Qualcomm @QCOMResearch Beyond 5G International Conference February 1st, 2024

Technology Innovation on the Path to 6G

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Expanding on-device intelligence at the edge

Enabling new hybrid AI architectures to scale intelligence

Best-in-class technology scalable to enable virtually every device

On-device intelligence — High performance, low power — Wireless everything

- Edge AI
- Processing
- Graphics
- Camera
- Multimedia
- Connectivity and RF

Opportunities for innovation

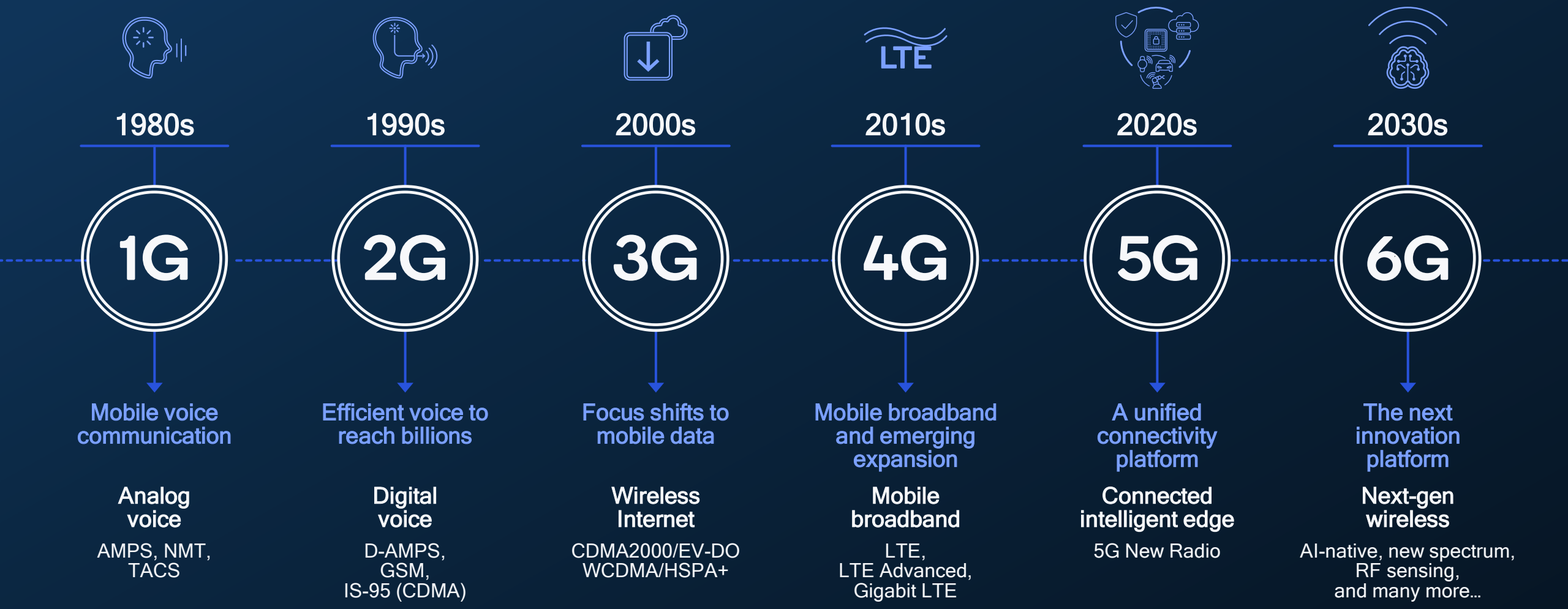
Handsets

Automotive

Consumer IoT

IoT edge networking

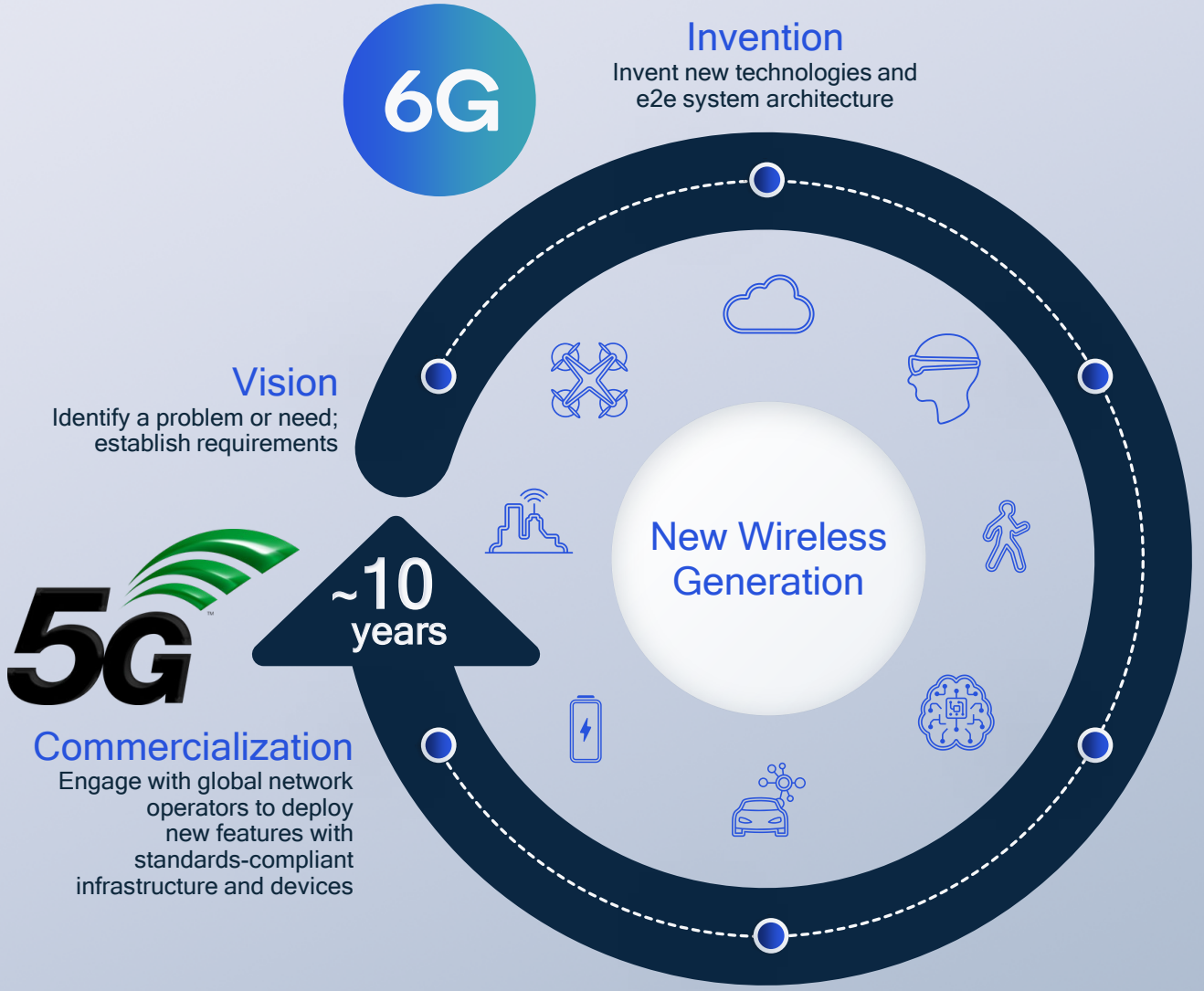
Industrial IoT



Mobile has made a leap every ~10 years

Foundation to “G” leadership is technology leadership

Early R&D and technology inventions essential to leading ecosystem forward



5G Accelerating Globally

265+
Operators with 5G commercially deployed

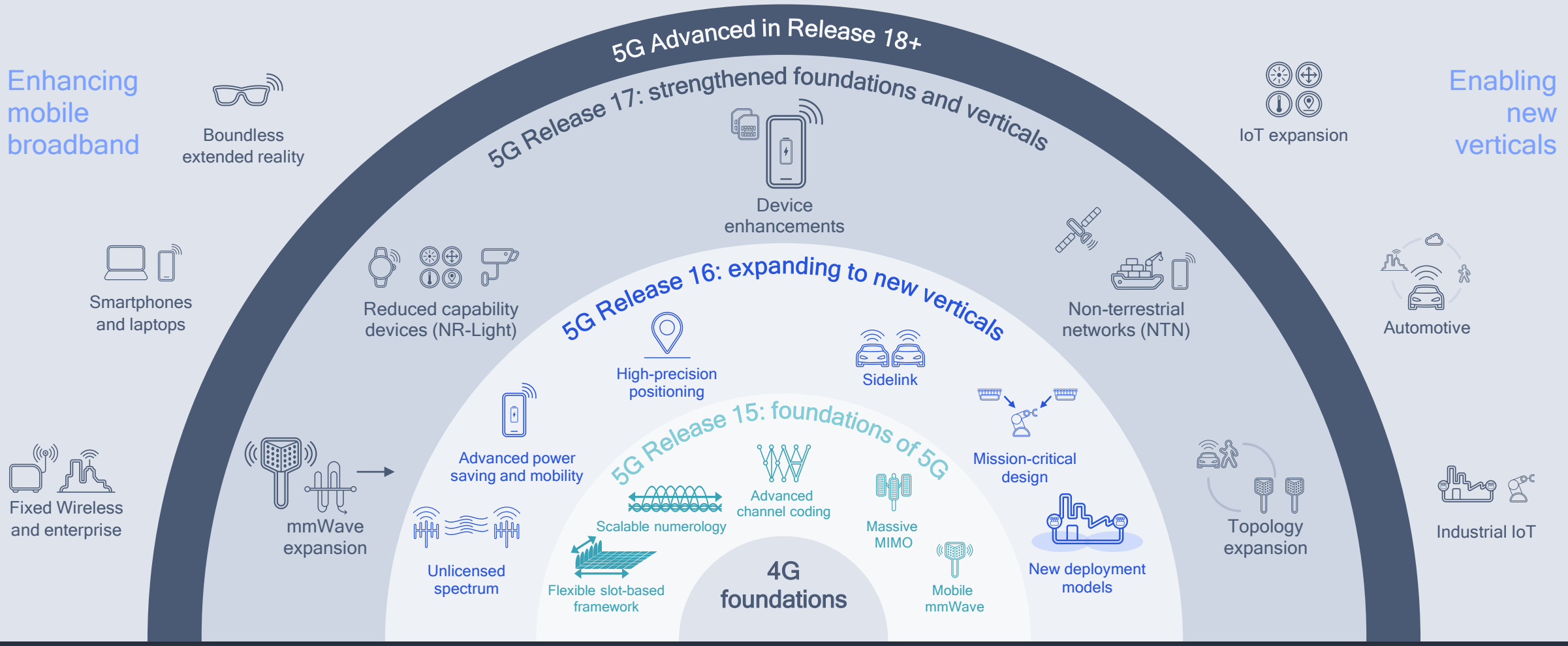
275+
Additional operators investing in 5G

