/ narrow beam width to overcome path loss. Comprehensive system simulations reusing existing sites.

Works only line-of-sight (LOS)[1]

Blockage from hand, body, walls, foliage, rain etc. severely limits signal propagation

Operating in LOS and NLOS[1]

Pioneered advanced beamforming, beam tracking leveraging path diversity and reflections.

Only viable for fixed use

As proven commercial mmWave deployments are for wireless backhauls and satellites

Supporting robust mobility

Robustness and handoff with adaptive beam steering and switching to overcome blockage from hand, head, body, foliage.

Requiring large formfactor

mmWave is intrinsically more power hungry due to wider bandwidth with thermal challenges in small formfactor

Commercializing smartphone

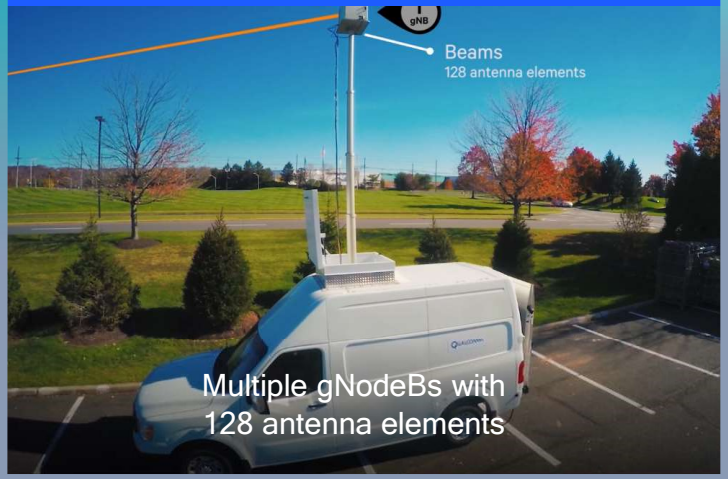
Announced modem, RF, and antenna products to meet formfactor and thermal constraints, plus device innovations.

1 LOS: Line of sight, NLOS: Non-line-of-sight

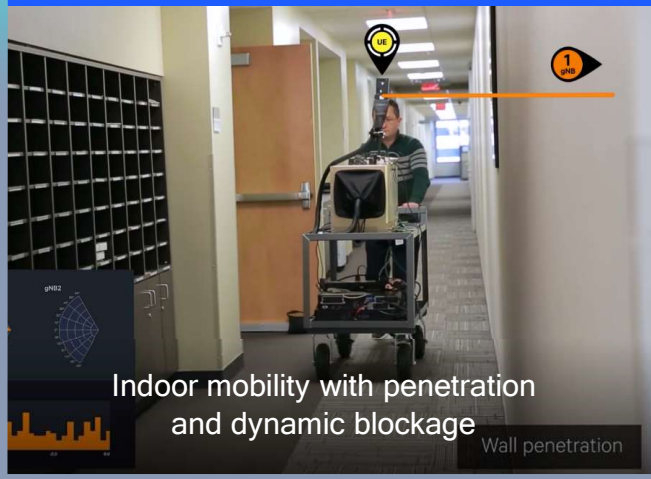
Mobilizing 5G mmWave in real-world environments

Demonstrating NLOS operation and robust mobility

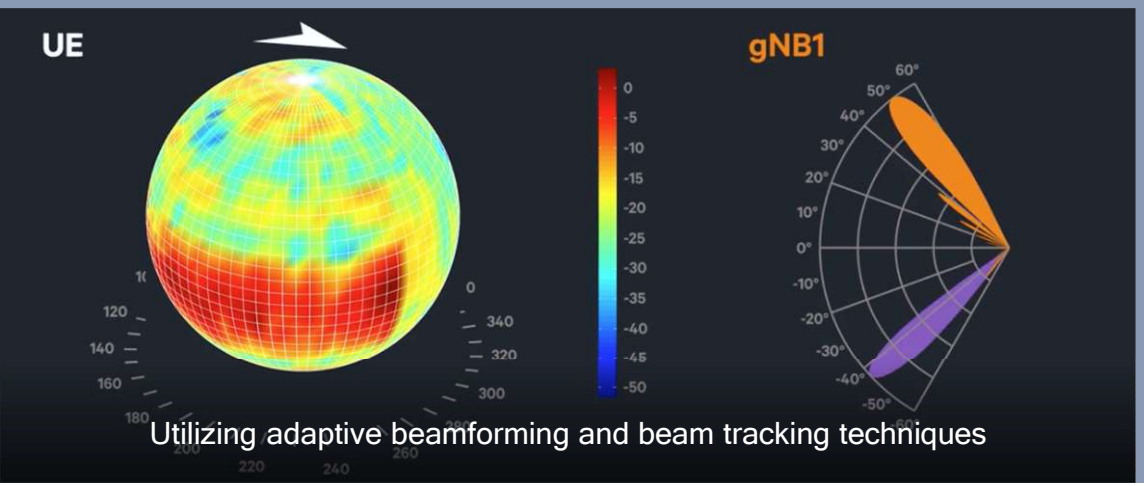
Handheld and in-vehicle UEs with four selectable sub-arrays



