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CEPT Workshop on 6G Mobile Communications

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3GPP roadmap towards 6G

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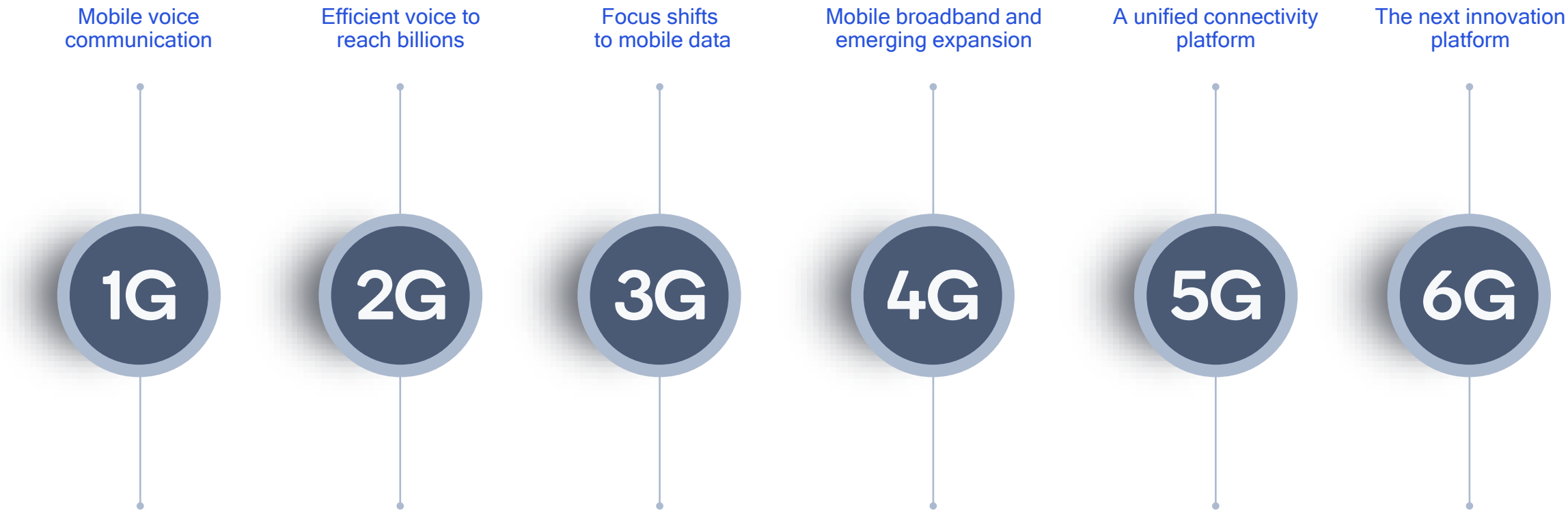
Mobile has made a leap every ~10 years

