Qualcomm

A closer look at 5G Advanced Release 18

Wireless innovations to supercharge the path toward intelligent computing everywhere

@QCOMResearch | San Diego, CA

July 2024

Agenda

1. Where are we on the 5G journey?

2. What's in 5G Advanced Release 18 and what are our key innovations?

3. How does 5G Advanced fit into our 6G vision?

4. Questions?

Mobile has made a leap every ~10 years

Analog voice	Digital voice	Wireless internet	Mobile broadband	Connected intelligent edge	Next-gen wireless
1980s	1990s	2000s	2010s	2020s	2030s
1G	**2G**	**3G**	**4G**	**5G**	**6G**
Mobile voice communication	Efficient voice to reach billions	Focus shifts to mobile data	Mobile broadband and emerging expansion	Connected intelligent edge	The next innovation platform
AMPS, NMT, TACS	D-AMPS, GSM, IS-95 (CDMA)	CDMA2000/EV-DO WCDMA/HSPA+	LTE, LTE Advanced, Gigabit LTE	5G New Radio	AI-native, new spectrum, RF sensing, and many more...

5G Services available globally

310+	153+	124+	585+	2.1B
Operators in 118 countries/territories deployed 5G services	Operators in 71 countries/territories deployed 5G FWA	Operators deployed or investing in 5G Standalone (SA)	Operators in 175 countries/territories investing in 5G	5G smartphones shipped globally

Where are we in the cellular innovation cycle?

5G

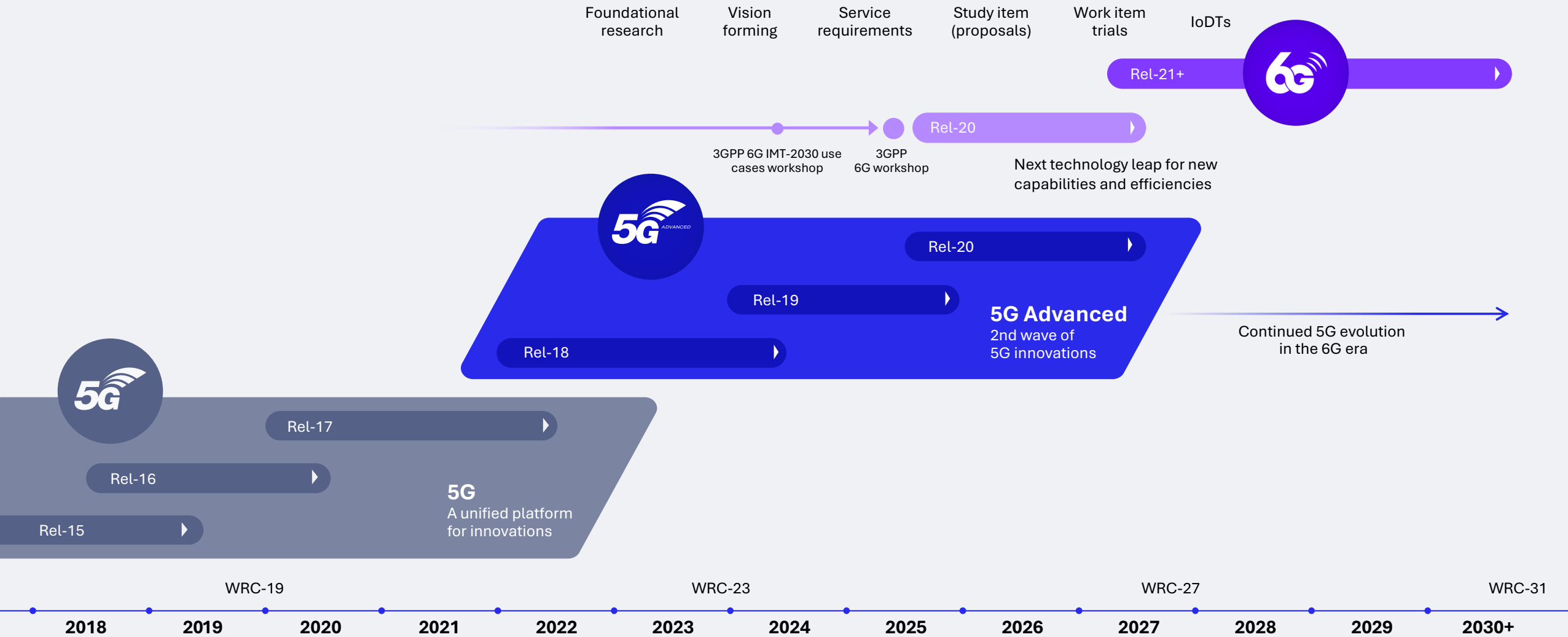Ramping volume and expanding to new use case

5G ADVANCED

Completing 1st standard —2nd phase of 5G innovations

6G

Aligning on vision, foundational research, timeline, requirements

INVENTION

Invent new technologies and e2e system architecture

VISION

Identify a problem or need; establish requirements

PROOF-OF-CONCEPT

Deliver end-to-end prototypes and impactful demonstrations

New Wireless Generation

~10 YEARS

STANDARDIZATION

Drive e2e design with ecosystem and through standards process

COMMERCIALIZATION

Engage with global network operators to deploy new features with standards-compliant infrastructure and devices