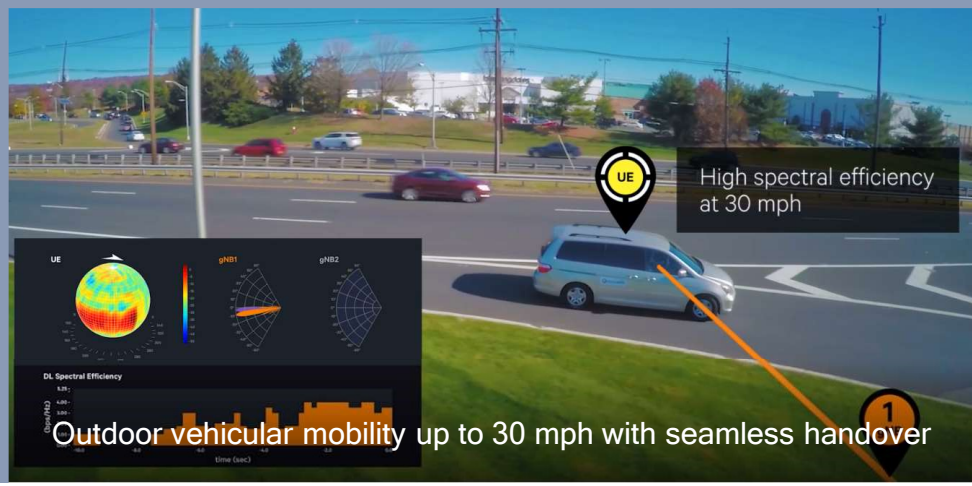
Multiple gNodeBs with 128 antenna elements



Indoor mobility with penetration and dynamic blockage

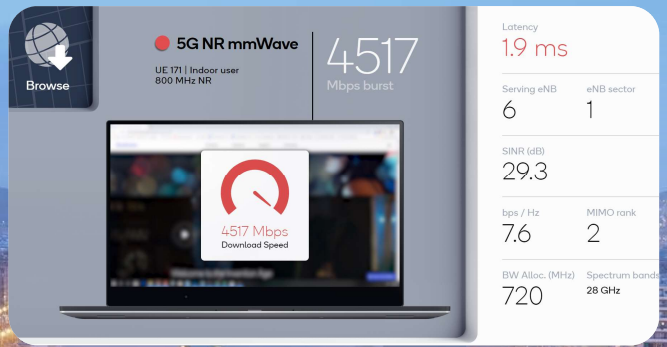


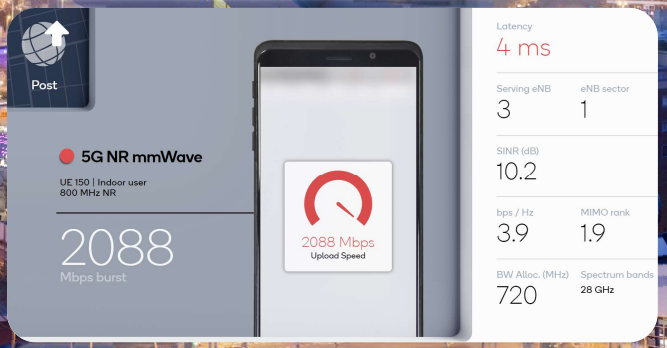
Utilizing adaptive beamforming and beam tracking techniques



Outdoor vehicular mobility up to 30 mph with seamless handover

Showcasing enhanced mobile mmWave user experiences

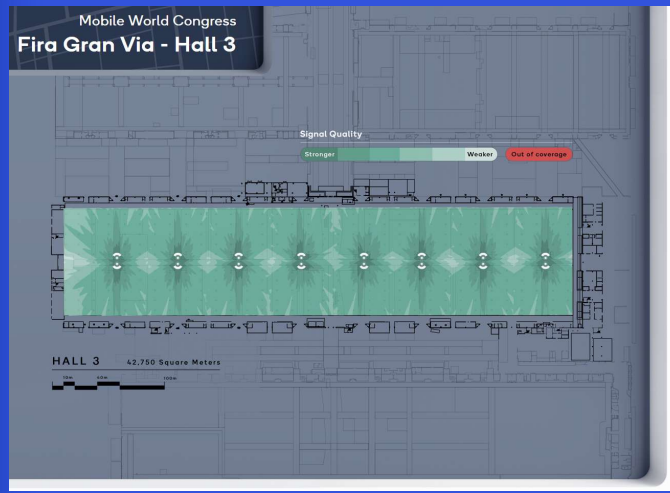




Simulation assumes 5G NR mmWave co-siting at actual LTE DAS locations in Fira Gran Via Hall 3, uses 800 MHz spectrum in 28 GHz, and is based on Qualcomm engineering simulation tools

