

# What's in the future of 5G?





**30+ launched in 6 months**  
Faster than 4G

# Delivering on the 5G vision

Where virtually everyone and everything is intelligently connected

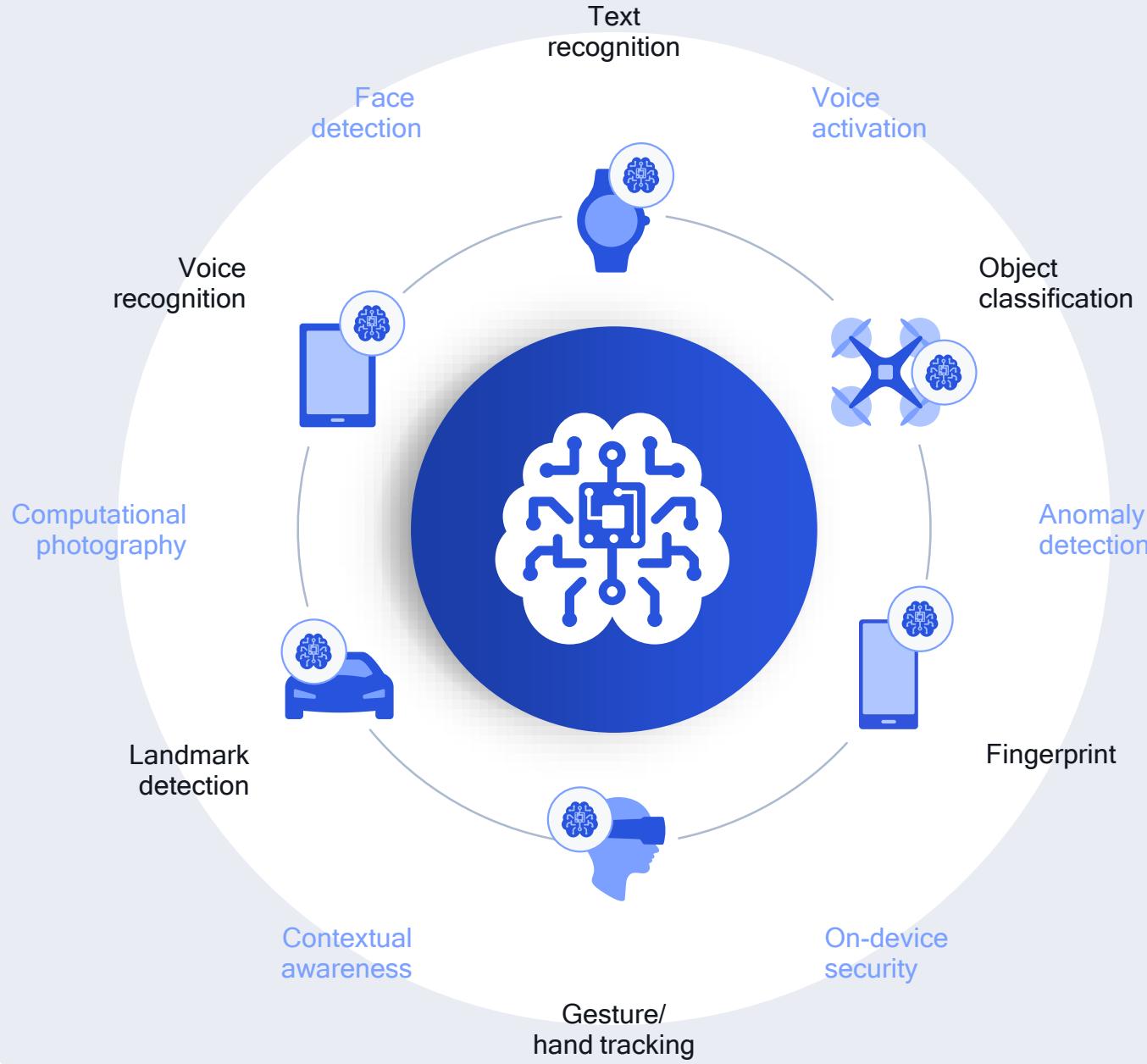


# Driving the 5G expansion

Our technology inventions drove  
the 5G foundation

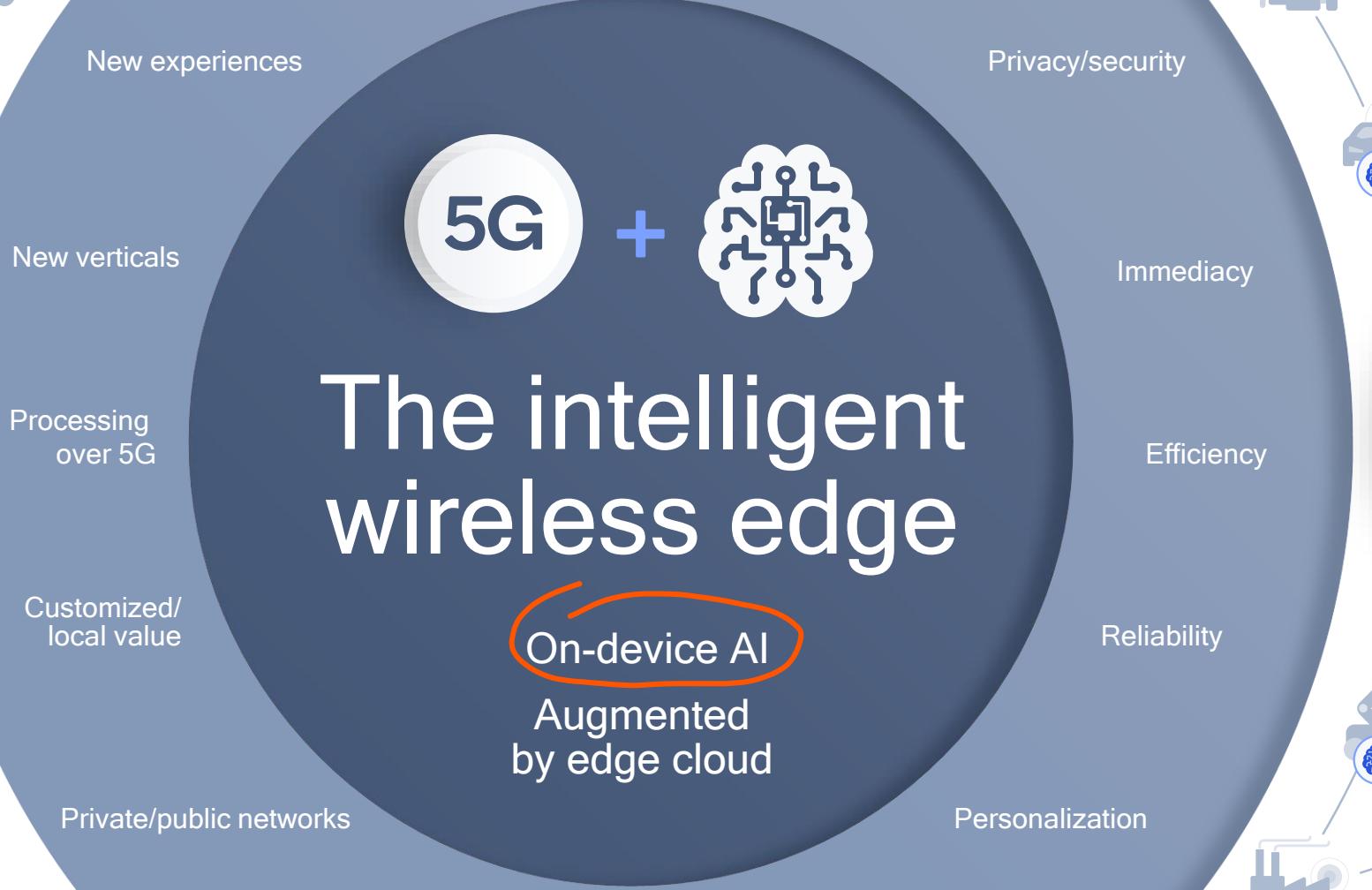
Rel.16-17





# On-device AI use-cases today

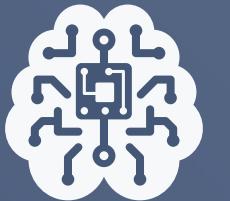
But we can do more  
with 5G



# The intelligent wireless edge

On-device AI  
Augmented by edge cloud

5G



New experiences

New verticals

Processing over 5G

Customized/local value

Private/public networks

Edge cloud

Privacy/security

Immediacy

Efficiency

Reliability

Personalization