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

6B+
5G smartphones to ship between 2020 and 2026

2,100+
5G designs launched or in development

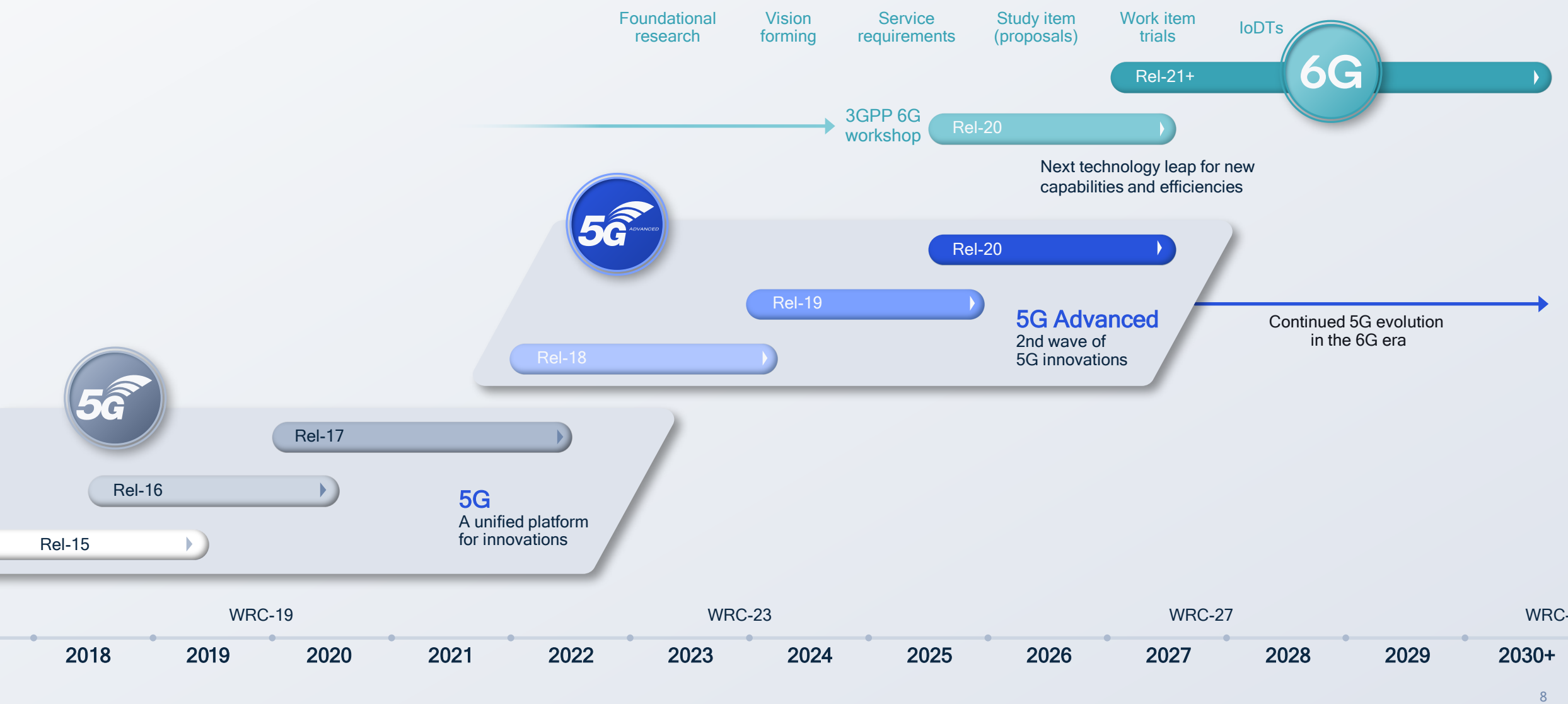
Sources: 5G commercial networks, operators investing in 5G, 5G devices launched: GSA, Aug 2023 amd Oc 2023; 5G connection projections - average of Ericsson (Feb 2023) and GSMA Intelligence (Feb 2023); 5G cumulative smartphone shipments - average of CCS Insight (Sept 2022), IDC (Dec 2022), and Strategy Analytics (Oct 2022).