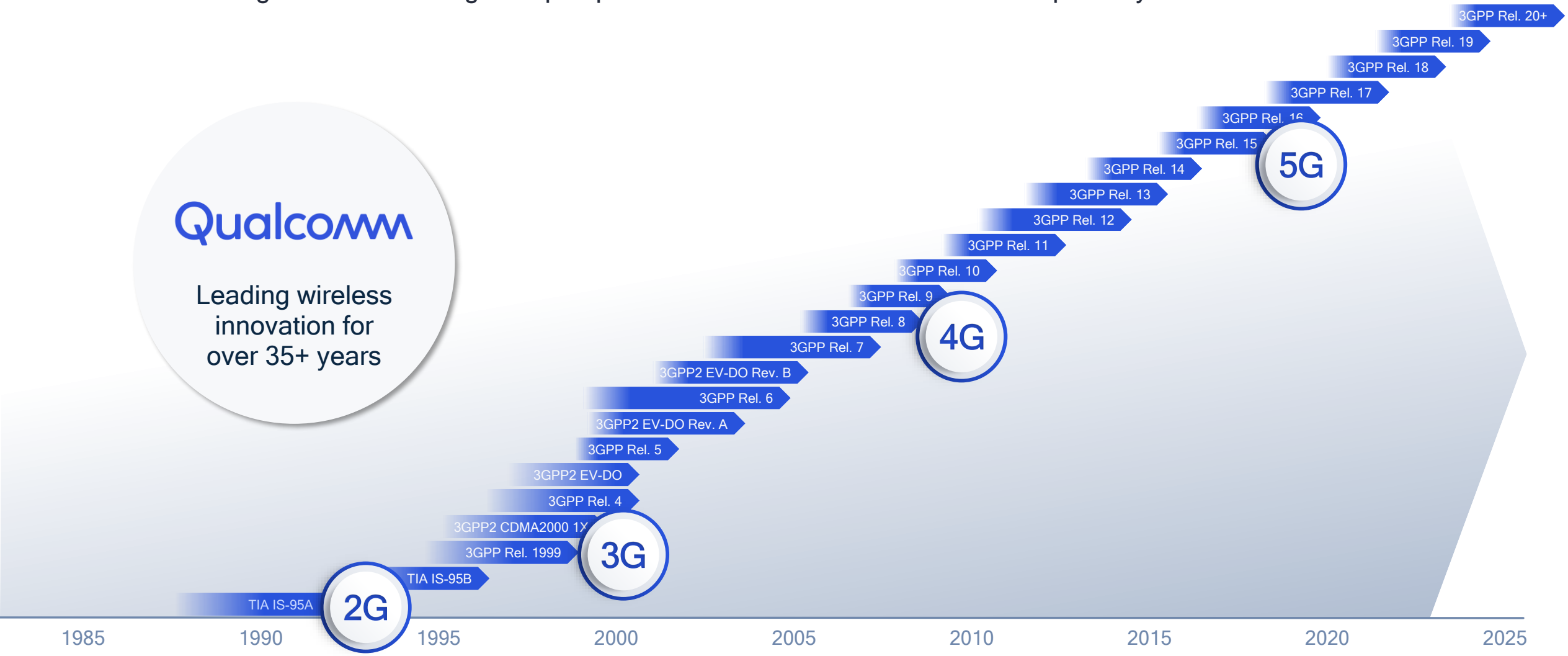


Cellular technology evolves gradually, building on itself

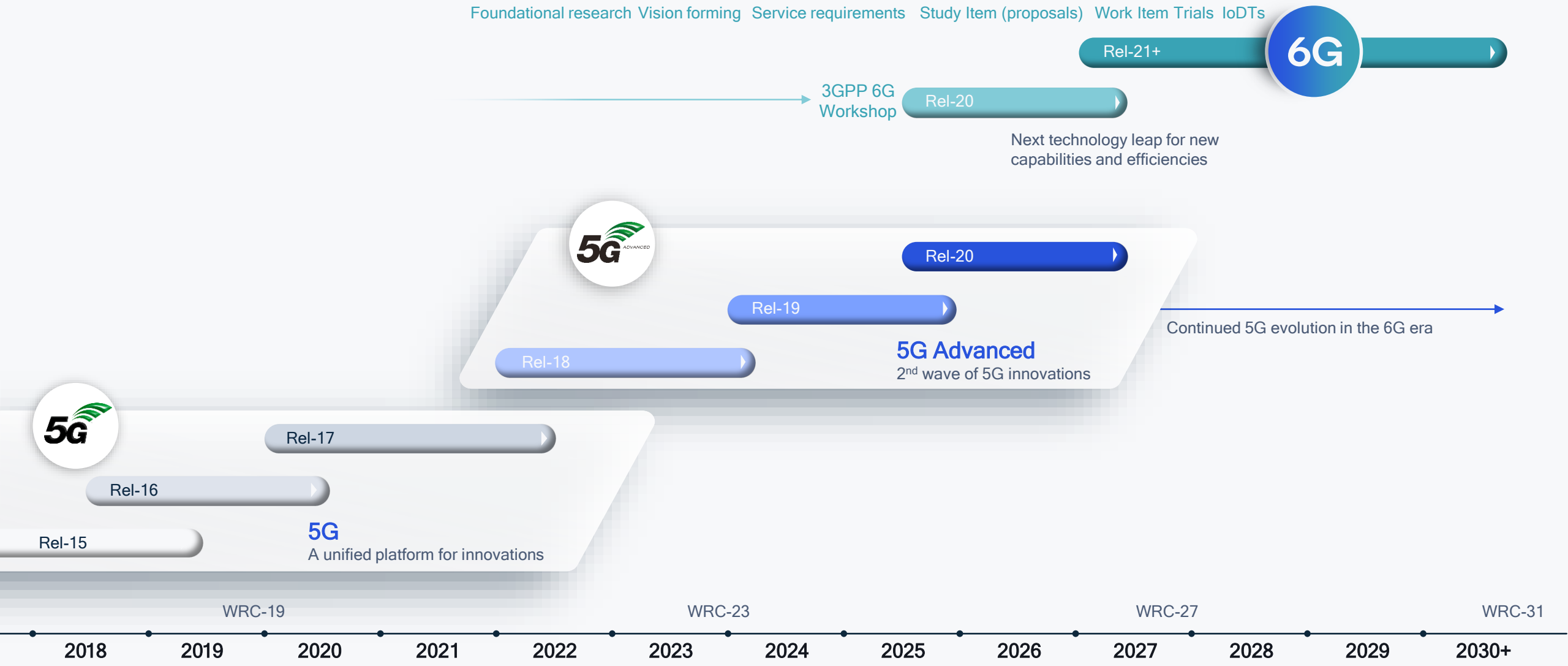
Each release or generation building on top of previous ones to enable backward compatibility