TRIALS

Collaborate on OTA field trials that track 3GPP standardization and drive ecosystem towards rapid commercialization

5

Leading the 5G Advanced evolution toward 6G

Foundational research • Vision forming • Service requirements • Study item (proposals) • Work item trials • IoDTs

Rel-21+

6G

3GPP 6G IMT-2030 use cases workshop

3GPP 6G workshop

Rel-20

Next technology leap for new capabilities and efficiencies

5G ADVANCED

Rel-20

Rel-19

Rel-18

5G Advanced
2nd wave of
5G innovations

Continued 5G evolution
in the 6G era

5G

Rel-17

Rel-16

Rel-15

5G
A unified platform
for innovations

WRC-19 | WRC-23 | WRC-27 | WRC-31

2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030+

Our advanced innovations lead the path to 6G

FOUNDATIONAL QUALCOMM INNOVATIONS LEAD ALL 3GPP RELEASES

Enhancing mobile broadband

Boundless extended reality

Smartphones and laptops

Fixed Wireless and enterprise

Broadband Evolution

Enhanced Uplink

Enabling new verticals

IoT expansion

Automotive

Industrial IoT

Efficient System Design

Wireless AI Foundation

6G

5G Advanced
Release 19/20

5G Advanced
Release 18

IoT Advancement and Expansion

Release 16
Advanced power saving & mobility
Mission-critical design
Precise positioning
Sidelink
Unlicensed spectrum
New deployment models

Release 15
Flexible slot-based framework
Scalable numerology
Advanced channel coding
Massive MIMO
Mobile mmWave

Release 17
Reduced capability devices (RedCap)
Non-terrestrial networks (NTN)
Device enhancements
Topology expansion
mmWave expansion

4G Foundations

Release 18+

Mobile broadband evolution and further vertical expansion

Deliver enhanced mobile broadband experiences and extend 5G's reach into new use cases

Immediate commercial needs and longer-term 5G vision

Drive new value in commercialization efforts and fully realize 5G's potential with future deployments
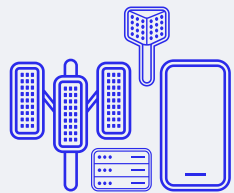
New and enhanced devices and network evolution

Focus on the end-to-end technology evolution of the 5G system to bring new levels of performance

What's in 3GPP Release 18?

Strengthen the end-to-end 5G system foundation
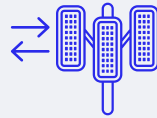
Advanced DL/UL MIMO

Enhanced mobility
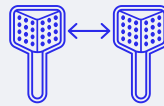
Mobile IAB, network-controlled repeater

Evolved duplexing

AI/ML data-driven designs

Green networks and devices

Proliferate 5G to virtually all devices and use cases

Boundless extended reality

RedCap evolution
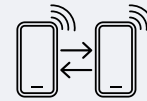
Expanded sidelink

Expanded positioning
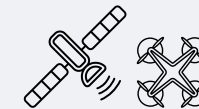
Drones & expanded satellites comm.

Multicast & other enhancements

3GPP RELEASE 18

Strengthen the end-to-end 5G system foundation
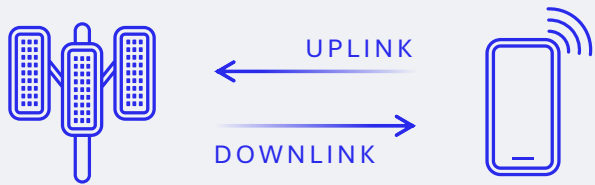
Continued 5G MIMO evolution to improve performance and efficiency

Release 18 Work Item

Enhanced CSI[1] & CSI-RS[2] in high or medium velocities to exploit time-domain correlation for sub-7 GHz

Extending Rel-17 unified TCI[3] framework for multiple DL/UL TCI states focusing on multi-TRP[4]

Supporting larger number of orthogonal DMRS[5] ports for DL/UL multi-user MIMO for CP-OFDM[6]

Supporting coherent-JT[7] for up to 4 TRPs, assuming ideal backhaul and synchronization in sub-7 GHz

Supporting 4+ Tx UL operations for 4+ layers per device targeting CPE[8], FWA[9], vehicle, industrial devices

Facilitating simultaneous multi-panel UL for mmWave and multi-TRP, targeting CPE, FWA, vehicle, industrial devices

Specifying asynchronous multi-TRP support including 2 TA[9] for UL multi-DCI[10] and power control for UL single-DCI

Driving additional 5G uplink coverage enhancements
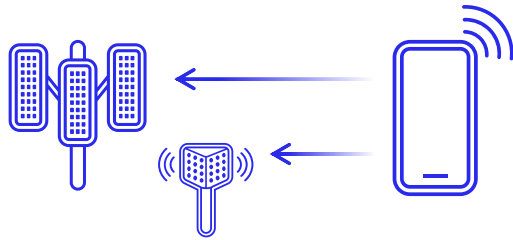
Uplink coverage enhancements
Release 18 Work Item