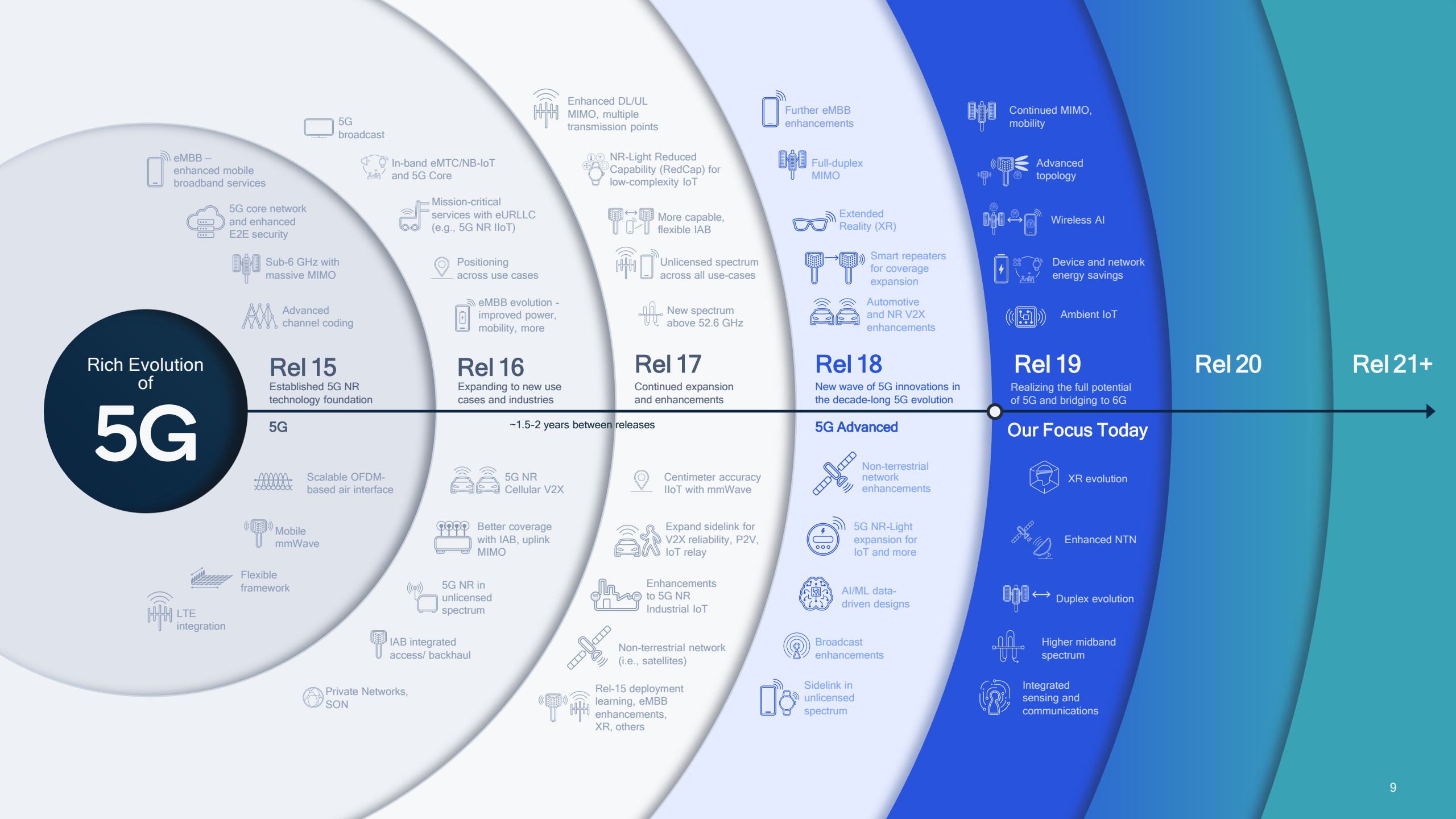


Our innovations expand the foundation of 5G

Foundational Qualcomm innovations lead 3GPP Releases 15,16 and 17

Leading the 5G Advanced evolution toward 6G




Rich Evolution of 5G
Rel 15
Established 5G NR technology foundation
5G
Rel 16
Expanding to new use cases and industries
Rel 17
Continued expansion and enhancements
Rel 18
New wave of 5G innovations in the decade-long 5G evolution
5G Advanced
Rel 19
Realizing the full potential of 5G and bridging to 6G
Our Focus Today
Rel 20
Rel 21+
~1.5-2 years between releases
eMBB – enhanced mobile broadband services
5G core network and enhanced E2E security
Sub-6 GHz with massive MIMO
Advanced channel coding
Scalable OFDM-based air interface
Mobile mmWave
Flexible framework
LTE integration
5G broadcast
In-band eMTC/NB-IoT and 5G Core
Mission-critical services with eURLLC (e.g., 5G NR IIoT)
Positioning across use cases
eMBB evolution - improved power, mobility, more
5G NR Cellular V2X
Better coverage with IAB, uplink MIMO
5G NR in unlicensed spectrum
IAB integrated access/ backhaul
Private Networks, SON
Enhanced DL/UL MIMO, multiple transmission points
NR-Light Reduced Capability (RedCap) for low-complexity IoT
More capable, flexible IAB
Unlicensed spectrum across all use-cases
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
Non-terrestrial network (i.e., satellites)
Rel-15 deployment learning, eMBB enhancements, XR, others
Further eMBB enhancements
Full-duplex MIMO
Extended Reality (XR)
Smart repeaters for coverage expansion
Automotive and NR V2X enhancements
Non-terrestrial network enhancements
5G NR-Light expansion for IoT and more
AI/ML data-driven designs
Broadcast enhancements
Sidelink in unlicensed spectrum
Continued MIMO, mobility
Advanced topology
Wireless AI
Device and network energy savings
Ambient IoT
XR evolution
Enhanced NTN
Duplex evolution
Higher midband spectrum
Integrated sensing and communications

CONTINUED TECHNOLOGY EVOLUTION

Key market trends and technology drivers

leading the way to 6G

Core technology advancements

Environmental and societal sustainability

Enhanced and new experiences

Global Momentum for 6G is growing

IMT-2030 defines next-gen mobile system requirements for 2030 and beyond

We are leading key discussions and working groups to promote early government investments in critical technologies

The standards body responsible for global 6G technology standardization

NEXT G ALLIANCE

United States
NextG Alliance

6G SNS IA

European Union
6G-IA (6G Smart Networks and Services Industry Association)