On-device



# Process data at the source to scale and make sense of a digitized world

Past

## Cloud-centric AI

AI training and AI inference  
in the central cloud



Today

## Partially-distributed AI

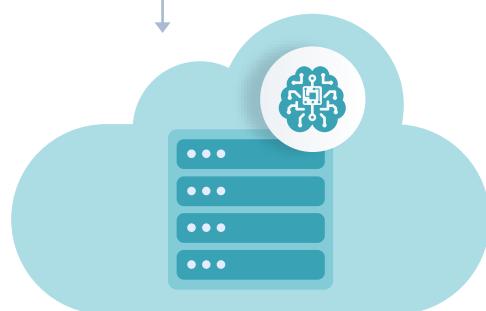
Power efficient  
on-device AI inference

Future  
**Fully-distributed AI**  
With lifelong on-device learning



# Enriched user experiences, new use case, new verticals

## Distributed functionality



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



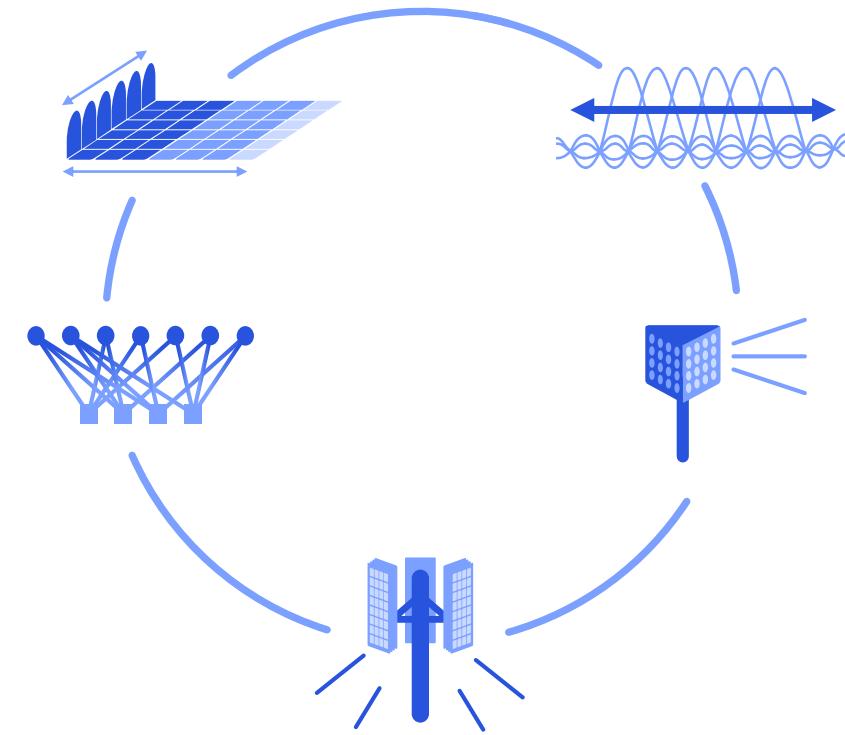
5G low latency  
Customized/local value  
Content/storage/AI/processing



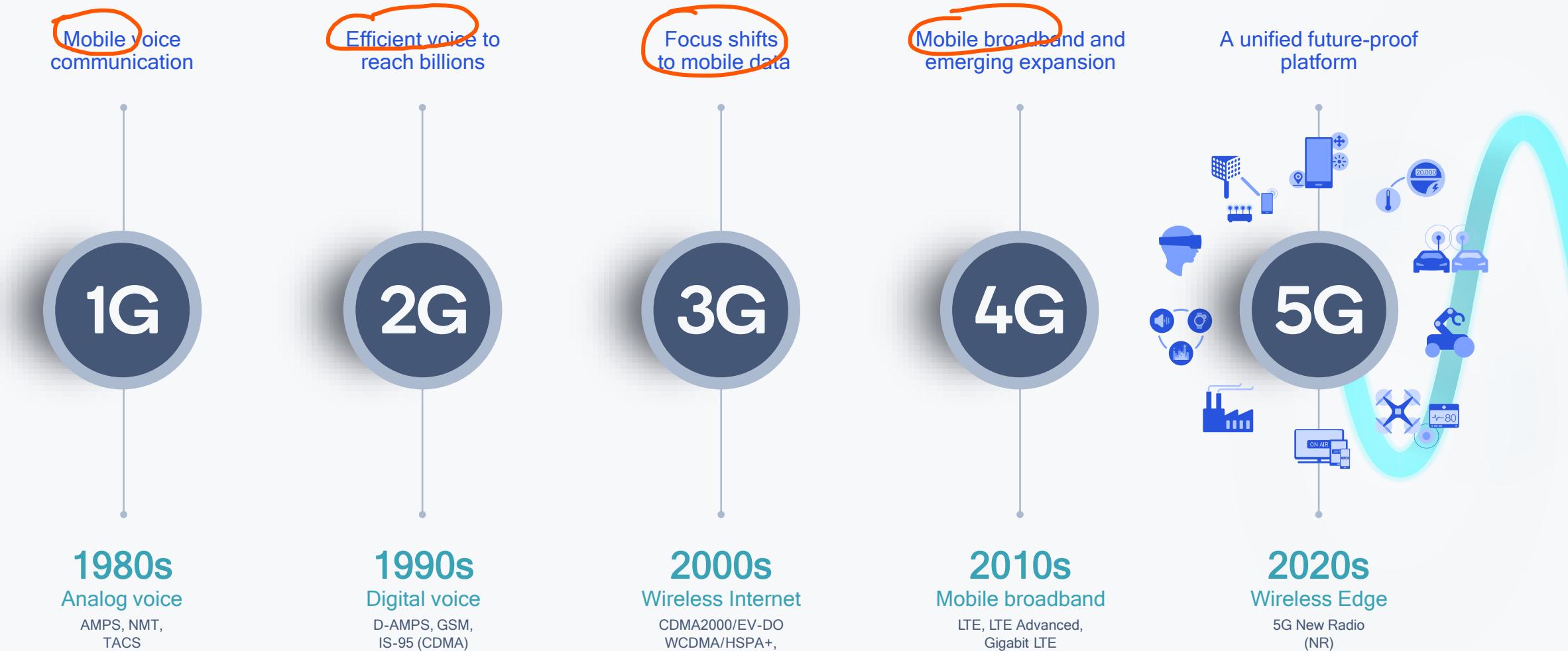
Compute, vision, sensing  
AI powered use cases  
Internal AI optimizations