Random access enhancements for multiple PRACH[1] transmissions with same beam for 4-step RACH[2], targeting mmWave as well as sub-7 GHz

Power domain enhancements with increased device power limit for CA[3]/DC[4] and reduced MPR[5]/PAR[6] via spectrum shaping without spectrum extension

Dynamic waveform switching enhancements for DFT-S-OFDM[7] and CP-OFDM[8]

Source: in RP-221858 (Further NR coverage enhancements)

1 Physical Random Access Channel; 2 Random Access Channel; 3 Carrier aggregation; 4 Dual connectivity; 5 Maximum power reduction; 6 Peak-to-average power ratio; 7 Discrete Fourier Transform Spread Orthogonal Frequency Division Multiplexing; 8 Cyclic-Prefix Orthogonal Frequency Division Multiplexing.

Further optimizing 5G device mobility management
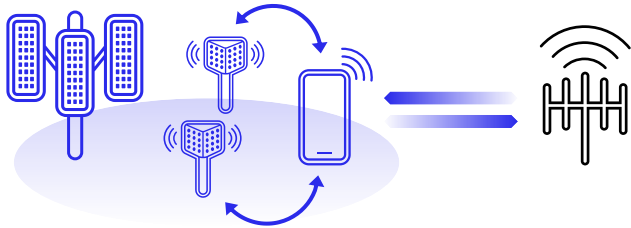
For operations in both sub-7 GHz and mmWave bands
5G NR Release 18 Work Item to address different deployment configurations

Layer 1 / 2 based inter-cell mobility
Dynamic switching among multiple candidate cells, enhanced L1 inter-cell beam management (e.g., L1 measurement reporting / beam indication), only intra-CU[1] scenario considered in Rel-18. Supported in MCG and in SCG without MN[2] involvement.

NR-DC[3] with selective activation of cell groups via L3 enhancements
Conditional PSCell[4] addition and change among multiple candidate SCGs. One SCG[5] active at a time

Conditional handover (CHO) enhancements
Conditional handover with candidate SCGs. Backhaul data forwarding optimizations for CHO including target MCG[6] and target SCG in NR-DC

mmWave enhancements
Improve SCell[7]/SCG setup delay by reusing IDLE/INACTIVE mode measurement results; device validity check for IDLE/INACTIVE mode measurements

Cost-efficient expansion of 5G coverage and capacity

Release 18 Work Item on new 5G deployment topologies

Mobile integrated access and backhaul (IAB)

To enable mobility for IAB nodes, e.g., mounted on vehicles for enhanced 5G coverage and capacity
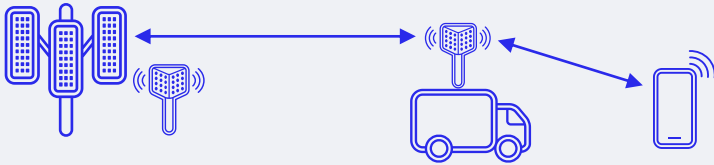
Define procedures for migration/topology adaptation to enable mobility, including inter-donor migration of entire node

Enhance mobility of an IAB together with its served devices

Mitigate interference due to IAB mobility (e.g., avoid potential reference and control signal collisions)

Maintain ability to serve legacy devices, optimizations can entail Release 18 backward compatible device enhancements

Network-controlled repeaters (NCR)

To support single-hop operation that is that is transparent to the devices for enhanced coverage

Beamforming

Control channel managed by the network
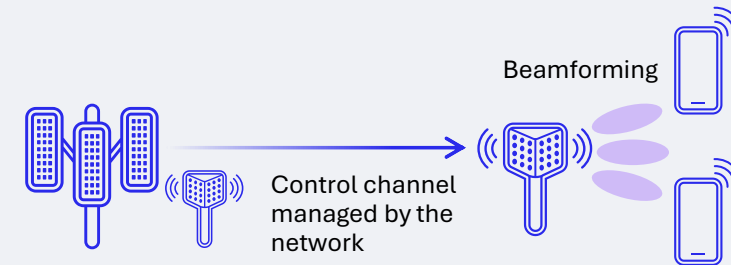
Specify signaling and behavior of side control information including beamforming, TDD configuration, and on/off setting

Define control plane signaling and procedures for side control information indication

Support solutions for NCR management (e.g., identification and authorization)

Specify RF, EMC and RRM requirements

5G Advanced introduces new network energy saving techniques

Release 18 Work Item

Low-power mode

Align cell DTX/DRX[1] and device DRX in connected mode as well as inter-node information exchange to enable network energy savings in non-active time

Power adaptation

Enhance CSI[2]-related procedures (e.g., signaling, measurement/report) to enable efficient adaptation to larger device power offsets between PDSCH[3] & CSI-RS

Spatial adaptation

Enhance CSI & beam management (e.g., signaling, measurement/report) to enable efficient adaptation to number of antenna ports, active transceiver chains, and others