China
IMT-2030 PG

Japan
Beyond 5G PC

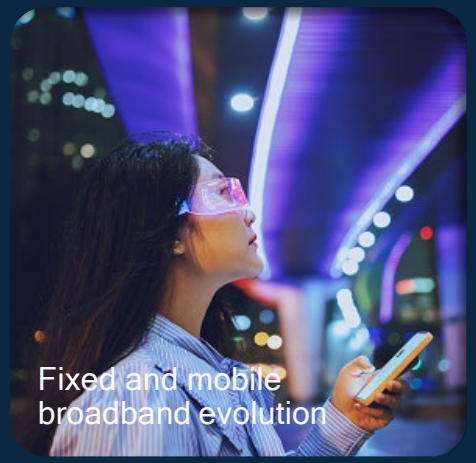
Bharat6G Alliance

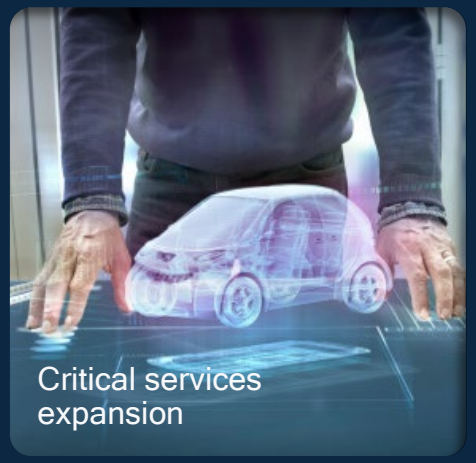
India
Bharat 6G Alliance

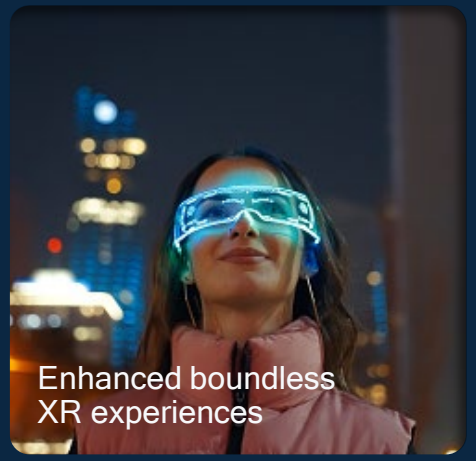
South Korea
6G Forum

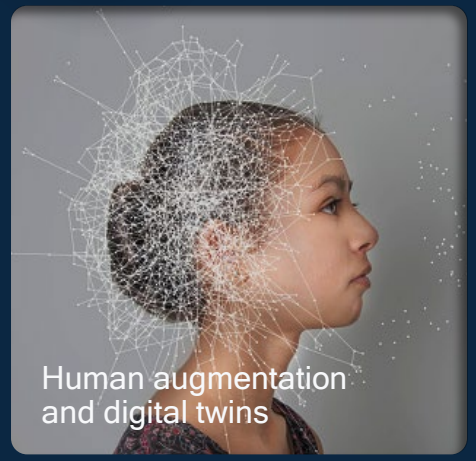
ITU WRC DUBAI 2023

WRC-23
Setting the agenda for WRC-27 to secure new 6G bands







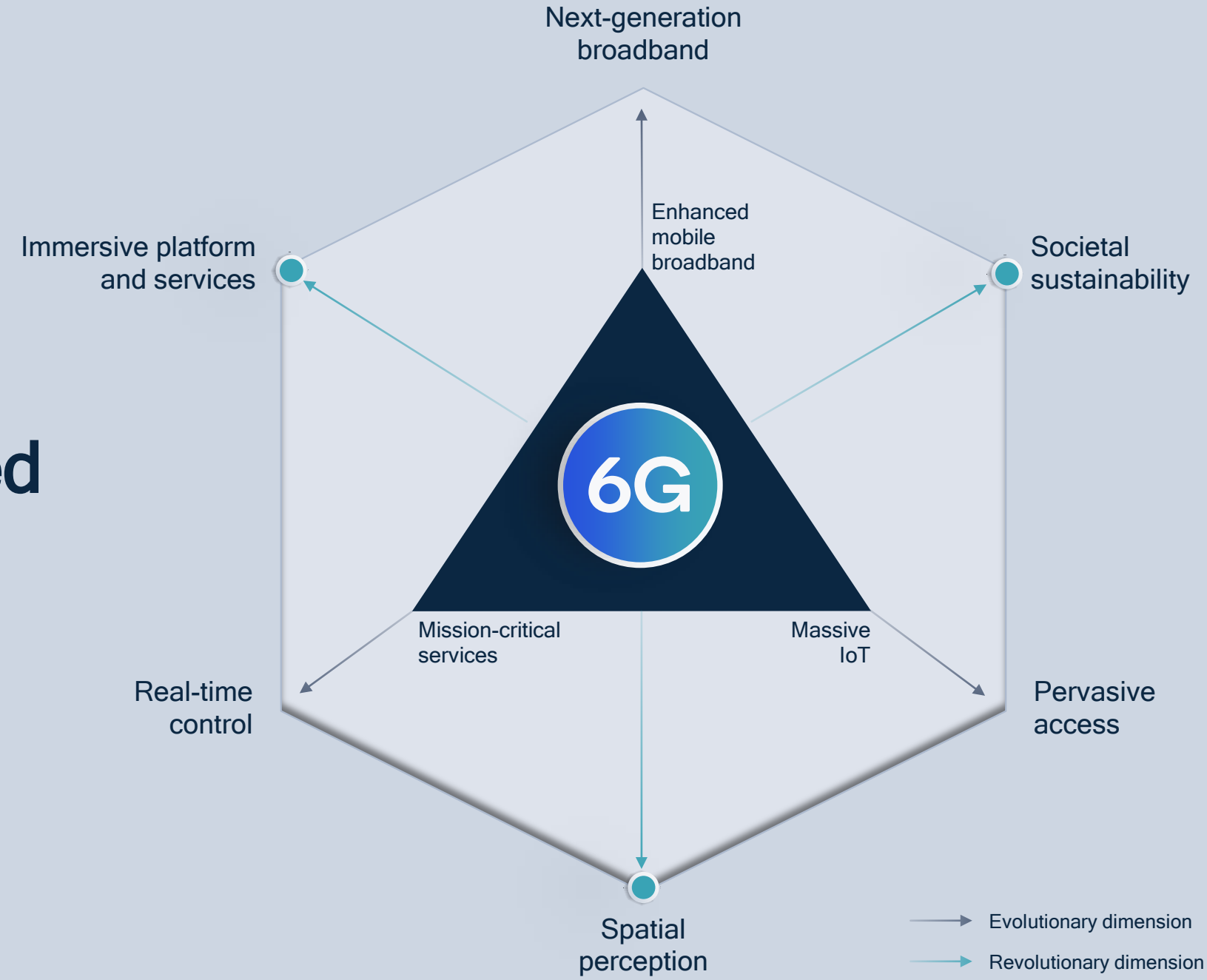


6G

Propelling next-level experiences and innovative use cases in the new era of the connected intelligent edge for 2030 and beyond