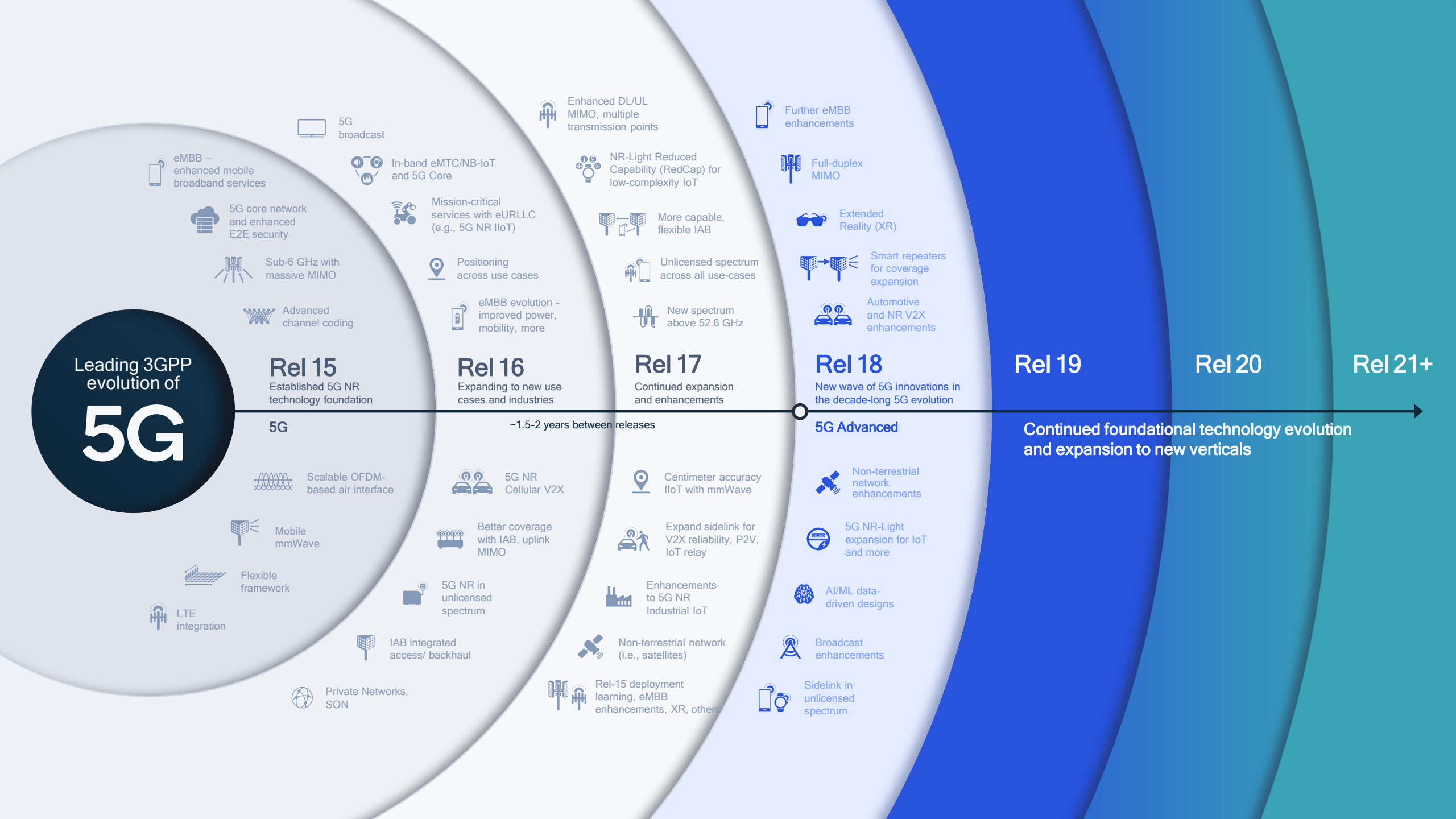
Qualcomm

Leading wireless innovation for over 35+ years



5G Advanced on the path to 6G




Leading 3GPP evolution of 5G
Rel 15
Established 5G NR technology foundation
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
Rel 19
Rel 20
Rel 21+
5G
~1.5-2 years between releases
5G Advanced
Continued foundational technology evolution and expansion to new verticals
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
Private Networks, SON
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
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 TECHNOLOGY EVOLUTION

Key market trends and technology drivers

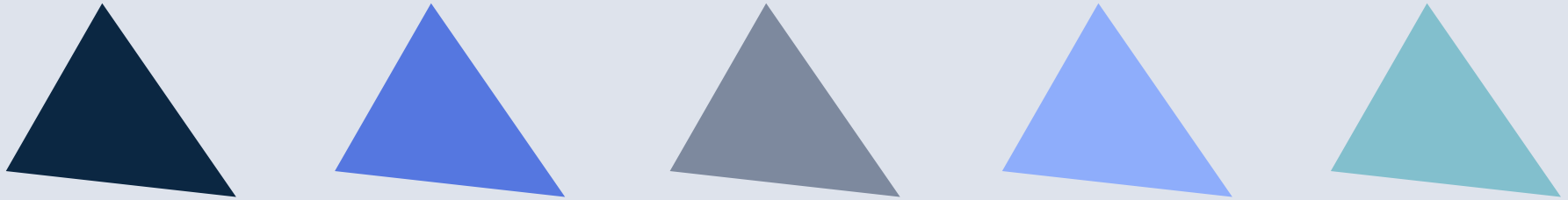
leading the way to 6G

Core technology advancements

Environmental and societal sustainability

Enhanced and new experiences

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

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

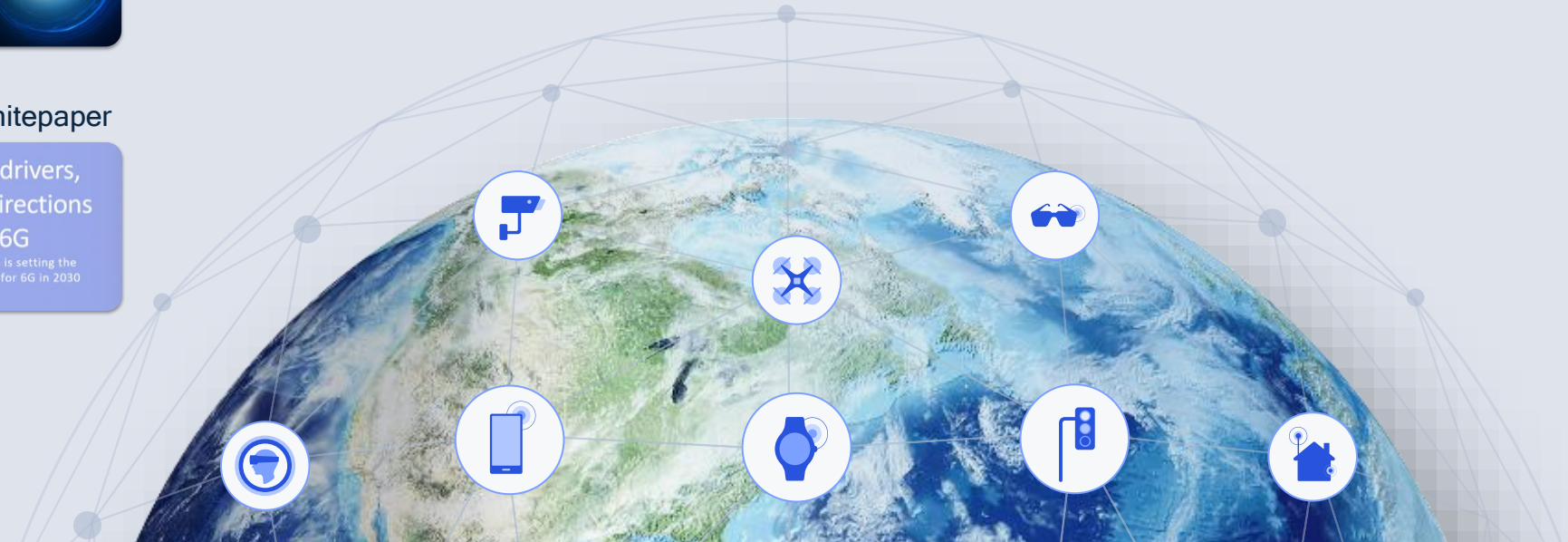
Physical, digital, virtual, immersive interactions taking human augmentation to next level via ubiquitous, low-power joint communication and sensing