Advanced Network Simulations

Deploying 28 GHz 5G NR mobile mmWave at Mobile World Congress venue



Ubiquitous coverage via co-siting

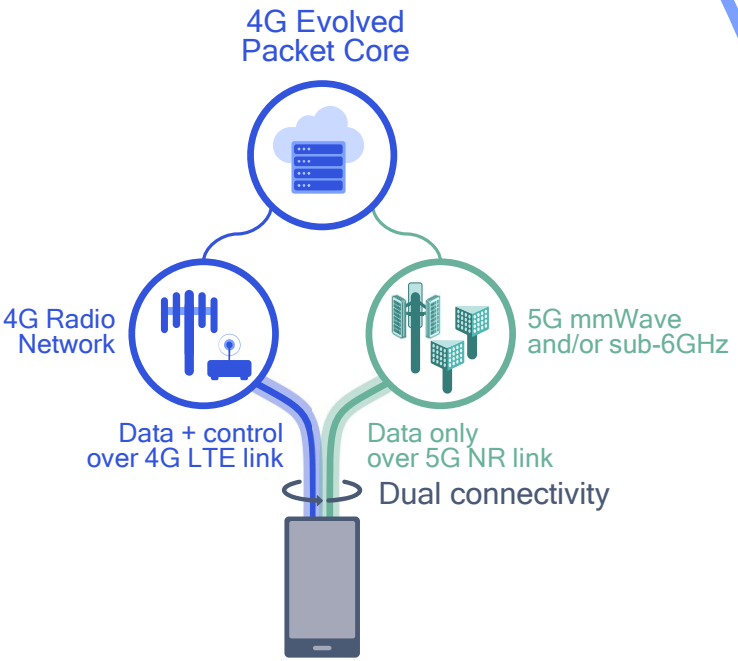
Virtually unlimited capacity

Multi-Gbps speed & low latency

More uniform user experience

For a wide range of mobile devices:

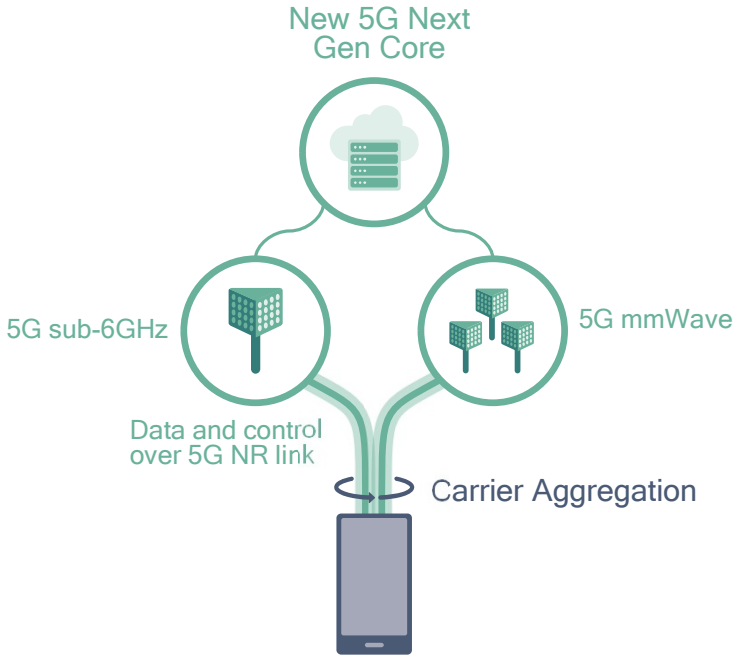
Non-Standalone (NSA) stepping stone to new core