Mobility management

Improve beam management during paging and conditional handover procedures and in case source/target cell is in network energy savings mode

Legacy device support

Prevent legacy devices camping on cells that support network energy saving techniques
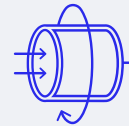
Carrier aggregation

Support SSB-less SCell[4] operation for inter-band carrier aggregation for sub-7 GHz and co-located cells

Testing requirements

Specify requirements to support network energy savings (e.g., RRM[5]/RF core, RRM performance, demodulation performance, base station conformance)

Toward a greener end-to-end communications system

Optimize energy efficiency in the core network and data center

Optimize network energy efficiency in the RAN, specially in the base station

Immediate focus

Implement device-only techniques that focuses on device energy savings

Explore end-to-end energy saving opportunities including foundational air-interface technologies that take into consideration traffic load in the network and device support/feedback

Opportunities to minimize environment impact — achieving reduced network operation cost expenditure and extended device battery life

Release 18 studies low-power wake-up signal / receiver (WUS/WUR)

Evaluate power saving schemes that do not require existing signals to be used as WUS for power-sensitive, small form-factor devices

Identify evaluation methodology for low-power WUS/WUR for lower complexity IoT devices (e.g., RedCap)

Study and evaluate low-power wake-up receiver architectures

Evaluate wake-up signal designs to support wake-up receivers
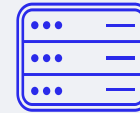
Determine L1 procedures and higher layer protocol changes to support the wake-up signals

Evaluate device power saving gains and latency, coverage impact compared to the existing power saving techniques

Laying the foundation for the future of full duplex communications

Identify applicable and relevant deployment scenarios and use cases

Study subband non-overlapping full duplex and potential enhancements on dynamic TDD[1]

Release 18 Study Item
evaluates the potential of non-overlapping subband full duplex (SBFD)

Simultaneous UL/DL in TDD spectrum

Duplex enhancements at base stations

Half duplex at devices

DOWNLINK	DOWNLINK	DOWNLINK	DOWNLINK
UPLINK	UPLINK	UPLINK	UPLINK
DOWNLINK	DOWNLINK	DOWNLINK	DOWNLINK
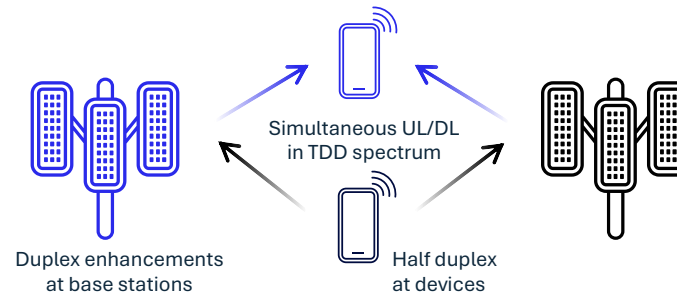
Total Bandwidth (e.g., 40 MHz x2 DL, 20 MHz UL)

Develop evaluation methodology for duplex enhancement
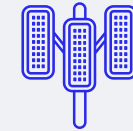
Study inter-base station/device CLI[2] management and impact on RF considering adjacent-channel coexistence with legacy operation

Summarize regulatory aspects and network energy impacts pertaining to duplex operations

Applying AI to solve difficult wireless challenges

Deep wireless domain knowledge is required to optimally use AI capabilities

Wireless
challenges

Hard-to-model problems

Computational infeasibility
of optimal solution

Efficient modem
parameter optimization

Dealing with non-linearity

AI-enhanced
wireless communications

AI
strengths

Determining appropriate
representations for
hard-to-model problems

Finding near-ideal and
computationally realizable solutions

Modeling non-linear functions

Release 18 Study Item scope

5G   **AI**
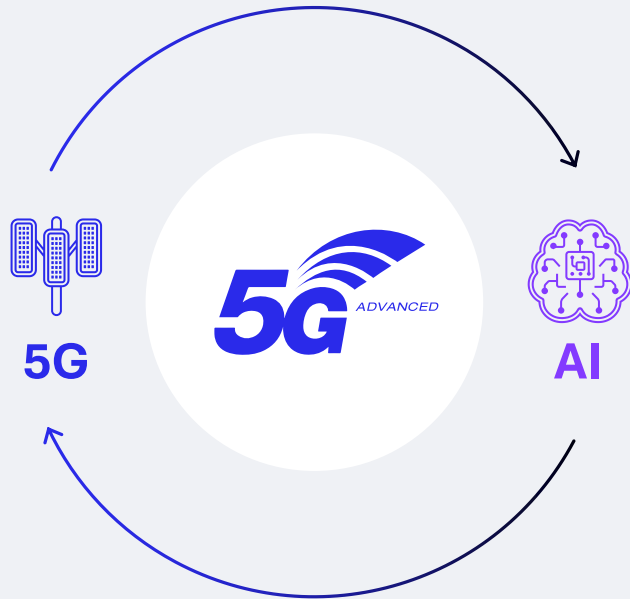
AI/ML-enabled air interface design

Use cases

Channel feedback (spatial/frequency-domain CSI compression[1] using two-sided model or in time-domain using single-sided AI model)

Beam management (spatial/temporal-domain beam prediction).