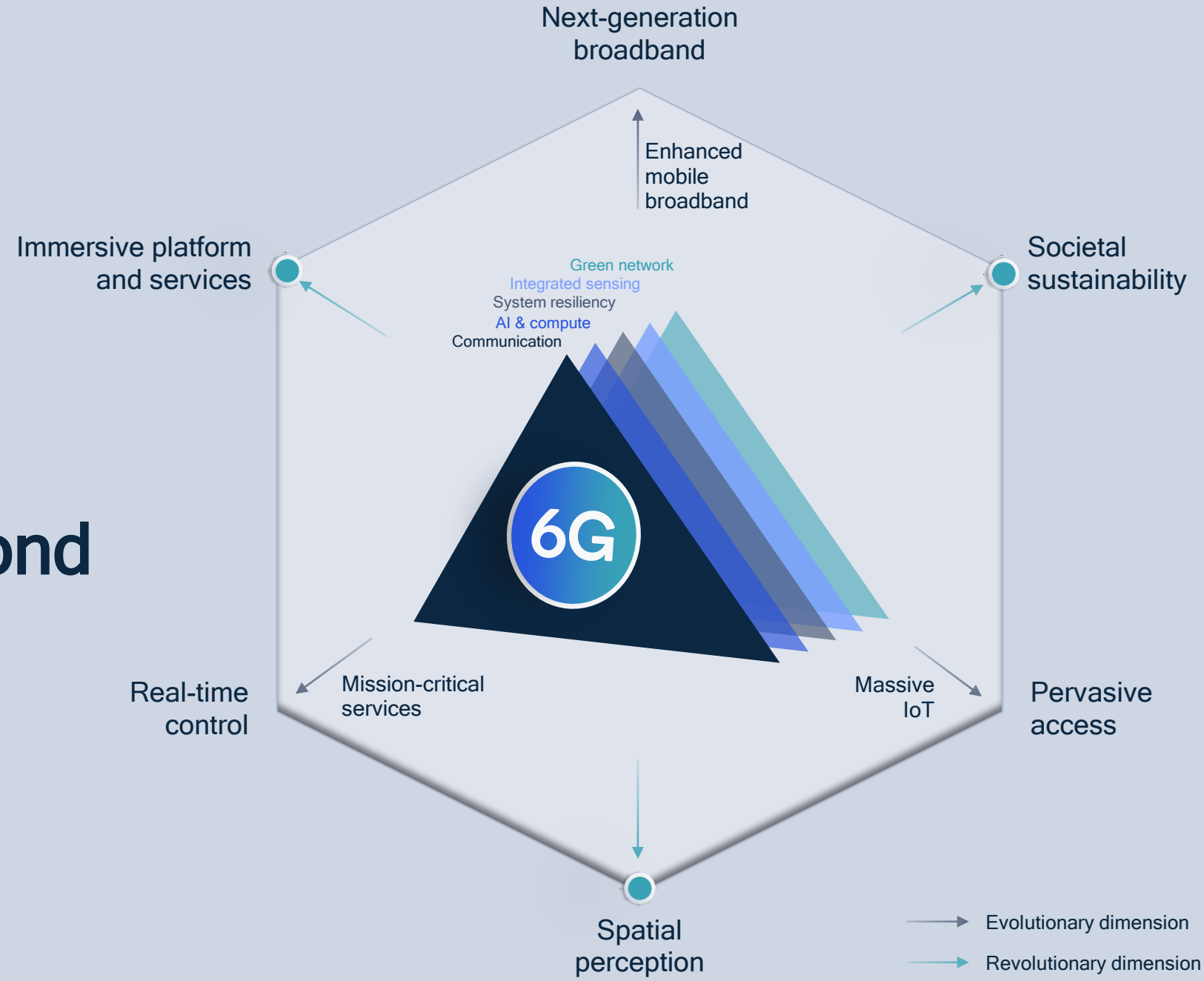
A smarter wireless platform to

support enhanced services and new use cases

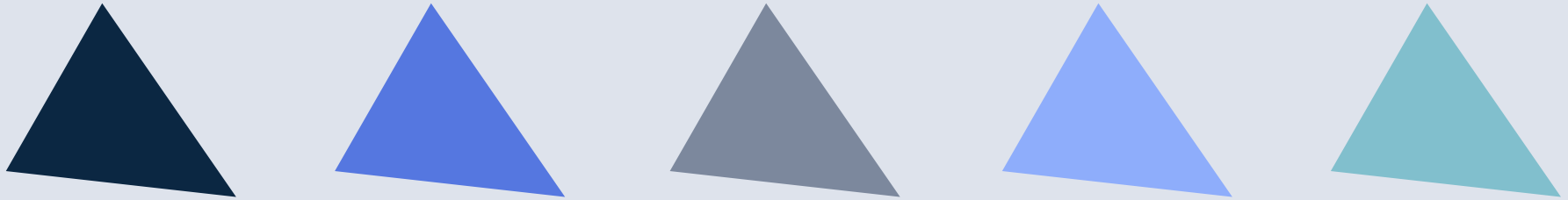


A smarter wireless platform with

new capabilities that expand beyond communication



System design targets for expanded 6G capabilities



Key Performance Indicators	Communication	AI & compute	System resiliency	Integrated sensing	Green network
	Capacity	Inference accuracy	Confidentiality	Range	Network energy efficiency
	Data rate	Model transfer latency	Integrity	Confidence level	Network carbon intensity
	Mobility	AI service roundtrip time	Availability	Sensing accuracy	Carbon neutrality
	Coverage	Compute capacity	Mean time to detect / resolve / contain	Resolution	ECO rating
	Connection density	Scalability / adaptability	...	Latency	Battery requirement
	...	...		...	...

6G will be designed to meet enhanced traditional communication requirements as well as KPIs for new capabilities

Key longer-term research vectors

enabling the path towards 6G

Key longer-term research vectors

enabling the path towards 6G

AI-native E2E communications

Data-driven communication and network design, with joint training, model sharing and distributed inference across networks and devices

Scalable network architecture

Disaggregation and virtualization at the connected intelligent edge, use of advanced topologies to address growing demand

Expanding into new spectrum bands

Expanding to THz, wide-area expansion to higher bands, new spectrum sharing paradigm, dynamic coordination with environmental awareness

Air interface innovations

Evolution of duplexing schemes, Giga-MIMO, mmWave evolution, reconfigurable intelligent surfaces, non-terrestrial communications, waveform/coding for MHz to THz, system energy efficiency

Merging of worlds