Fast-to-launch

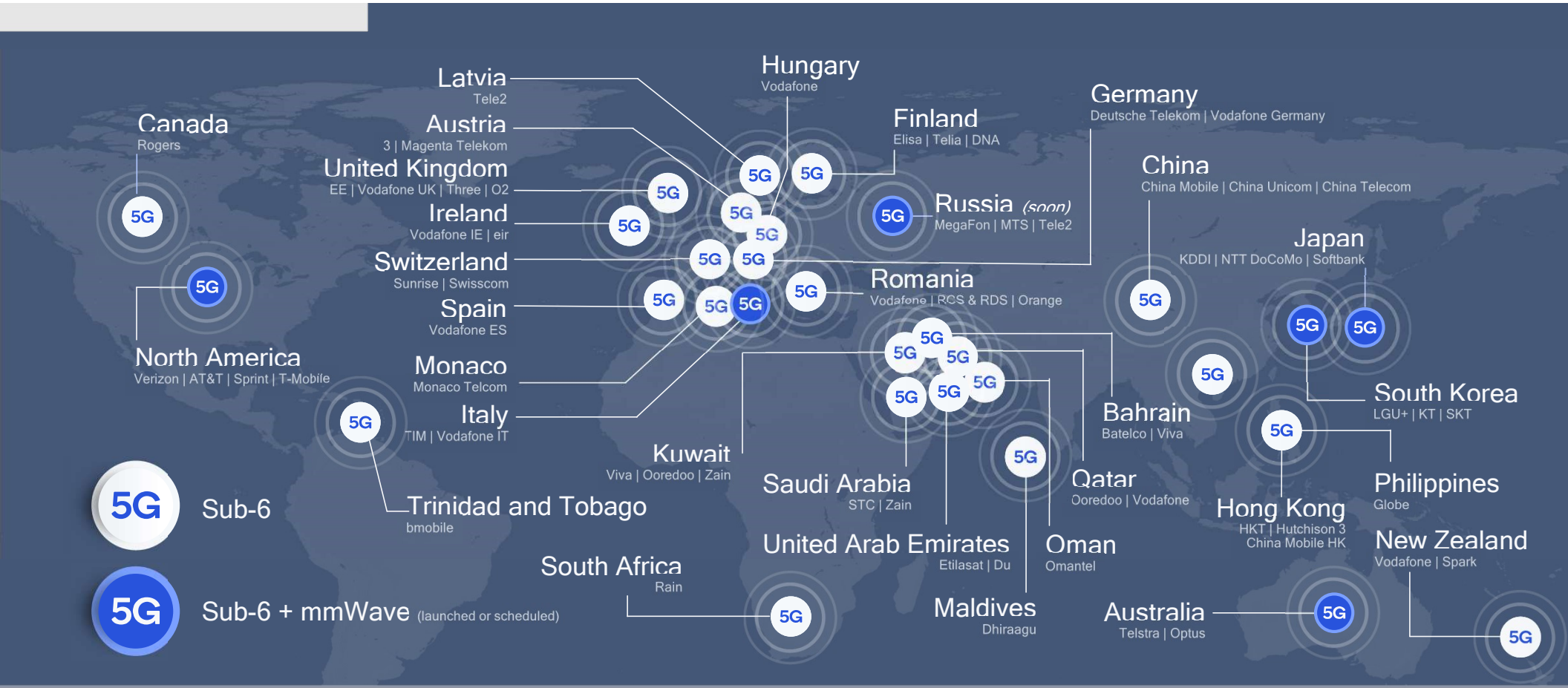
5G NR

Standalone (SA) for new core benefits



Built on 5G Core Network

5G NR Commercialization



Comparison of Year 1 announcements

4G

4 Operators launched
3 OEMs launched

5G

80+ Operators in 35+ countries

Sources - 5G commercial networks and operators investing in 5G: GSA and operator announcements, Apr. '19; 5G device shipment projections: Qualcomm estimates (2020 projection is at mid-point of guidance range), Nov. '19; 5G connection projections: 2023 - GSMA Intelligence (Dec. '19); ABI (Nov. '19); 2025 - ABI (Oct. '19), CCS Insight (Oct. '19), Ericsson (Nov. '19)