- 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

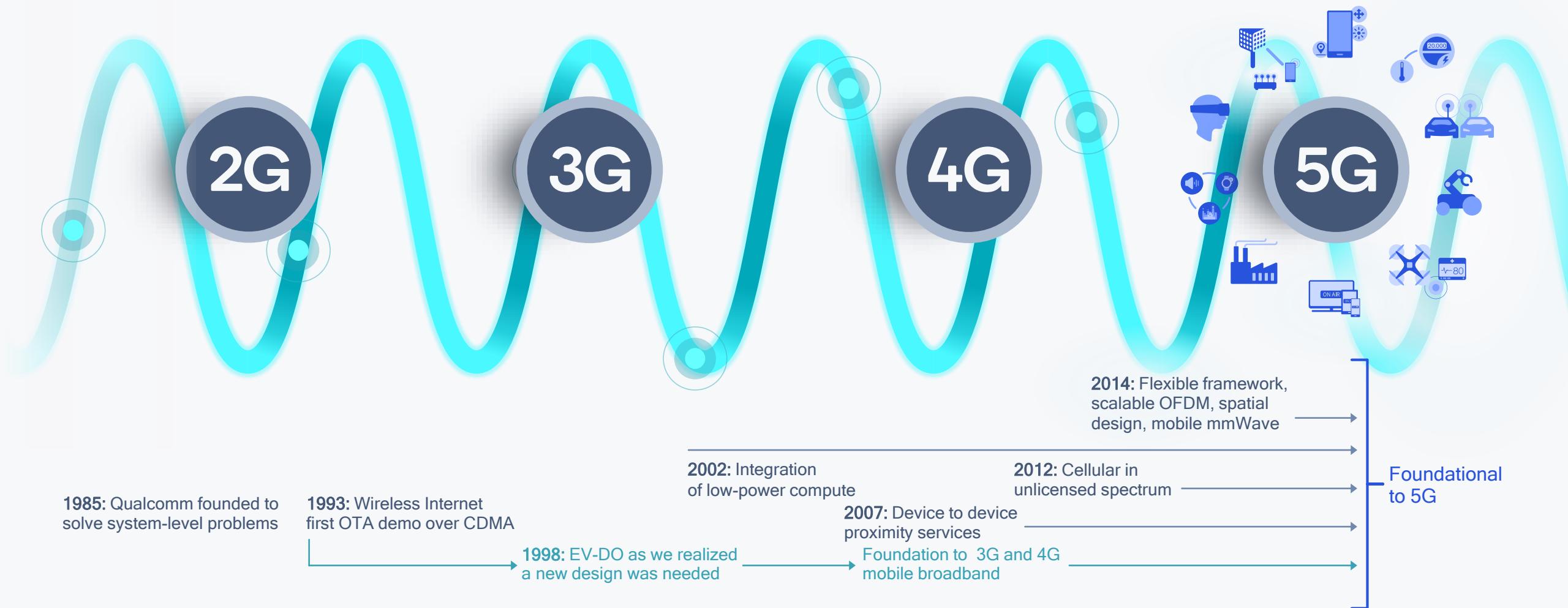
# Why is the 5G foundation key for the future?



# Mobile has made a leap every ~10 years



# The 5G foundation started long ago



# EV-DO is the foundation to mobile broadband

1993 vision: Wireless Internet

Megabit/s

Data optimized channel with Turbo Codes<sup>1</sup>  
Adaptive modulation/coding<sup>2</sup>  
Opportunistic scheduling<sup>3</sup>

10's megabit/s

OFDM in EV-DO (broadcast)  
Multiple antennas for RX diversity  
Carrier aggregation (rev B/HSPA+)  
Mobile VoIP with QoS

100's megabit/s

Unlicensed spectrum  
OFDM/A for wider spectrum  
More antennas-MIMO  
FDD/TDD/DC/SDL aggregation

Multi gigabit/s

Gigabit/s

Our inventions drove the 5G foundation



Mobile mmWave



Unified, flexible framework



Scalable OFDM numerology



Reciprocity-based massive MIMO



Multi-Edge LDPC & CRC-Aided Polar codes

All-IP EV-DO

Demo

Launch

Foundation to HSPA

Foundation to LTE

Foundation to 5G NR eMBB

1996

1998

2000

2002

2004 2006

2008

2010

2012

2014

2016

2018

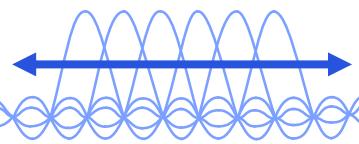
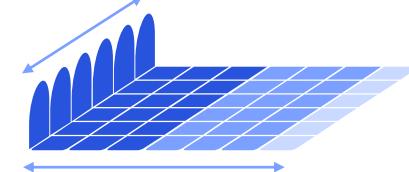
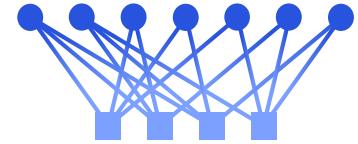
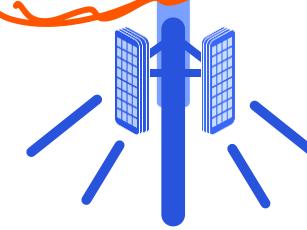
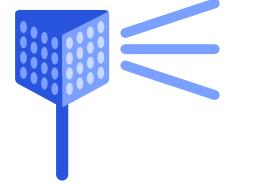
2020

2022

Continuous research and innovations, early prototyping, industry-first demos and trials