Physical, digital, virtual, immersive interactions taking human augmentation to next level via ubiquitous, low-power joint communication and sensing

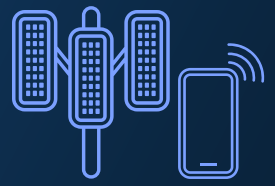
Communications resiliency

Multifaceted trust and configurable security, post quantum security, robust networks tolerant to failures and attacks

Key drivers for the 6G air interface design

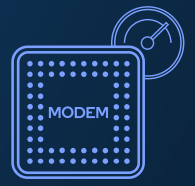
Improving spectral efficiency for all bands

- Targeting ~1.5x spectral efficiency gains from better link performance
- Targeting ~2-3x network capacity gain in dense networks from cloud RAN with joint processing with interference reduction and dimension increase
- ML-based dynamic air interface with “hyper-localized” performance optimization



Unlocking wide-area broadband access in new “FR3” upper mid-band (i.e., 7–16 GHz)

- Supporting downlink coverage with 8+ Rx antennas in smartphones, high Tx efficiency Giga-MIMO base stations
- Supporting uplink coverage with 4+ Tx antennas in smartphones, subband full duplex in base stations, Rx distortion corrections



Increasing performance for future modem chipsets

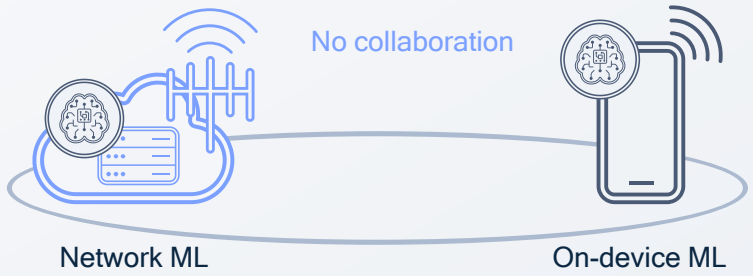
New area-efficient and power-efficient coding, modulation, and MIMO designs

Enabling integrated services beyond data transport

Cross-layer optimized design for outdoor AR, new device types, RF sensing, precise positioning, ambient IoT, and more

Overlay AI/ML

Independently at the device or network



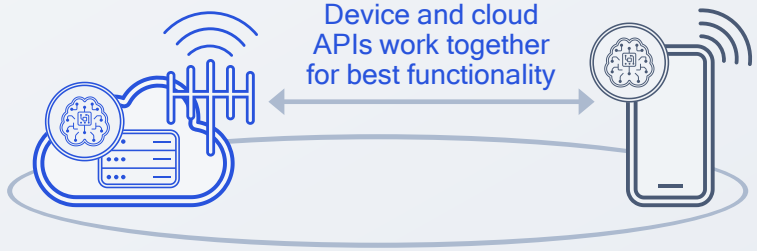
ML operates independently at the device and network as an optimization of existing functions

Proprietary ML procedures including model development and management

Proprietary and standardized data collection used as input to training

Cross-node AI/ML

Coordinated between device and network



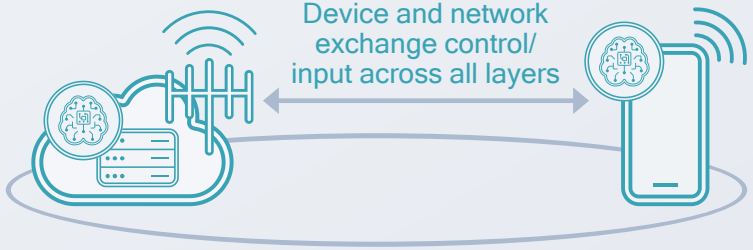
ML operates in a coordinated manner between the device and network