Positioning accuracy (direct AI or AI-assisted positioning)
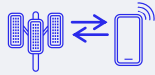
AI/ML model and framework

Defining stages, collaboration levels, life cycle management, and datasets for training, validation, testing, inference

Evaluation methodology

Existing 3GPP framework and field data to assess performance and identify KPIs

Impact assessment

Physical layer (e.g., lifecycle management, signaling for training/validation, assistance info, protocols (e.g., capability indication), and interoperability/testability

AI/ML framework for next-gen RAN

Network optimization

Data collection enhancements and signaling support for network energy saving, load balancing, mobility optimization

Future study

New use cases (e.g., AI/ML for slicing, QoE[2]), network functionality and interface procedures

Further enhancing the 5G system

Other RAN projects in 3GPP
Release 18

Improved DSS[1]
Enable NR PDCCH[2] reception in symbols with LTE CRS[3] and allow two overlapping CRS rate matching patterns with/without multiple TRPs[4]

Multi-carrier enhancements
Define multi-cell PUSCH[5] / PDSCH[6] scheduling with single DCI[7] and UL Tx switching across 3 or 4 bands with simultaneous 2 Tx in sub-7 GHz

Enhanced multi-SIM[8]
Enhance simultaneous network connections and switching (e.g., collision handling, gap coordination, temporary capability restriction)

In-device coexistence
Improve interference management in FDM[9] (i.e., more granular indication) and in TDM[10] (i.e., preferred pattern indication), with LTE baseline

Small data transmission
Support mobile-terminated small data transmissions in inactive state for e.g., enhanced paging

SON/MDT[11] enhancements
Support MRO[12] for MR-DC[13] SCG[14] failure and IRAT[15] handover voice fallback, enhanced handover reporting, random access, expanded use cases

Improved QoE[16]
Support new service types (e.g., XR, broadcast), QoE in NR-DC[17] (e.g., reporting via secondary node)

Timing resiliency/eURLLC
Specifying timing synchronization status/reporting, TSN transport network interworking, low-latency scheduling

Enhanced NPN[18] & slicing
Enhance NPN mobility for idle and connected mode, non-3GPP access, and network slicing service continuity

Other RAN[19] projects
Enhance RF in sub-7 (e.g., 4Tx/8Rx) & mmWave (e.g., UL 256-QAM[20]), air-to-ground, <5MHz for trains, broadcast, CA[21], BWP[22], 6 GHz, new bands, others

5G ADVANCED

3GPP RELEASE 18

# Proliferate 5G to virtually all devices and use cases

Further improving XR experience with 5G Advanced

XR traffic awareness

Support additional buffer size table to reduce quantization errors, device reporting of uplink assistance info., congestion signaling, and others