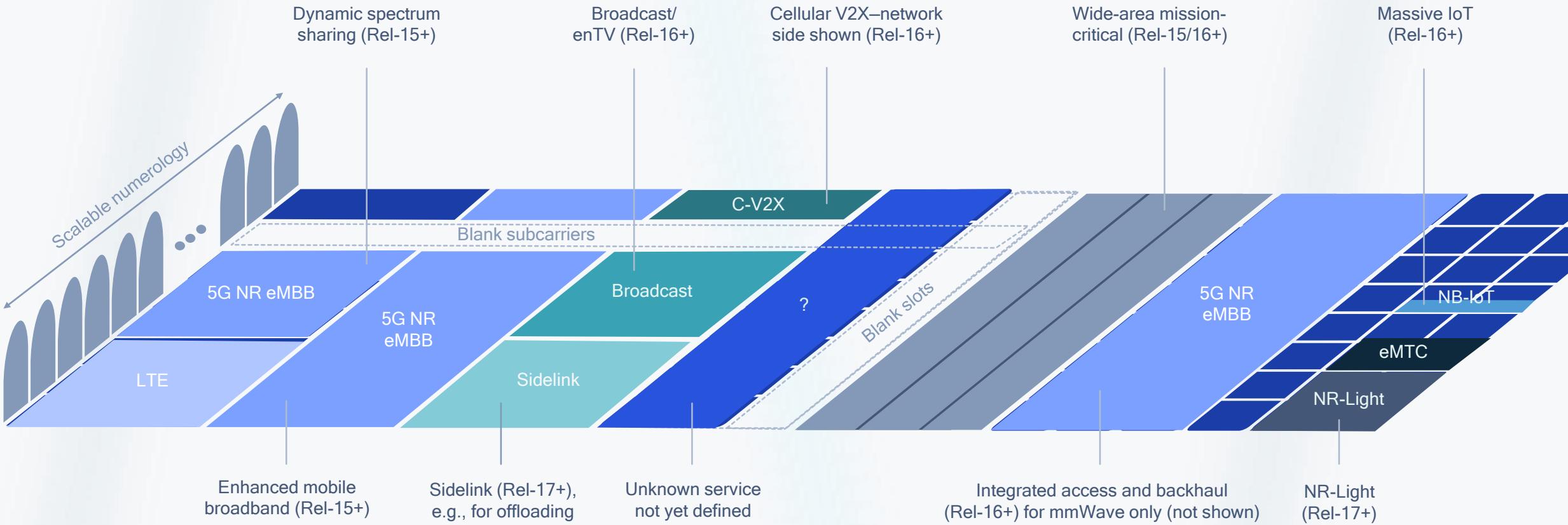
1. Assign all resources to a user, fast hybrid ARQ and power control 2 Higher order modulation for users with good signal quality 3 Multi-user diversity to prioritize users with better radio signal—with fairness

# Our technology inventions drove Release 15 specifications

<b>Scalable OFDM-based air interface</b> 	<b>Flexible slot-based framework</b> 	<b>Advanced channel coding</b> 	<b>Massive MIMO</b> 	<b>Mobile mmWave</b> 
Scalable OFDM numerology Address diverse services, spectrum, deployments	Self-contained slot structure Low latency, URLLC, forward compatibility	Multi-Edge LDPC and CRC-Aided Polar Support large data blocks, reliable control channel	Reciprocity-based MU-MIMO Large # of antennas to increase coverage/capacity	Beamforming and beam-tracking For extreme capacity and throughput

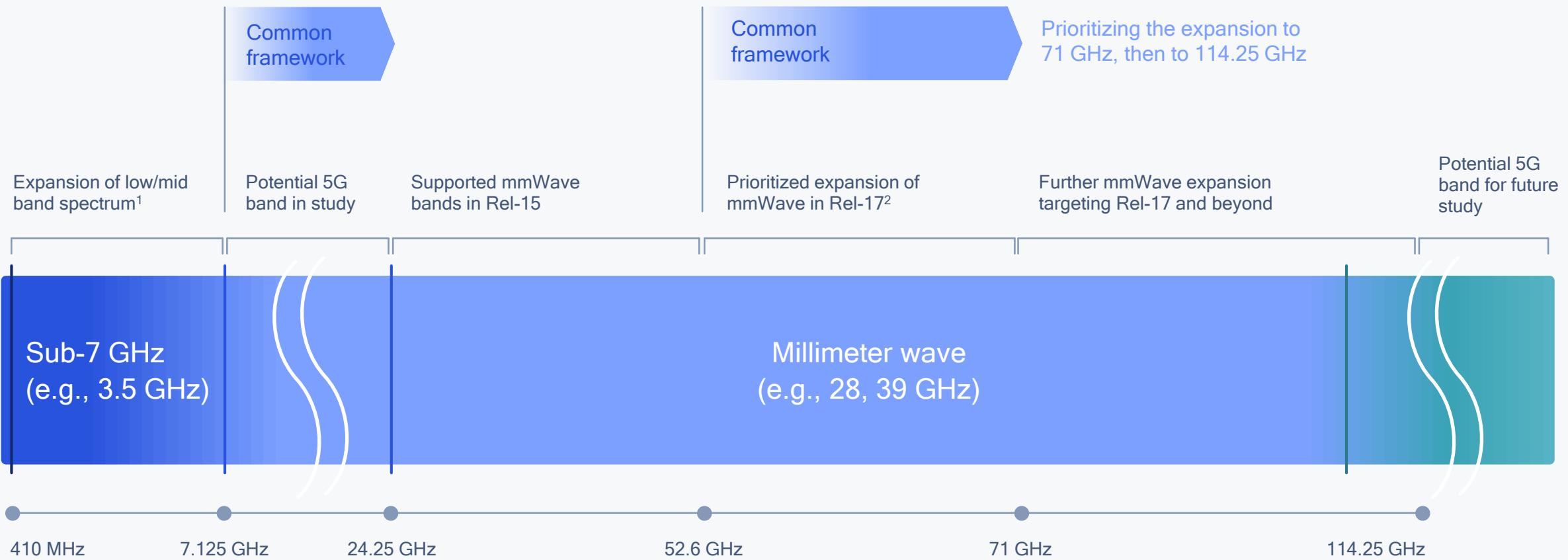
Early R&D investments | Cutting-edge prototypes | Fundamental contributions to 3GPP