5G momentum accelerating globally

5G smartphones

5G embedded modules

Hotspots and CPEs

Qualcomm snapdragon

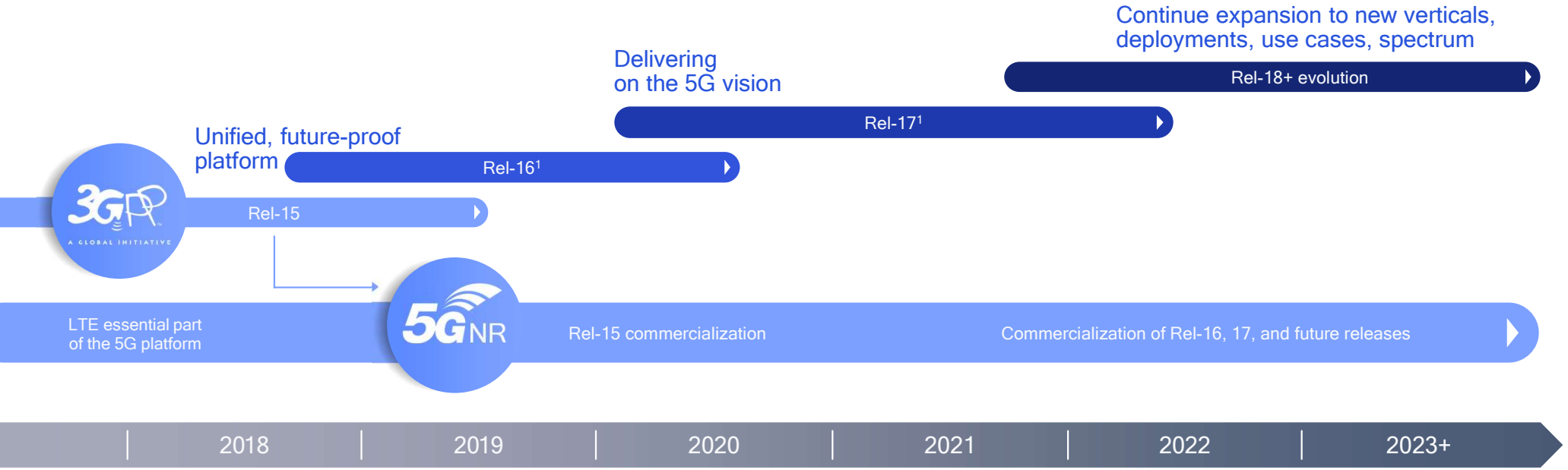
375+

5G devices launched or in development

Driving 5G NR evolution and expansion

3GPP Release-16 and beyond

Driving the 5G technology evolution