Enhanced device power saving

Support non-integer DRX[1] periodicities to match frame rates (e.g., 15, 30, 45, 60, 72, 90, 120 fps) and CG[2] without uplink retransmissions
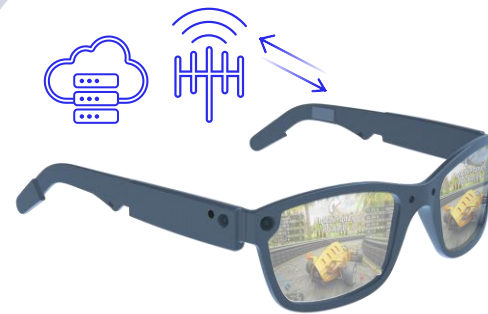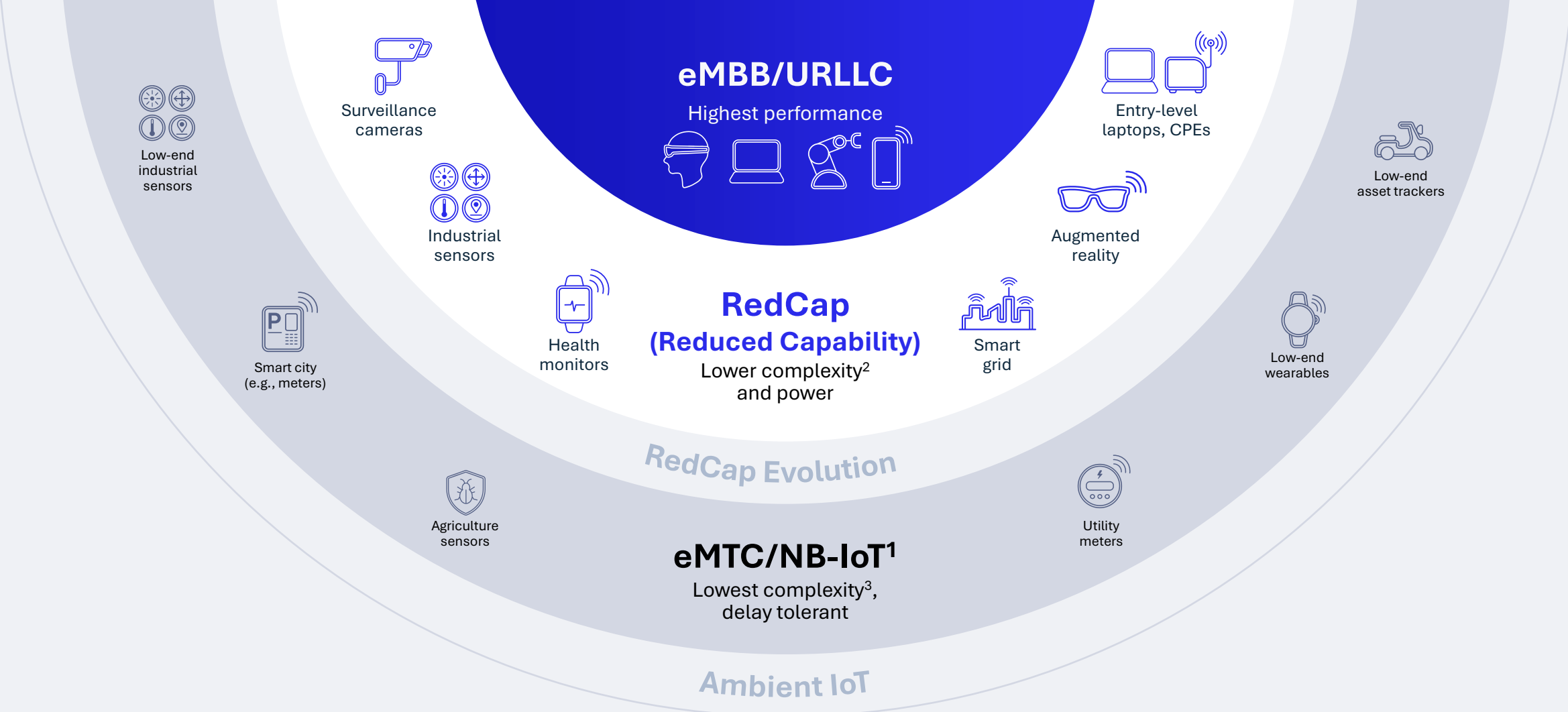
Release 18 Work Item

System capacity improvement

Support multiple CG PUSCH[3] in a period, dynamic indication of unused CG PUSCH based on UCI[4], PDU set-based discard, shorter discard timer, and others

Reduced RF complexity

Define a non-RedCap device class for AR/VR devices to support only 2Rx antennas in sub-7 GHz band with new performance requirements

eMBB/URLLC

Highest performance

**RedCap
(Reduced Capability)**

Lower complexity[2]
and power

Surveillance
cameras

Industrial
sensors

Health
monitors

Smart
grid

Augmented
reality

Entry-level
laptops, CPEs

Low-end
industrial
sensors

Smart city
(e.g., meters)

Low-end
asset trackers

Low-end
wearables

RedCap Evolution

eMTC/NB-IoT[1]