# Expanding 5G with the flexible slot-based framework



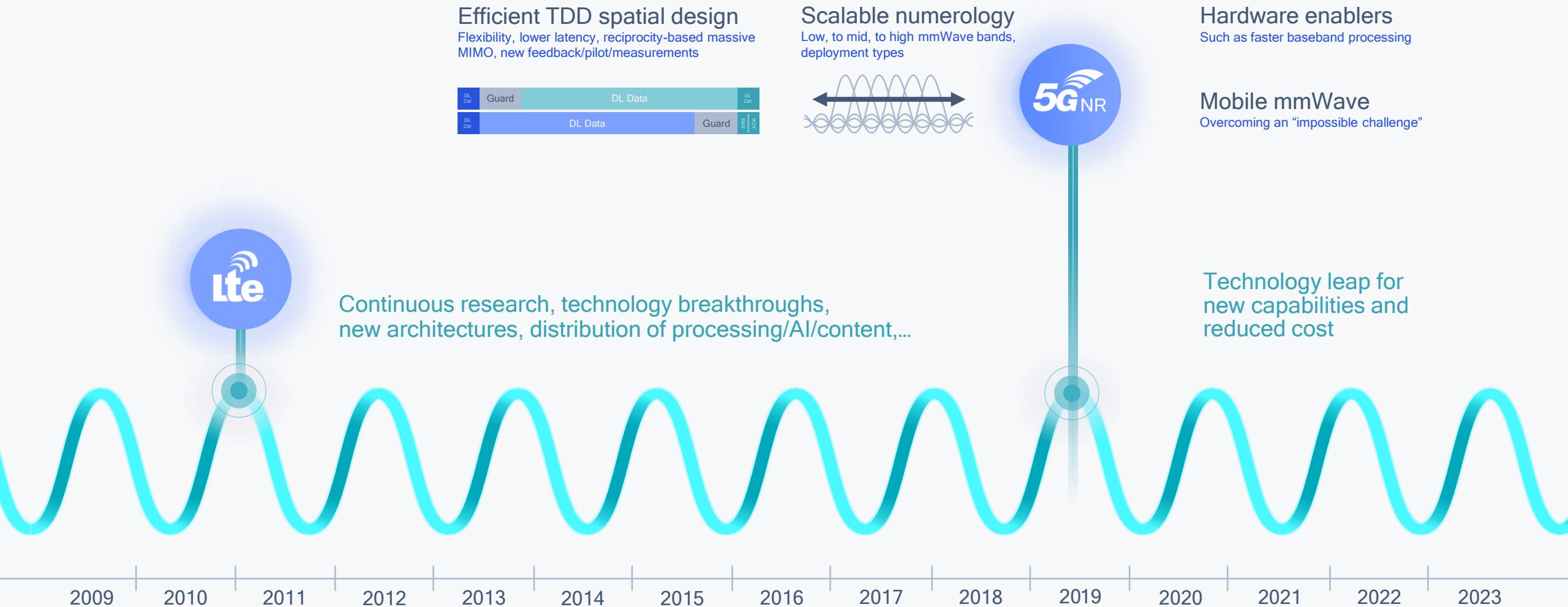
# Expanding mmWave spectrum with the common framework

millimeter wave

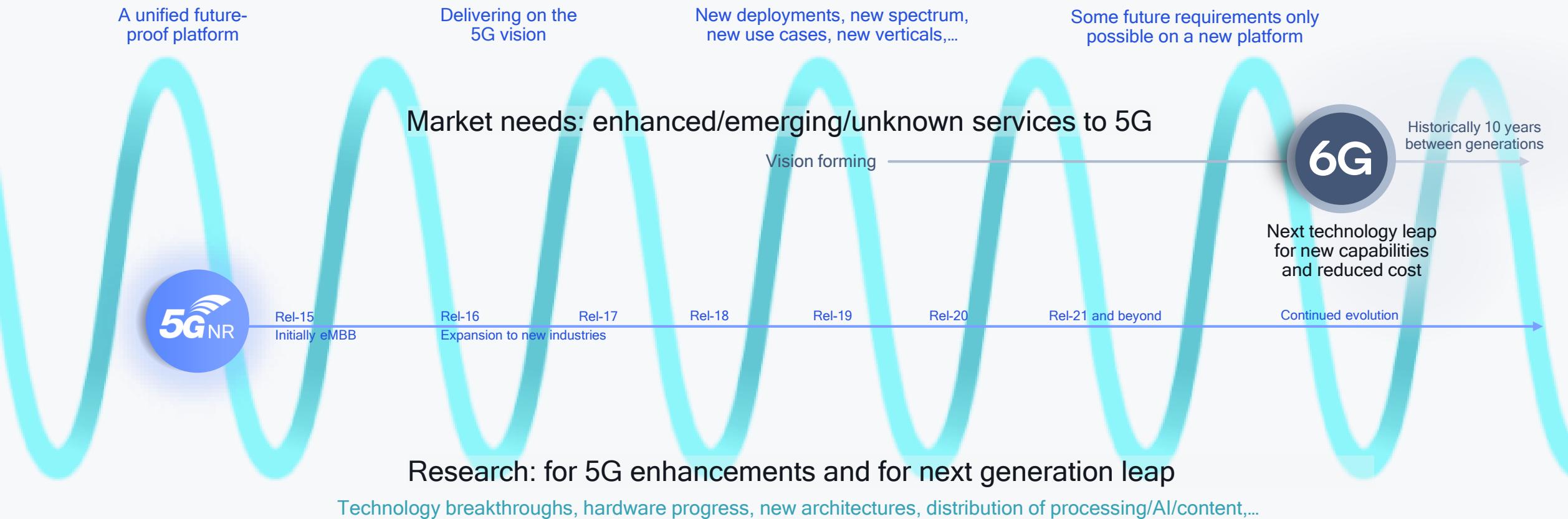


1. Rel-15 supported 450 MHz to 6 GHz; 2 To support global unlicensed 60 GHz bands, SCS scaling from 24.25-52.6 GHz band with same characteristics (e.g., waveforms)

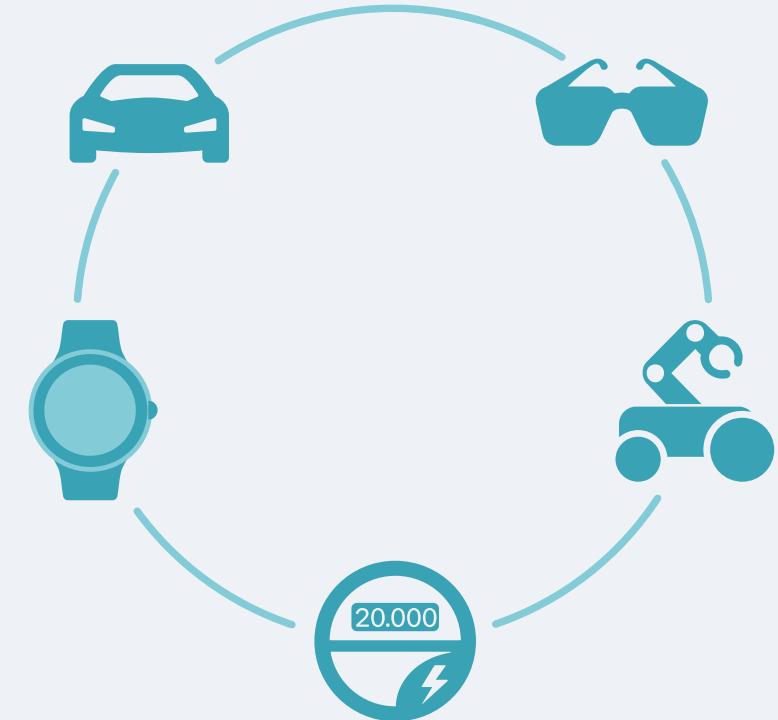
# 5G enabled capabilities not possible when 4G was defined