Proprietary and standardized ML procedures including model development and management

Further data collection used as input to training as well as monitoring

Native AI/ML

At all device and network layers



ML operates autonomously between the device and network across all protocols and layers

Integrated ML procedures across to train performance and adapt to different environments

Data fusion for integrated dynamic ML lifecycle management

5G — 5G ADVANCED — 6G

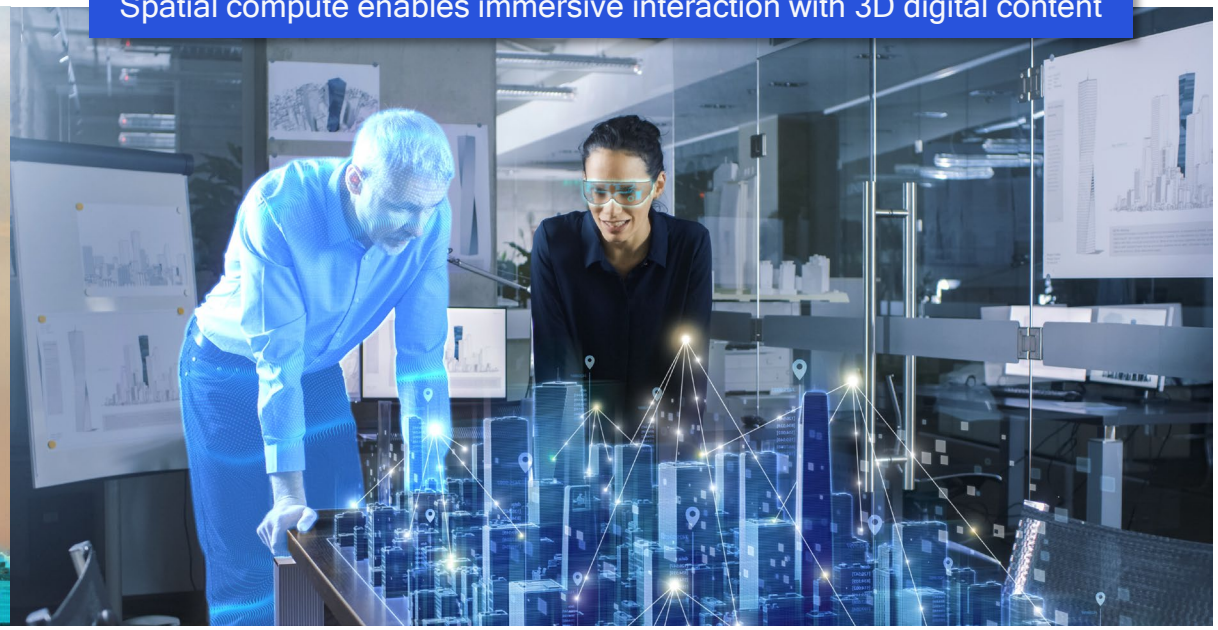
Evolving towards native wireless AI/ML

Multiple wireless AI/ML training and inference scenarios

6G XR requirements fueled by digital twins and spatial compute

Digital twins digitize the complex physical world in the metaverse

Spatial compute enables immersive interaction with 3D digital content



100x network capacity

0.1-10 Gbps per user

Use multiple frequency bands

(sub-THz, mmW, sub 7GHz, 7-24GHz, unlicensed, shared spectrum)

Driving Technology Innovation on the Path to 6G

External Qualcomm 6G Vision

External presentation

Webinar

Qualcomm.com webpage


OnQ blog post

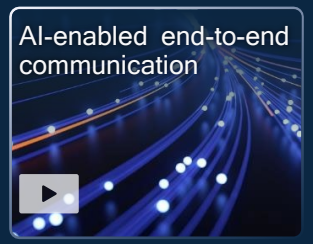
Whitepaper

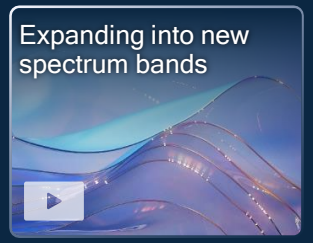
Social

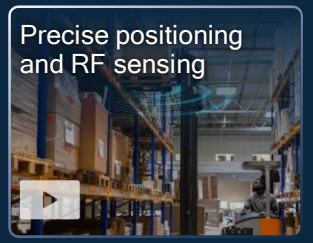
Newsletter

External Demo Videos

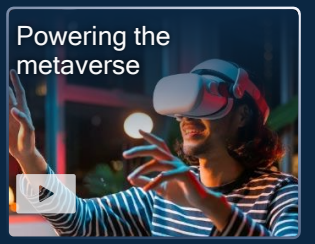
Building a stronger, more capable wireless system foundation

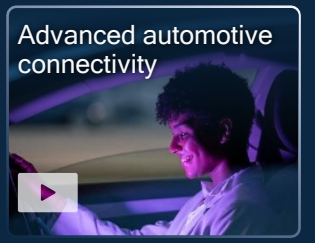






Taking 5G to new, more diverse verticals and use cases





Driving the 5G Advanced technology evolution into 6G

Next technology leap for new capabilities and efficiencies

Foundational research, vision, requirements, etc.

6G

Rel-21 and beyond
New innovation platform

Historically 10 years between generations

A key enabler of the connected intelligent edge

Technology foundation for the next generation

5G

Rel-15
eMBB focus

Rel-16 and 17
expanding to new industries

5G ADVANCED

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

Strong 5G momentum sets stage for global expansion

Thank you

Qualcomm

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