Communications resiliency

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

Qualcomm Webinar

Qualcomm Whitepaper



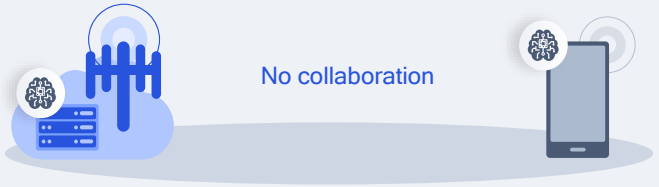
Evolving towards native wireless AI/ML

Different wireless AI/ML training and inference scenarios

6G

Overlay AI/ML

Independently at the device or network



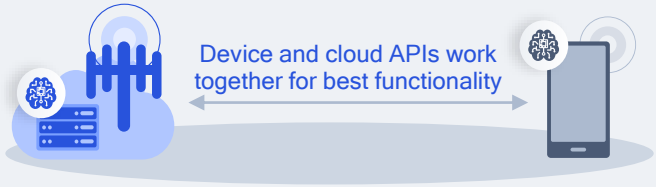
ML operates independently at the device and network as an optimization of existing functions

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



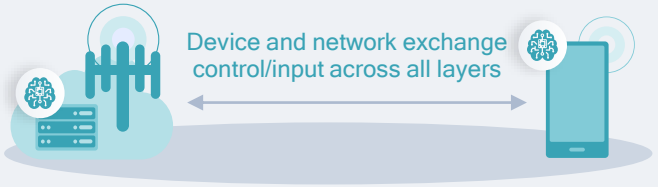
ML operates in a coordinated manner between the device and network

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

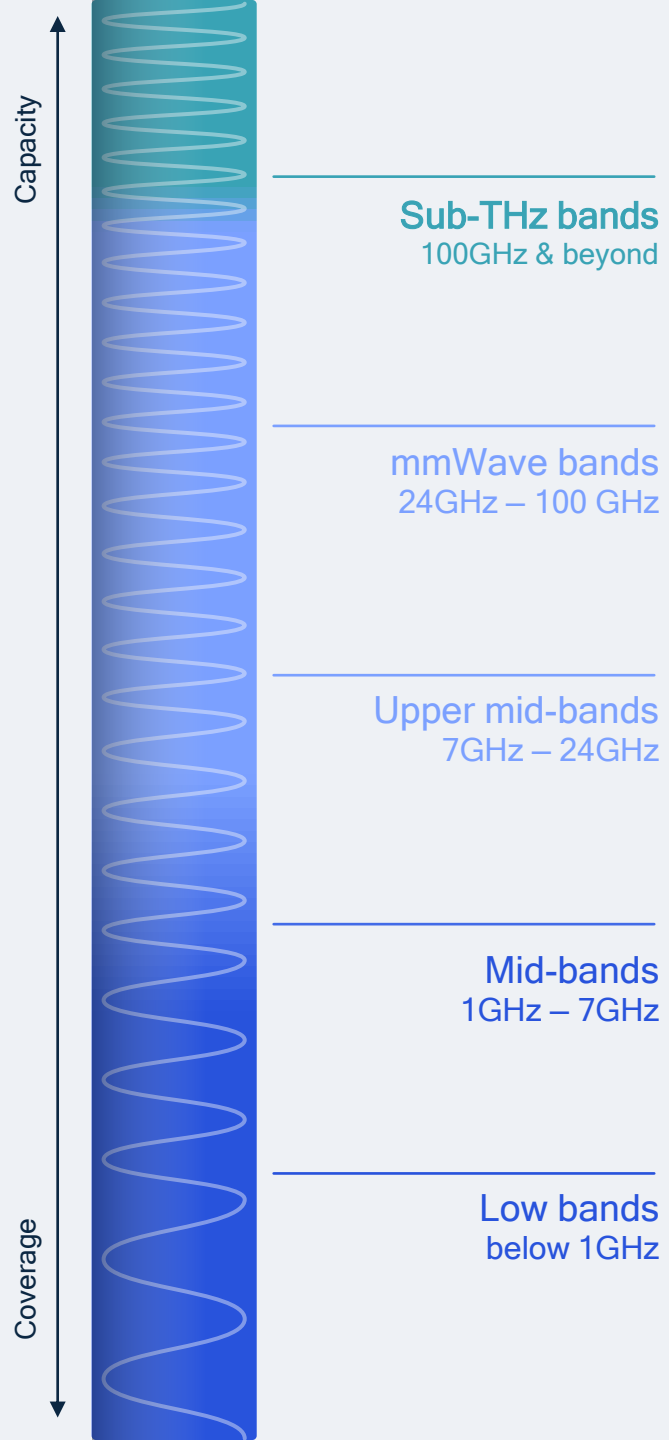
5G

5G ADVANCED

6G system targets all spectrum types and bands

Critical for the success of next-generation wireless systems

“Sharing by design” approach



Licensed spectrum

Exclusive use of spectrum that remains the industry’s top priority

Unlicensed spectrum

Shared use of more available spectrum

Shared spectrum

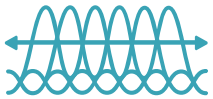
Evolving spectrum sharing that allow fair and more efficient sharing

6G technology platform will require a new air interface design

An innovation opportunity to achieve higher capacity, system throughput and efficiency

Channel Coding

Advanced channel coding targeting high-throughput, low-power, cost efficient implementation, approaching the theoretical bound on different block length and SNR regimes



Waveform

New waveforms and advanced signal processing to deliver higher spectral and power efficiency across a variety of spectrum bands within 6G unified air interface (UAI)

Modulation

Enhanced modulation schemes to achieve more efficient use of spectrum and resources, while enabling higher data rates and adapting to different MIMO transmission schemes

Multiple Access

Continued evolution of scheduled multiple access in conjunction with advanced MIMO, duplexing technologies to support extremely high cell capacity. Development of contention based random access to facilitate scaling up massive large number of devices in cellular system

Foundational PHY designs are crucial for enabling 6G new features:

Advanced RF and baseband joint design
Supporting wider bandwidth, faster Tx/Rx switching, higher PA efficiency, massive spectrum aggregation across new bands and existing bands