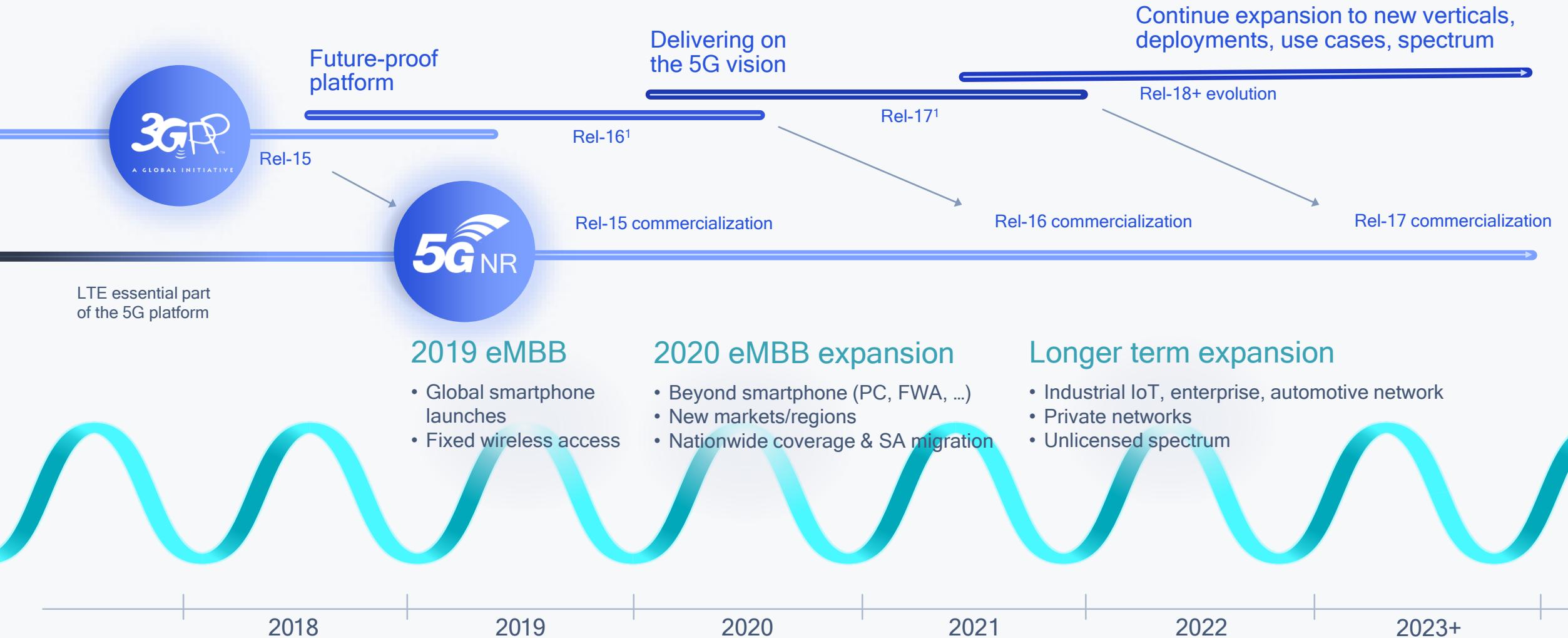
# 5G is the innovation platform for the next decade



# How will 5G NR evolve in Rel-16 and beyond?

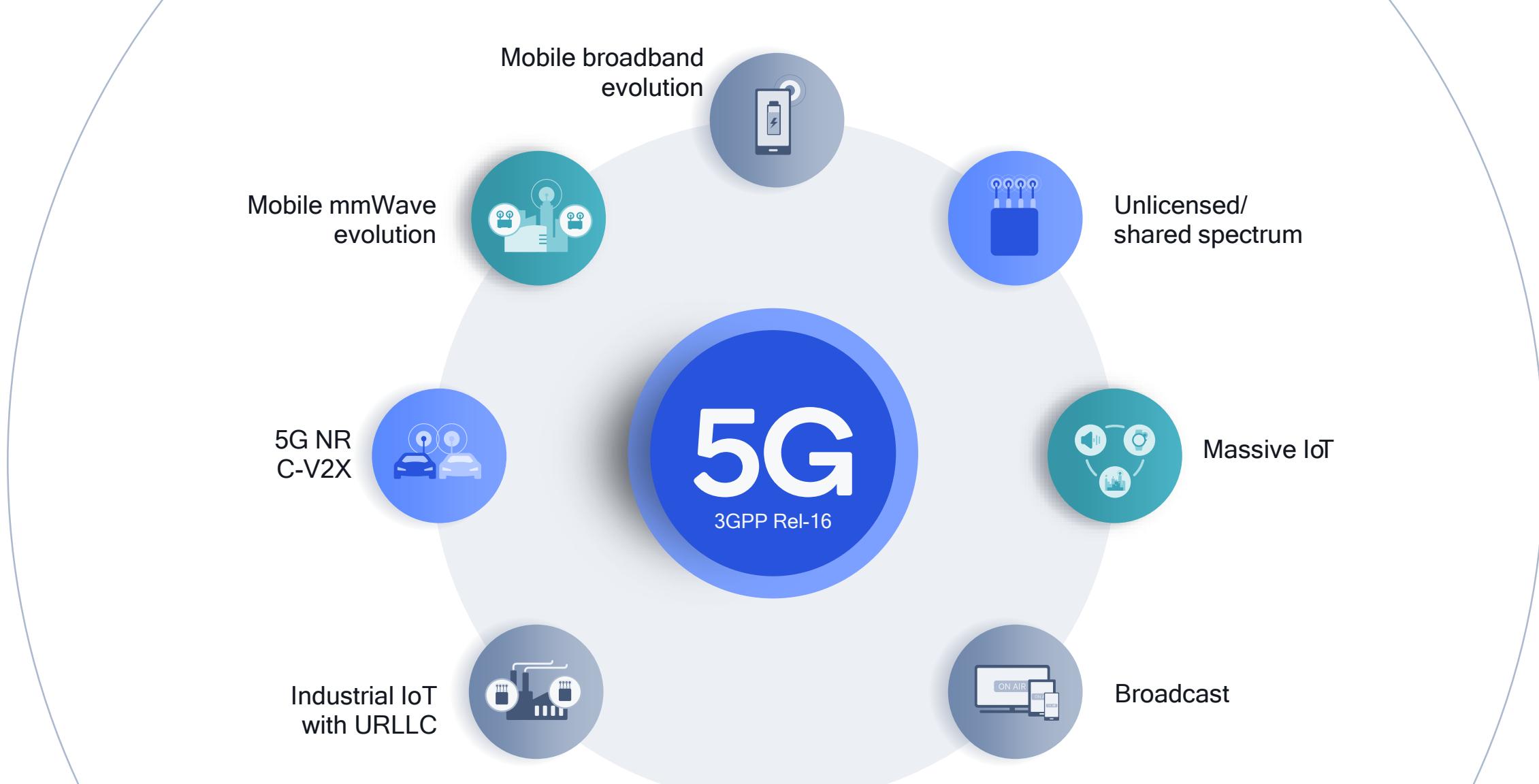


# Driving the 5G expansion



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 NR is expanding to new use cases and verticals



# Continue to enhance the eMBB foundation

## Rel-15 lessons learned

Optimizations to Rel-16 and  
New features to Rel-17



## Foundational

Coverage, capacity, latency,  
power saving, mobility



Enhanced DL/UL MIMO and  
multiple transmission points



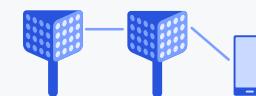
Device power saving with  
C-DRX and 2-step RACH



More robust mobility with minimal  
interruption during handover

## Deployment

New spectrum, topologies,  
integrated backhaul, ...