Rel-15 eMBB focus

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

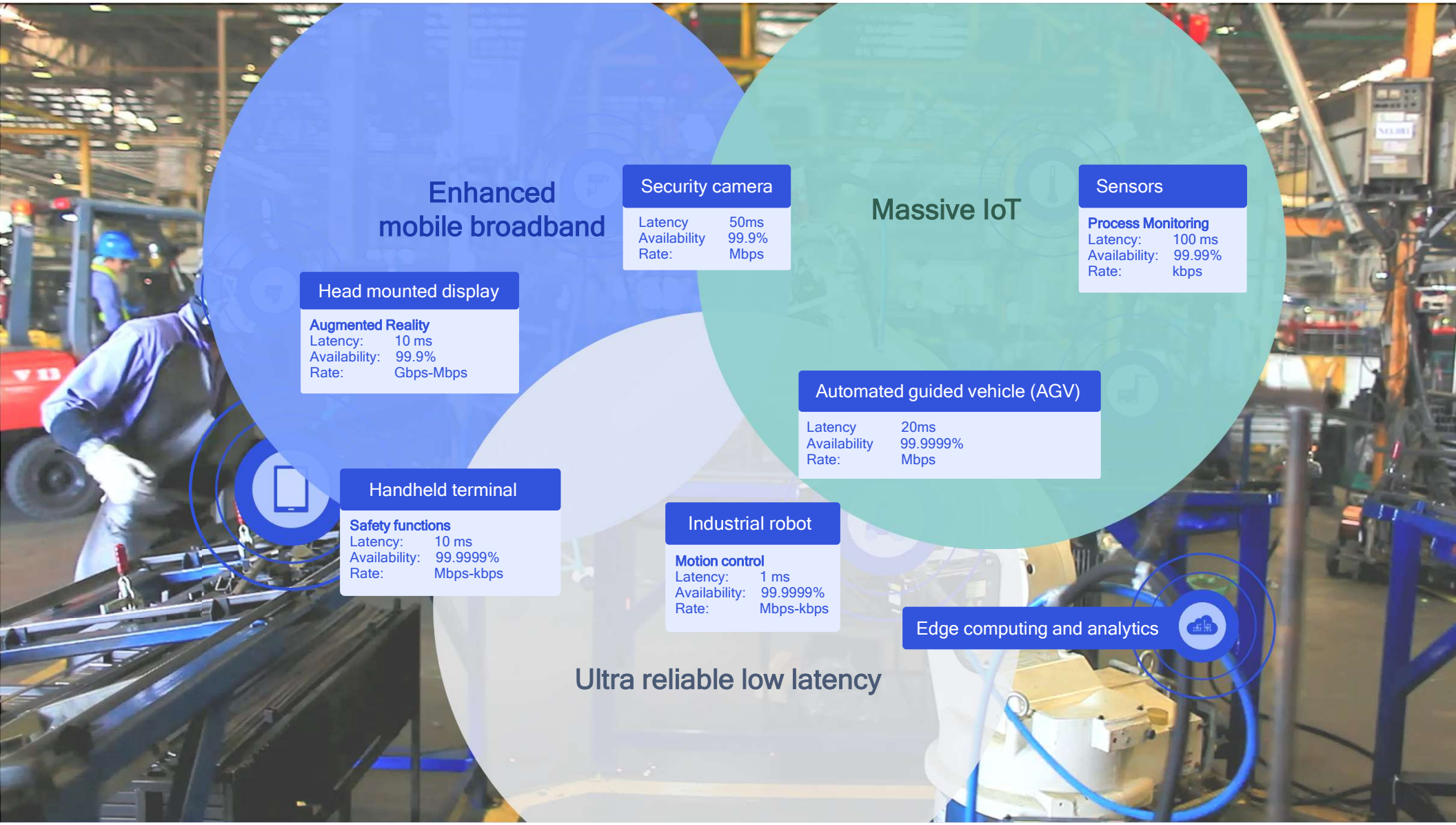
Rel-16 industry expansion

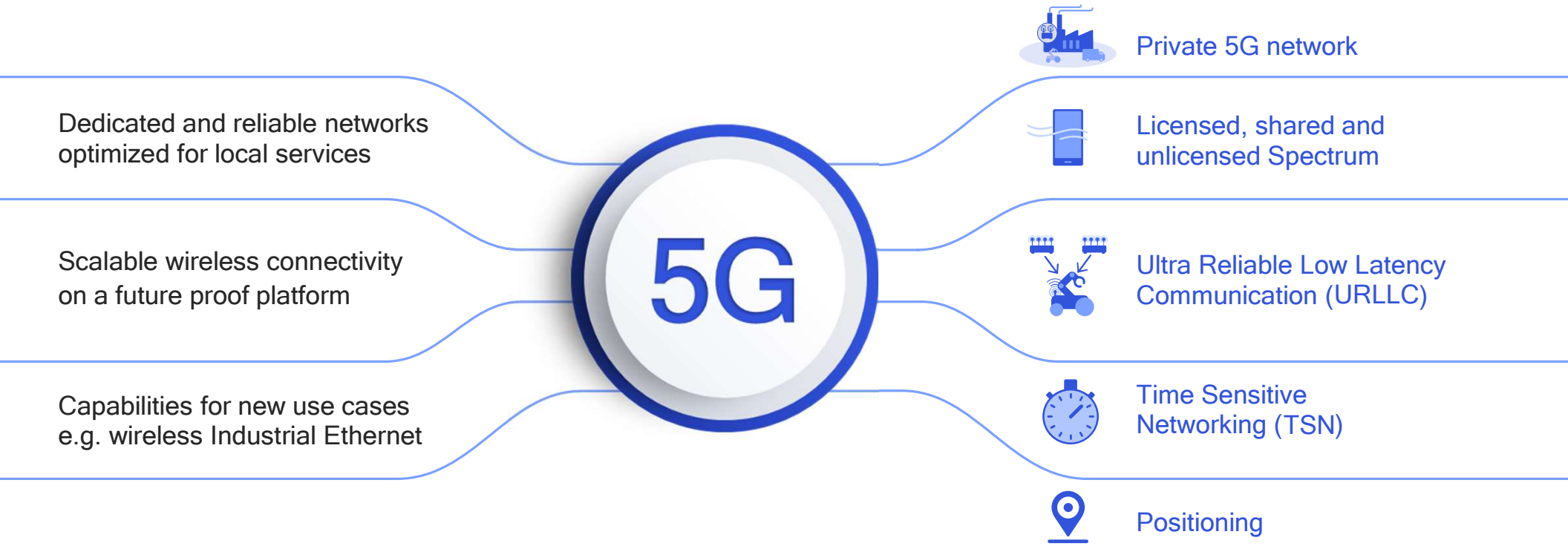
- eURLLC and TSN for IIoT
- NR in unlicensed (NR-U)
- Positioning
- 5G V2X sidelink multicast
- In-band eMTC/NB-IoT