Efficient modem system implementation
Modem-RF implementation friendly PHY to facilitate data rate envelope scaling while maintaining superior power efficiency

Advanced air interface features
Coevolution of waveform and multiple access with next-gen MIMO, flexible/full duplex

Extreme energy-efficient devices
Diverse devices and use cases, ranging from extreme data rate to passive IoT

Seamless multi-RAT connectivity and spectrum sharing
Flexibility and efficient multi-RAT (5G/6G) spectrum access and resource sharing over multiple users and multi-RAT connectivity on the same device

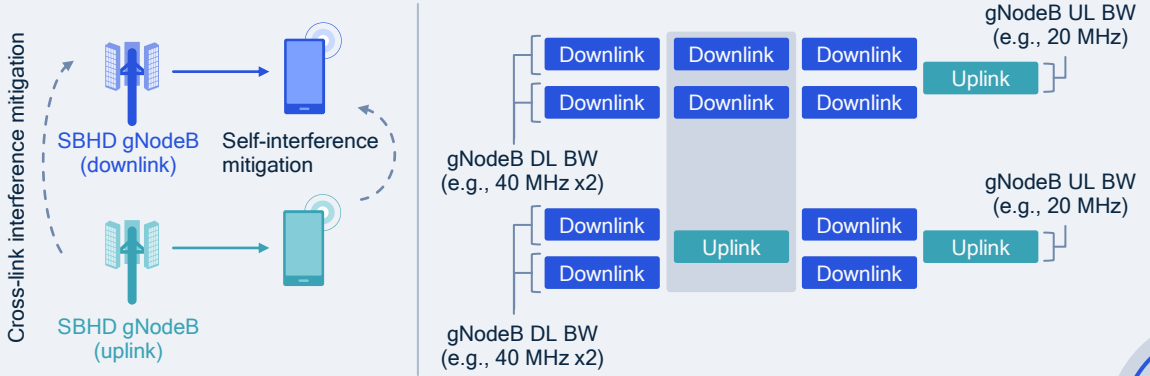
Enabling immersive experience
Enabling high capacity XR to facilitate immersive metaverse experiences using 6G air interface and new network topology technologies

Driving towards a full duplex wireless system

Lower latency, better coverage, expanded capacity, flexible spectrum deployment and service multiplexing

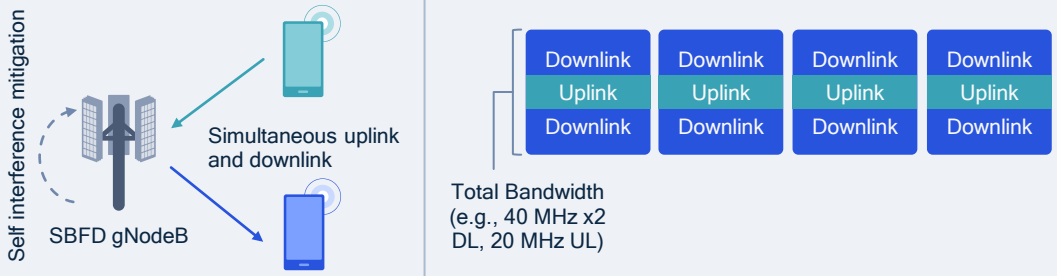
Subband half duplex (SBHD)

Frequency aligned to avoid inter-site interference; Time separation to avoid self-interference; Implemented in SD test network (MWC'21)



Subband full duplex (SBFD)

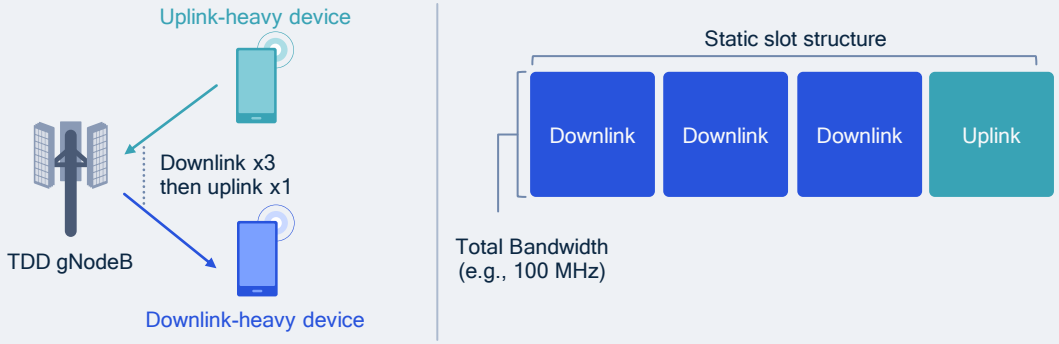
Frequency aligned to avoid inter-site interference; Frequency separation + interference cancellation to avoid self-interference; Implemented in SD test network (MWC'22)



Duplexing evolution

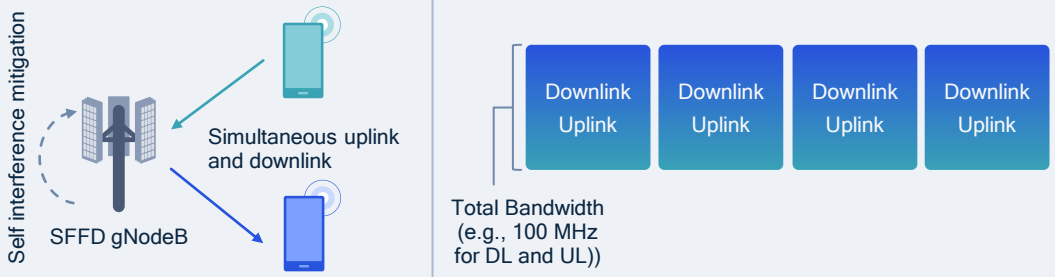
Static TDD

Time aligned to avoid inter-site interference; Time separation to avoid self-interference; Existing 5G systems (i.e., Rel-15) adopt static TDD (and FDD) duplexing



Single frequency full duplex (SFFD)