Lowest complexity[3],
delay tolerant

Agriculture
sensors

Utility
meters

Ambient IoT

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

Further scaling down the complexity of RedCap device family

Enhanced RedCap Devices

Focusing on sub-7 GHz

3GPP Release 18 Work Item

RedCap Evolution

5 MHz baseband bandwidth with 20 MHz RF for DL/UL data channels (PDSCH/PUSCH). 20 MHz baseband bandwidth also supported.

10 Mbps limitation of peak data rate

>10.24s extended discontinued reception (DRX) for RRC_Inactive mode

New signaling for Rel-18 eRedCap, coexisting with other 5G device types

RedCap / eRedCap

eMTC / NB-IoT

Ambient IoT

eMBB / URLLC

Relay/repeater

Logistic tracking
Ambient IoT devices are attached to items, such as pallet containers and individual product, to track and manage inventory
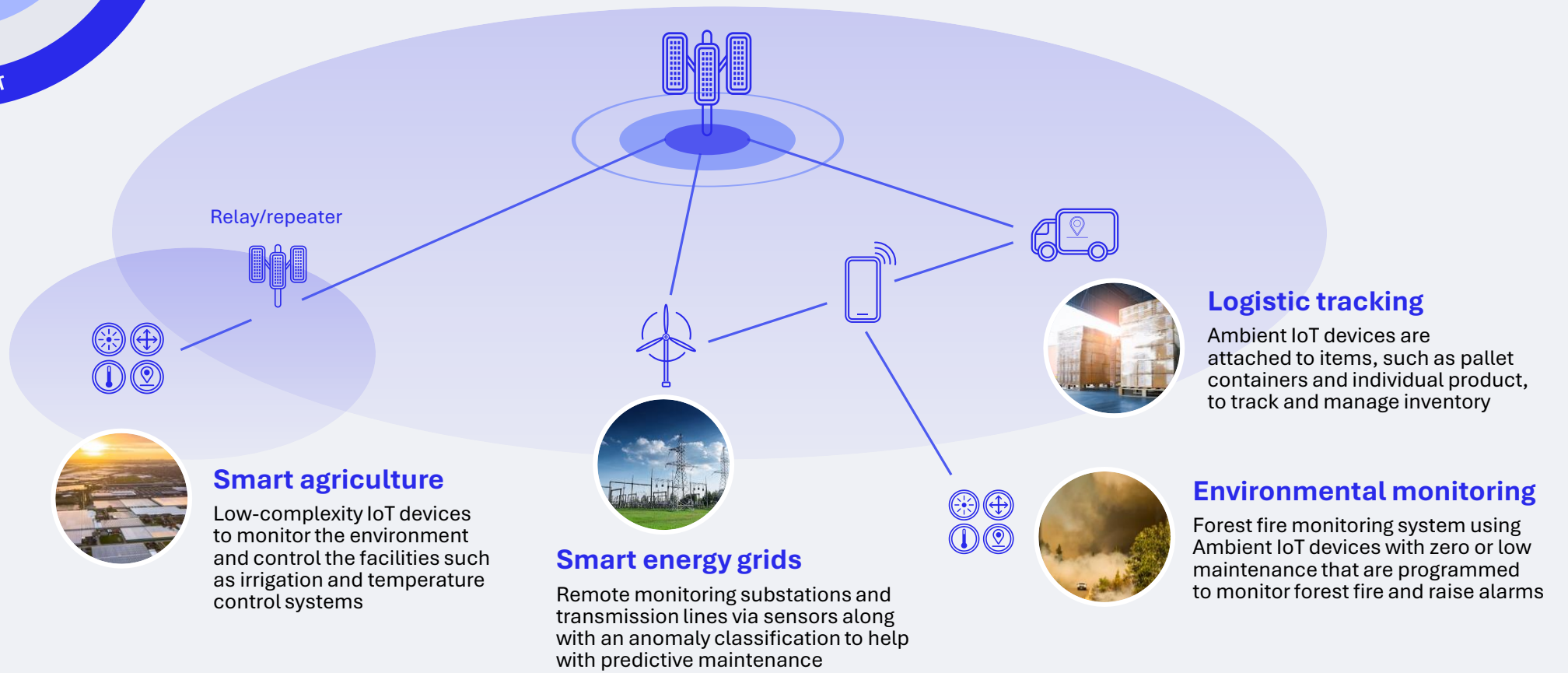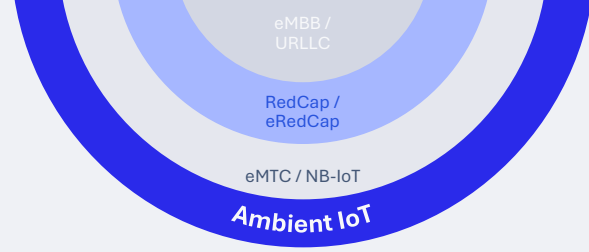
Smart agriculture
Low-complexity IoT devices to monitor the environment and control the facilities such as irrigation and temperature control systems

Smart energy grids
Remote monitoring substations and transmission lines via sensors along with an anomaly classification to help with predictive maintenance

Environmental monitoring
Forest fire monitoring system using Ambient IoT devices with zero or low maintenance that are programmed to monitor forest fire and raise alarms

Release 18 RAN Plenary Study Item to enable standardization in Release 19+

A harmonized air interface design to enable ambient IoT devices

1 — 100's µW peak power with or without energy storage, DL/UL amplification, UL backscattered or generated by device

Sub-7 GHz FDD for in-band to 5G NR, in guard-band to LTE/5G NR, or stand-alone

For device-terminated (DT), device-originated, device-terminated triggered (DO-DTT)

Expanding 5G sidelink capabilities in Release 18

For public safety, IoT, commercial use cases and beyond

Sidelink enhancements

Unlicensed spectrum

Optimized sidelink operations in unlicensed 5 and 6 GHz bands

Multi-beam operation

Studying sidelink beam management by reusing and enhancing existing framework and concepts

Sidelink carrier aggregation

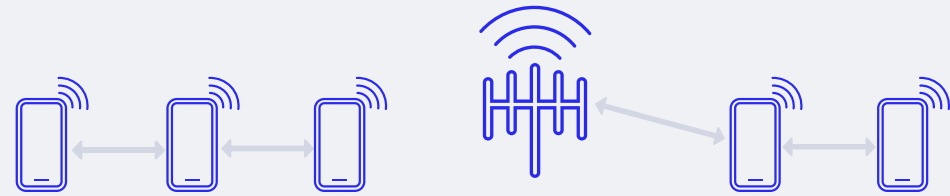With only intra-band aggregation for use cases that can benefit from wider bandwidths

Co-channel coexistence

For LTE and 5G NR sidelink in the same channel of 15/30 kHz subcarrier spacing

Sidelink relay enhancements

Device-to-device relay

Single-hop relay for unicast with forward compatibility for more hops

Service continuity enhancements

Device-to-network relay with inter-gNodeB device mobility and intra-gNodeB indirect-to-indirect path switching