Integrated access/backhaul for  
easier mmWave deployments



Unlicensed spectrum including  
standalone and license assisted



Enhanced low/mid-band  
and mmWave CA and async DC



Further improved MIMO  
for e.g., higher mobility



Further power saving  
for idle and small data



Further enhanced mobility  
for mixed topologies



Enhanced IAB with full duplex  
and spatial multiplexing



Supporting even higher bands,  
up to 114.25 GHz



Others such as, >4 Rx,  
1024-QAM, multi-SIM

Rel-15

Rel-16

Rel-17:  
Likely candidates

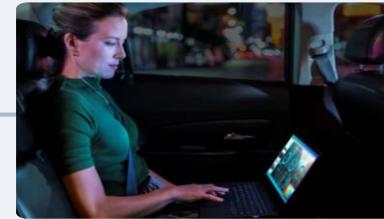


# Expanding our eMBB solution beyond the smartphone

Expand 5G coverage and performance



Expand device classes to always connected PC/Laptop



Expand fixed wireless access, integrated with Wi-Fi



Expand experiences, like XR tethered to smartphones



Expand mobile gaming including cloud gaming



Expand 5G eMBB modules to more verticals



Expand reach with our small cell solutions



Expand eMBB to vehicles – initially with R14 C-V2X



# Indoor enterprises

Offices, meeting rooms, auditoriums



# Indoor/outdoor venues

Conventions, concerts, stadiums



# Transportation hubs

Airports, train terminals, subway stations



## Expanding mmWave indoors, public/private networks



Multi-Gigabit speeds with  
virtually unlimited capacity



Beyond smartphones, laptops,  
tablets, extended reality, ...

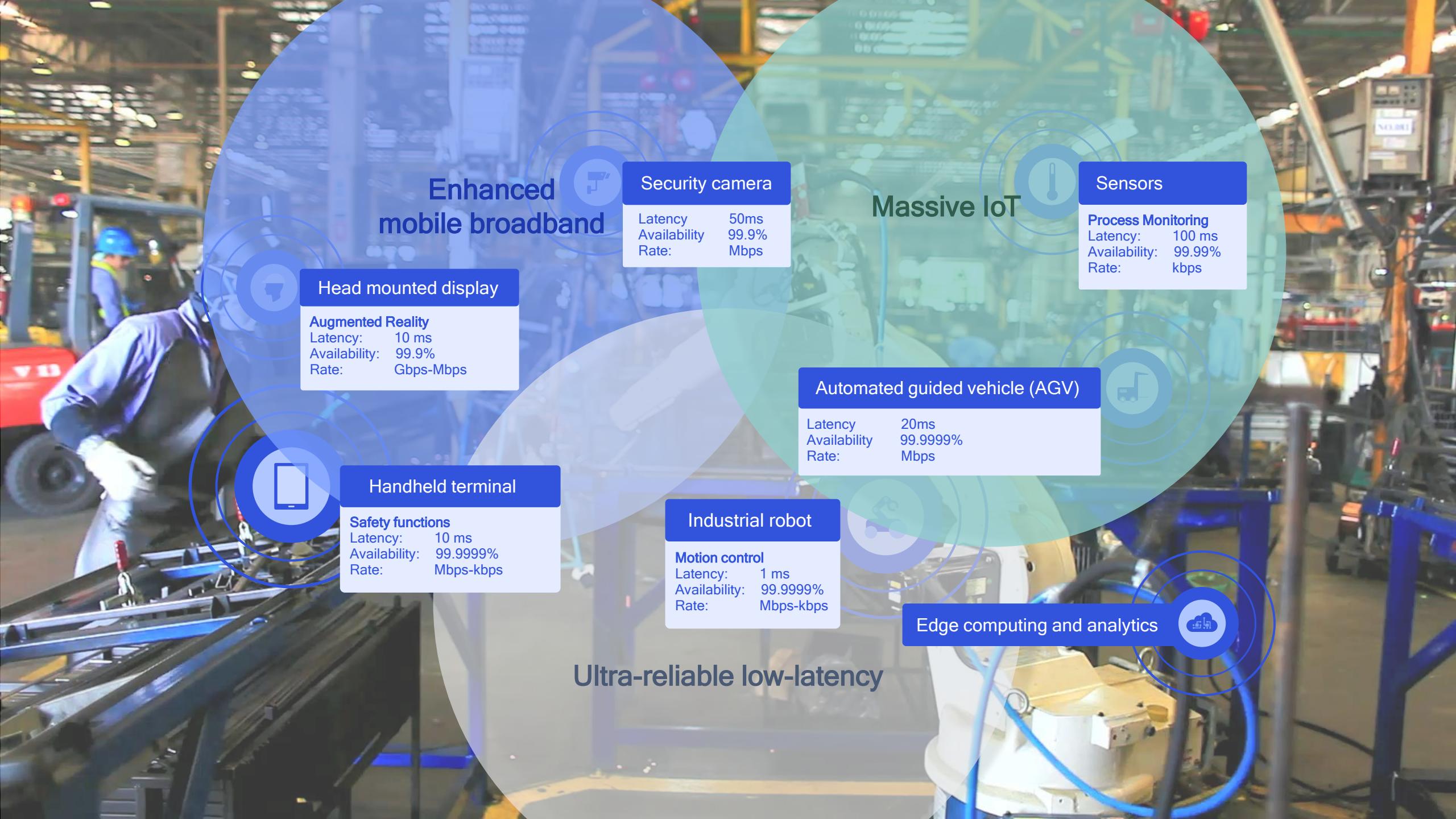


Leveraging existing Wi-Fi or  
cellular by co-siting

# Emerging dedicated private networks for targeted needs



5G NR  
Private network



# 5G

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

## Designing 5G to meet industrial IoT requirements

# 5G



## Private 5G network

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



## Licensed, shared and unlicensed spectrum

With NR-U, 5G NR will support:

- Licensed spectrum
- Shared spectrum
- Unlicensed spectrum



## Ultra-reliable low-latency communication (URLLC)

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



## Time Sensitive Networking (TSN)

- Ethernet over 5G
- 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

# Multiple spectrum options

For private 5G networks



## Licensed spectrum by mobile operators

Operators can allocate spectrum in a specific area



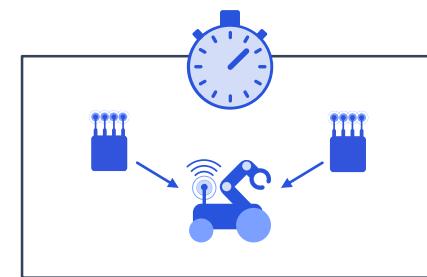
## Unlicensed spectrum with async sharing

NR-U with asynchronous sharing work for many applications



## Dedicated regional spectrum

Regional spectrum such as 3.7GHz in Germany for IIoT



## Unlicensed spectrum with synch sharing

Synchronized sharing can provide reliability and eURLLC for IIoT

## Enhanced network communication

Faster access to cloud for in-vehicle experiences, car OEM services and telematics