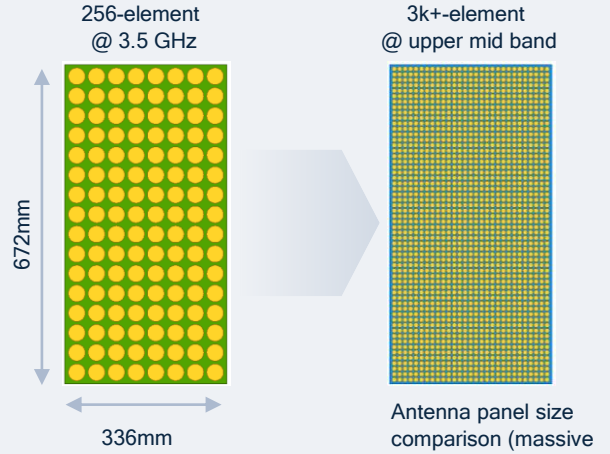
Interference cancellation to avoid self-interference; Targeting future simulations, prototyping, and standardization in 6G and beyond



Giga-MIMO expands network coverage

Giga MIMO with wide bandwidth and large number of antenna elements (i.e., >2k)

More antenna elements with same aperture, 3-4x wavelength reduction vs. sub-7 GHz



Antenna panel size comparison (massive MIMO vs. Giga MIMO)

For supporting wide-area use cases in higher frequencies

Experimentations ongoing

256-element
@ 3.5 GHz

2048-element
@ 10 GHz

Network coverage testing near Qualcomm campus in San Diego, CA

Better coverage capacity trade-off

GHz bandwidth –10x more capacity than existing massive MIMO systems

Expanding frequency range for wide-area coverage compared to massive MIMO in sub-7 GHz

Higher positioning, radar, and RF sensing resolutions

Better radiation control

Larger arrays enable a better control of intra-system and inter-systems interference

Higher degree of freedom to improve co-channel coexistence and sharing

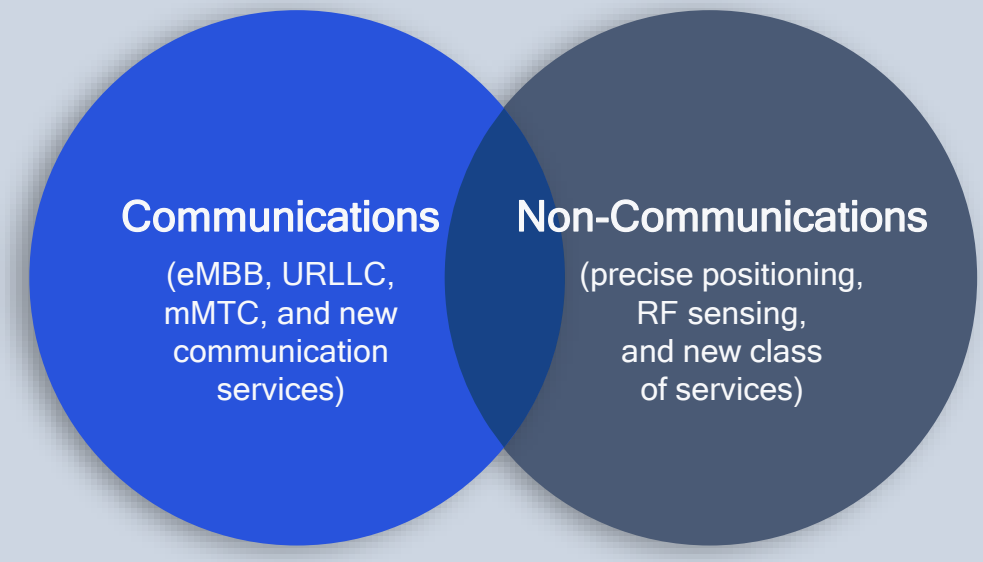
Note: Part of the spectrum may be studied or supported already in 5G NR Release 19+

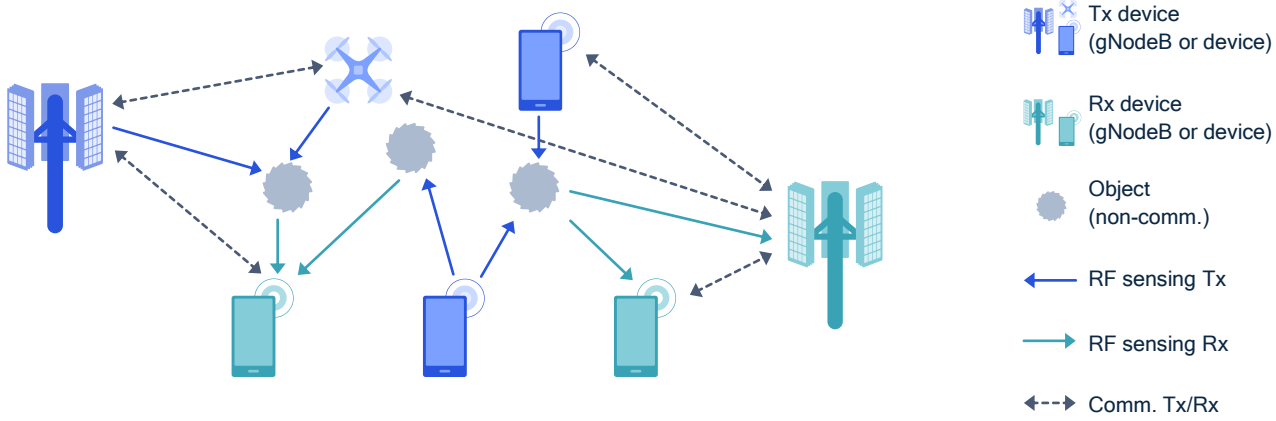
Joint communications, positioning, RF sensing

Utilizing existing waveform and other fundamental physical layer designs in existing and new higher-band spectrum