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

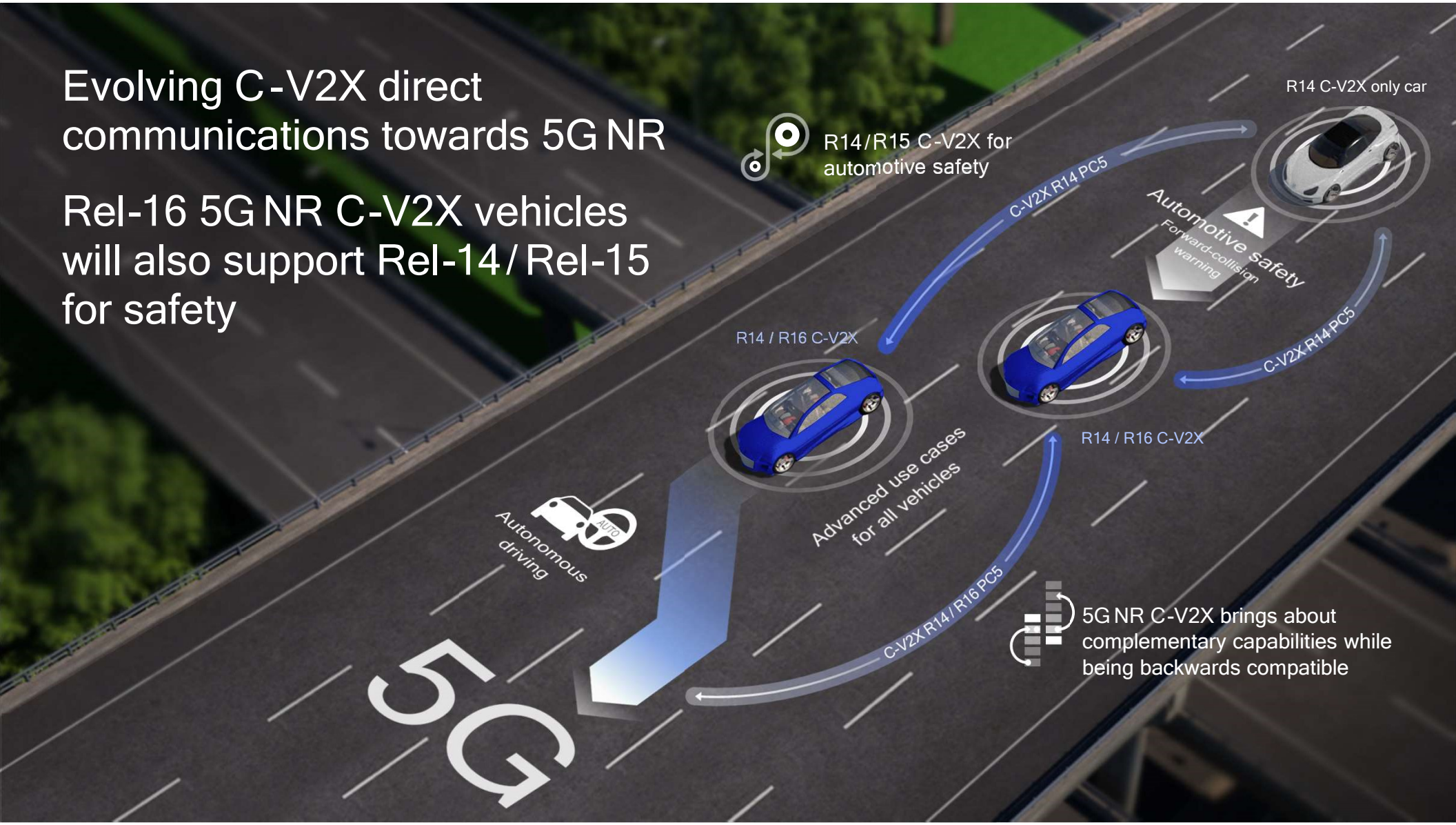

Enhanced mobile broadband
Head mounted display
Augmented Reality
Latency: 10 ms
Availability: 99.9%
Rate: Gbps-Mbps
Security camera
Latency 50ms
Availability 99.9%
Rate: Mbps
Massive IoT
Sensors
Process Monitoring
Latency: 100 ms
Availability: 99.99%
Rate: kbps
Automated guided vehicle (AGV)
Latency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



Designing 5G to meet industrial IoT requirements

Evolving C-V2X direct communications towards 5G NR

Rel-16 5G NR C-V2X vehicles will also support Rel-14/Rel-15 for safety



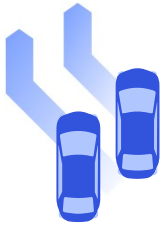
5G NR C-V2X enables advanced use cases

Increased situational awareness

Sharing of vehicle-specific info with other vehicles and road infra-structure (e.g. door open warning)

Sensor sharing

Sharing of sensor data, e.g., vehicle's perception, including road world model



Coordinated driving/ intention sharing

Exchanging intention and sensor data for more predictable, coordinated autonomous driving

Real-time infrastructure updates

Real-time sharing of 3D HD map and other information between vehicles and infrastructure

Higher throughput

Lower latency

Higher reliability

Application aware

5G NR enhancements for mmWave

Completed Release 16 Projects

Integrated access and backhaul (IAB)

Enabling flexible deployment of small cells reusing spectrum and equipment for access and backhaul