## New direct communication

V2V, V2I, and V2P communications for latency-sensitive use-cases, e.g. collision avoidance



## Massive Internet of Things

Deeper coverage to connect road infrastructure (e.g. sensors and traffic cameras)



V2N



V2N



Road hazard  
warning

V2I

RSU



Speed  
harmonization

V2V



Road safety



Transportation efficiency



Connected road sensors

Connected car services



In-vehicle experiences



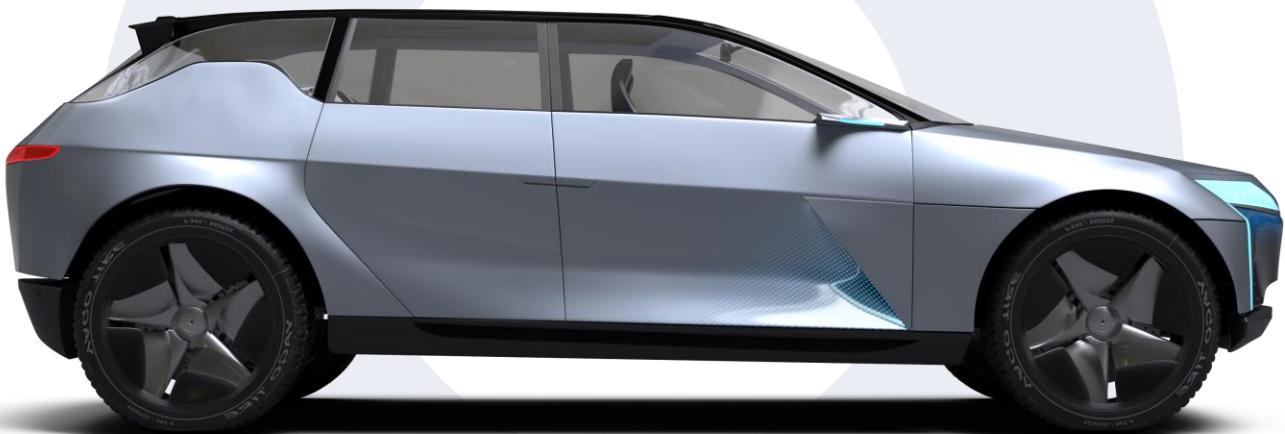
Evolution to 5G is designed to serve as the unified connectivity fabric



# Evolving 5G for smart transportation

# 5G NR C-V2X

Brings new benefits



Increased situational awareness

Sensor sharing

Coordinated driving / intention sharing

Real-time infrastructure updates



## Advanced safety

Real-time situation awareness and sharing of new kinds of sensor data take safety to the next level

## Faster travel / energy efficiency

More coordinated driving for faster travel and lower energy usage

## Accelerated network effect

Sensor sharing and infrastructure deployment bring benefits, even during initial deployment rollouts

# Virtual telepresence collaboration



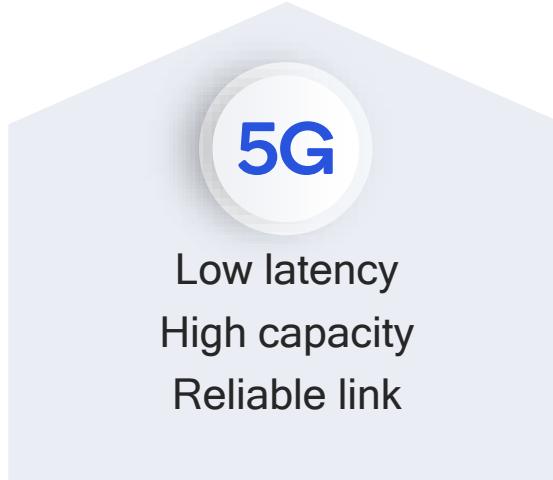
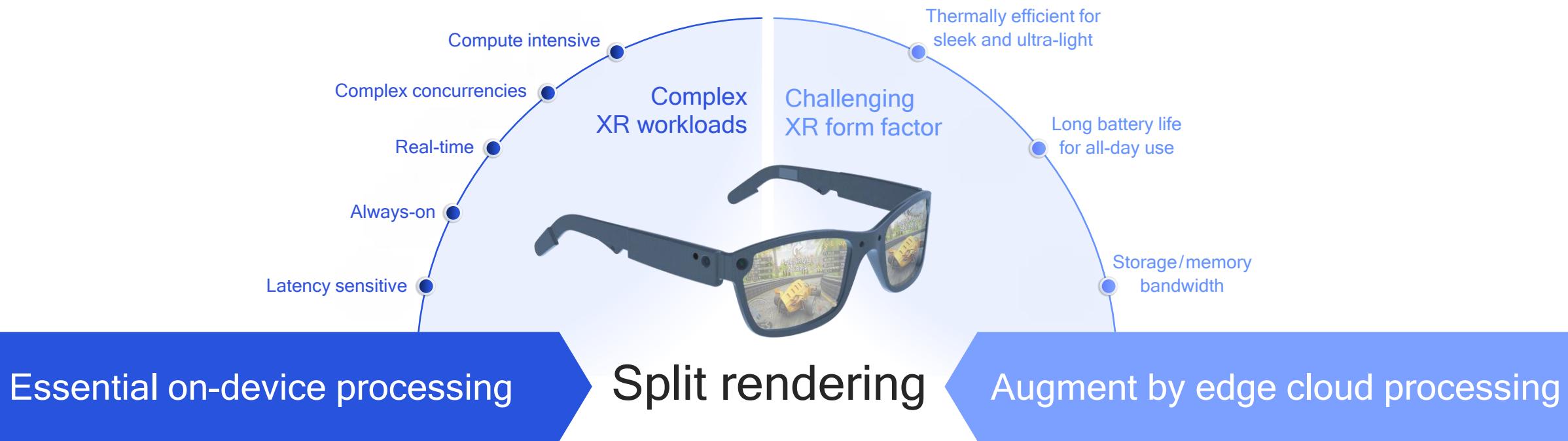
5G



Edge cloud—but  
not necessarily  
on-premise

Augmenting  
on-device  
processing  
over 5G

# A new era in distributed processing

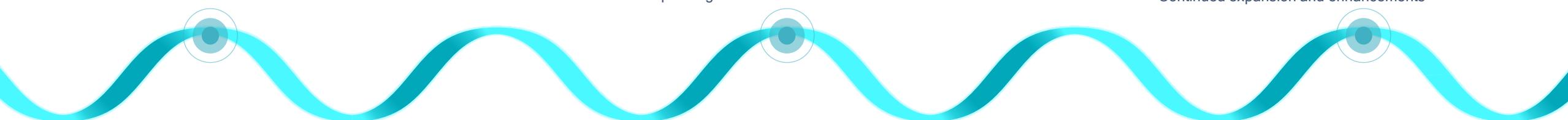


# Continued evolution to deliver on the 5G vision



## Rel-15

Established 5G NR technology foundation



## Rel-16

Expanding to new use cases and industries

## Rel-17: Likely candidates

Continued expansion and enhancements

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

# Thank you

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