Integrating environmental detection capabilities

Providing cooperative sensing capability across networks and devices





1. Transmission and Reception Point

Leveraging cellular for non-terrestrial communication

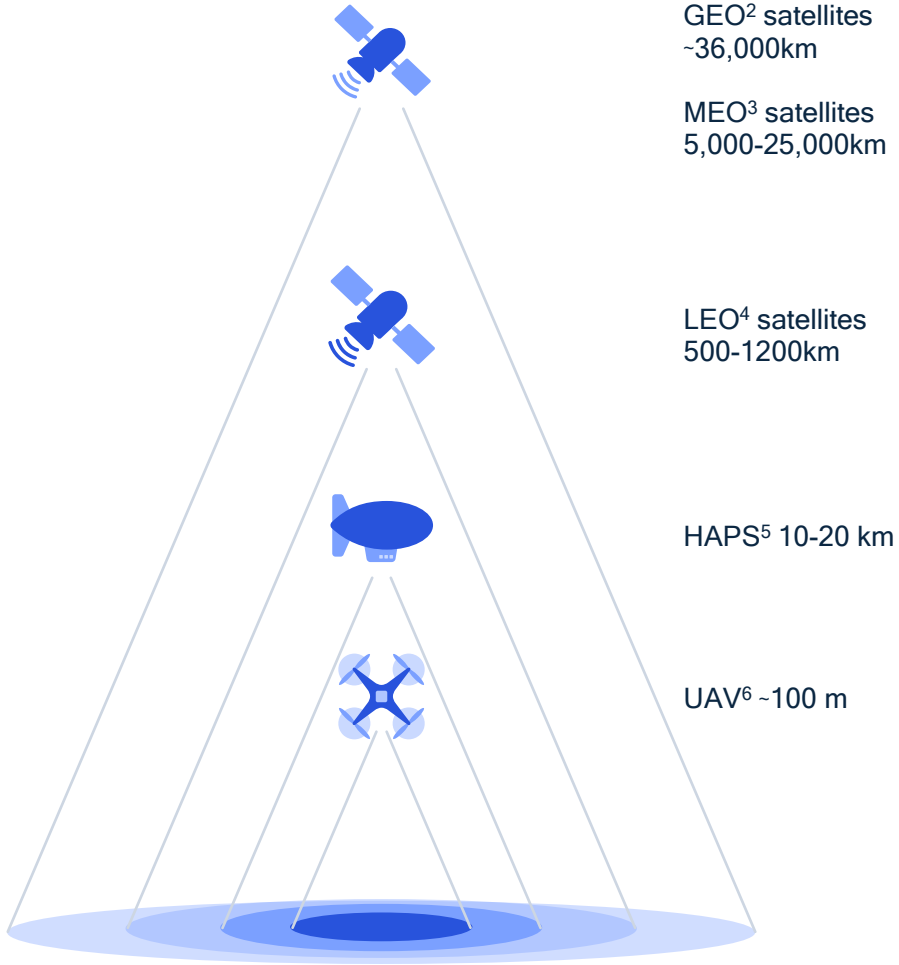
5G Rel-15
Study focused on deployment scenarios and channel models

5G Rel-16
Study focused on adapting 5G NR to support NTN

5G Rel-17
Projects focused on satellites for eMBB & IoT[1] and HAPS/UAV

5G Rel-18+
Further enhancements for UAV, HAPS, and satellites

6G
Continued evolution of 5G NTN & NTN IOT into the 6G era, depending on ecosystem status at that time



1 eMTC and NB-IoT; 2 Geostationary; 3 Medium Earth Orbit; 4 Low Earth Orbit;
5 Unmanned Aerial Vehicles; 6 High Altitude Platform Station;

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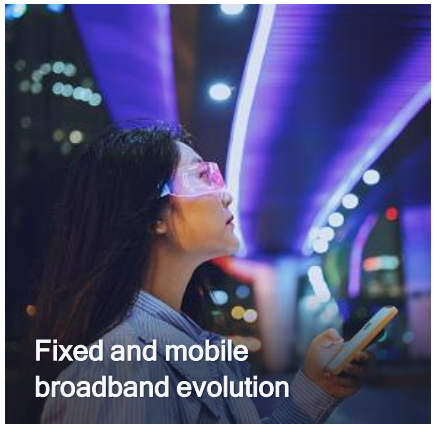
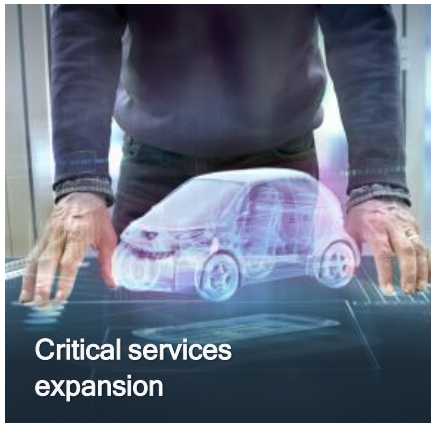
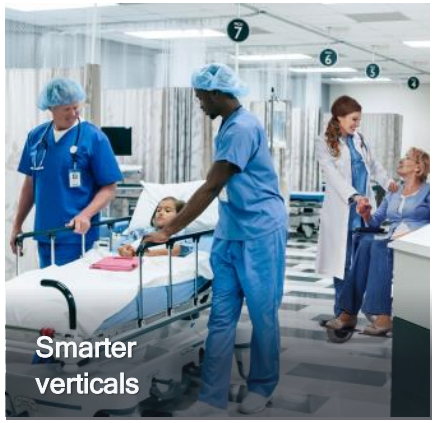
Driving the path to 6G

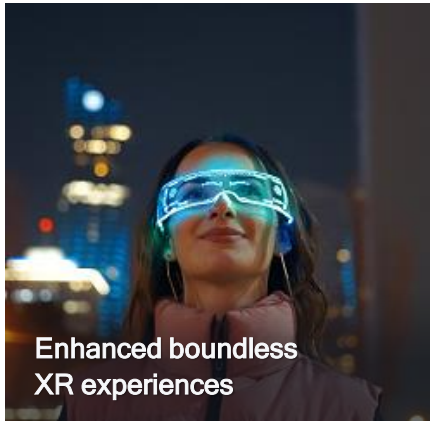
ongoing research vectors to enable innovative use cases for 2030 and beyond