Enhanced beam management

Improving latency, robustness and performance with full beam refinement and multi-antenna-panel beam support

Power saving features

Maximizing device sleep duration to improve power consumption as well as allowing faster link feedback

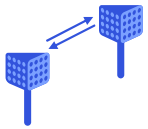
Dual connectivity optimization

Reducing device initial access latency and improving coverage when connected to multiple nodes

Positioning

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

Release 17+ Projects



Improved IAB for distributed deployment

Introducing full duplex operations and mobile relays for improved capability, coverage, and QoS

Optimized coverage & beam management

Reducing overhead, enhancing performance (e.g., beam selection), improving coverage

Expanded spectrum support

Supporting licensed and unlicensed spectrum in frequencies ranging from 52.6 GHz to 71 GHz

New use cases beyond eMBB

Expanding mmWave support for sidelink, URLLC, and industrial IoT use cases (e.g., NR-Light)

Enhanced positioning

Enhancing capability for a wide range of use cases – cm-level accuracy, lower latency, higher capacity

Strong Alignment between 5G and AI

Past

Cloud-centric AI

AI training and AI inference
in the central cloud

Today

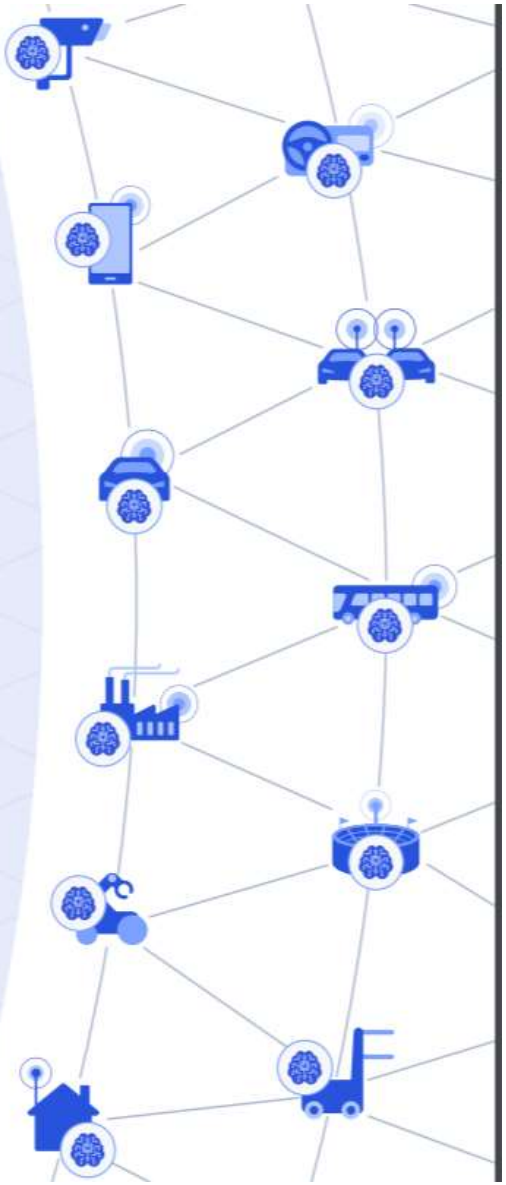
Partially-distributed AI

Power-efficient
on-device AI inference

Future

Fully-distributed AI

With lifelong on-device learning

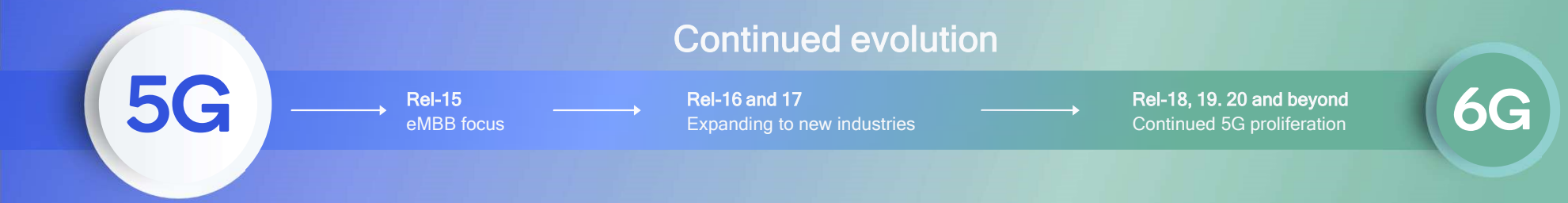


Intelligently connecting

our world in the 5G era

A unified connectivity fabric this decade

Next technology leap for new capabilities and efficiencies



Strong 5G momentum sets the stage for the global expansion

Historically 10 years between generations

Questions?

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http://www.slideshare.net/qualcommwirelessevolution

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