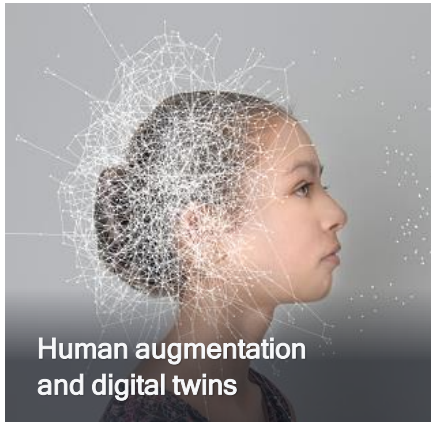
- Communications
- AI & compute
- System resiliency
- Integrated sensing
- Green network and devices

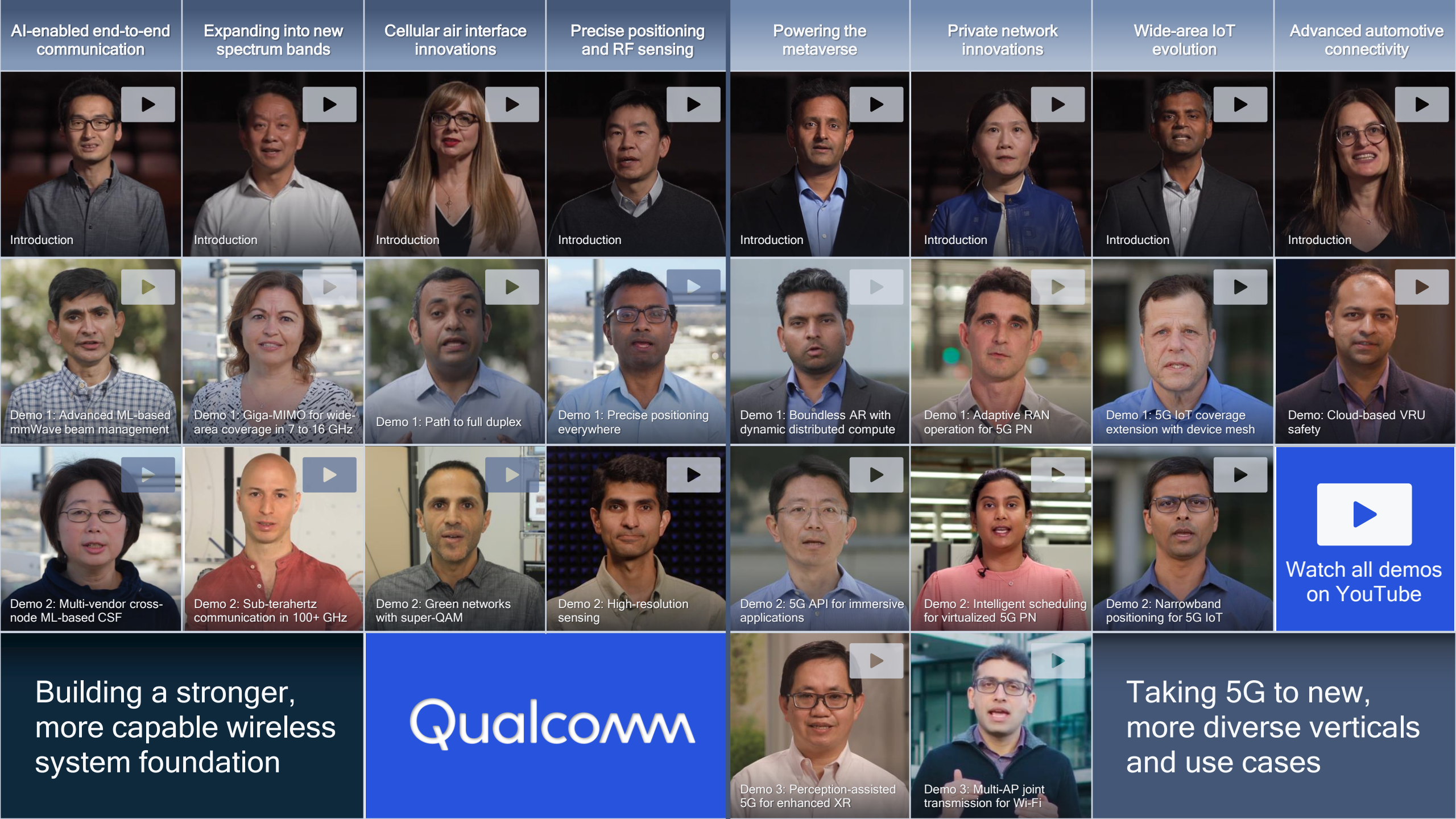











AI-enabled end-to-end communication
Expanding into new spectrum bands
Cellular air interface innovations
Precise positioning and RF sensing
Powering the metaverse
Private network innovations
Wide-area IoT evolution
Advanced automotive connectivity
Introduction
Introduction
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Introduction
Demo 1: Advanced ML-based mmWave beam management
Demo 1: Giga-MIMO for wide-area coverage in 7 to 16 GHz
Demo 1: Path to full duplex
Demo 1: Precise positioning everywhere
Demo 1: Boundless AR with dynamic distributed compute
Demo 1: Adaptive RAN operation for 5G PN
Demo 1: 5G IoT coverage extension with device mesh
Demo: Cloud-based VRU safety
Demo 2: Multi-vendor cross-node ML-based CSF
Demo 2: Sub-terahertz communication in 100+ GHz
Demo 2: Green networks with super-QAM
Demo 2: High-resolution sensing
Demo 2: 5G API for immersive applications
Demo 2: Intelligent scheduling for virtualized 5G PN
Demo 2: Narrowband positioning for 5G IoT
Watch all demos on YouTube
Building a stronger, more capable wireless system foundation
Qualcomm
Demo 3: Perception-assisted 5G for enhanced XR
Demo 3: Multi-AP joint transmission for Wi-Fi
Taking 5G to new, more diverse verticals and use cases

Thank you

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