Multi-path relay

Aggregation or switching between direct and indirectly relayed path for enhanced reliability and throughput

Pushing forward with the 5G positioning technologies

5G POSITIONING EVOLUTION

5G Advanced in Release 18
Improving performance, expanding to new devices and deployments

Release 16

Accuracy of 3m/10m (indoor/outdoor)

RTT[1], AoA/AoD[2], TDOA[3], single-cell positioning

Evaluation scenarios for IIoT

Release 17

Centimeter-level absolute accuracy of down to 0.3m

Positioning latency as low as 10 ms
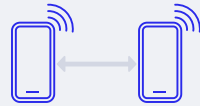
Higher capacity for millions of simultaneous devices

Improved positioning performance

PRS/SRS bandwidth aggregation across 3 intra-band contiguous carriers

DL/UL carrier phase positioning (CPP) for device-based / assisted, and network-assisted positioning with existing PRS/SRS

Sidelink positioning and ranging

AoA & TDOA with up to 100 MHz bandwidth in licensed & ITS spectrum

Unicast, groupcast, broadcast with Tx power control of sidelink PRS

Sidelink-only & network + sidelink coverage

Service authorization

RedCap device positioning

PRS/SRS frequency hopping beyond maximum RedCap bandwidth for Tx/Rx

RRM requirements for positioning with/without frequency hopping

Low-power, high-accuracy positioning

>10.24s of eDRX cycle in inactive mode

SRS config enhancements for UL- & DL/UL-based methods

PRS measurements in idle mode and reporting in connected mode

PRS and eDRX configuration alignment in inactive mode

Integrity for RAT dependent positioning

Error modeling parameters, signaling and procedures for device-based and network-based positioning methods

Continued enhancements to 5G satellite communications

5G Non-Terrestrial Network (NTN) in 5G Advanced Release 18

5G NR for NTN

Broadband service complementing terrestrial networks in underserved areas

Coverage enhancements for voice and low-data rate services, including HARQ-ACK[1] repetition and DMRS[2] bundling with pre-compensation

Deployment in 10+ GHz bands (i.e., Ka band in n510, n511 and n512) and support for VSAT[3]/ESIM[4]

Network verified device location based on multi-RTT[5] with single satellite measurements across time

Mobility and service continuity enhancements for NTN-TN & NTN-NTN
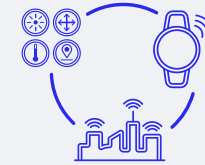
5G IoT for NTN

Low data rate service expanding addressable market for the 5G massive IoT

Enhanced GNSS[6] operation for long connections and reduced power consumption and HARQ feedback disabling

Improved radio link failure triggering and extending of NTN mobility features to eMTC[7]

Discontinuous coverage with enhanced mobility management and power saving

5G drones are getting ready to take off

Release 18 work leverages the drone communication foundation in LTE Advanced Pro

Measurement reporting enhancements

- Device-triggered measurement report (height, location, speed)
- Flight path reporting
- Based on a configured number of cells fulfilling the triggering criteria simultaneously

Defining drone device type and out-of-band emission interference requirement in specified bands

- 1710-1785 MHz
- 2500-2570 MHz
- 2570-2620 MHz

Support for drone broadcast remote identification (BRID) and detect and avoid (DAA) using sidelink in designated spectrum

Signaling to support subscription-based drone identification and capability indication (e.g., Rel-18 enhancements and altitude event triggers)

5G Multicast Broadcast

Release 18
Work Item
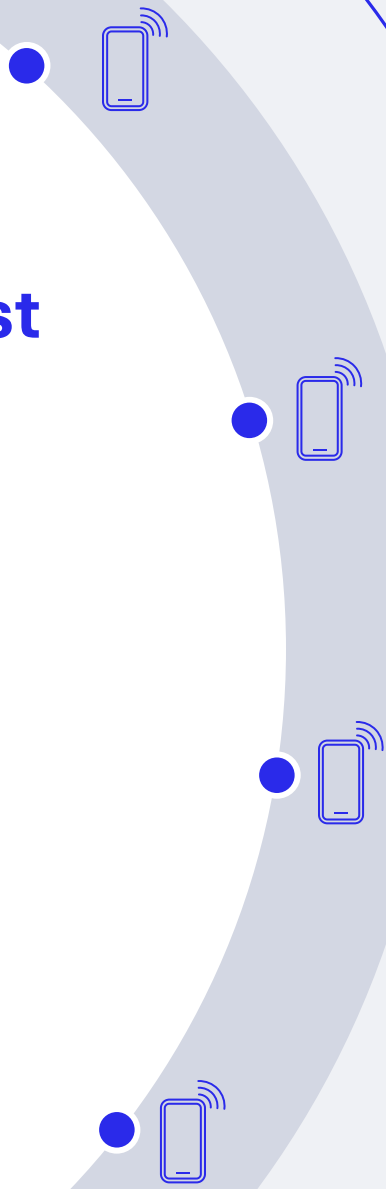
Continued enhancement to 5G multicast / broadcast

Multicast reception by devices in RRC Inactive mode
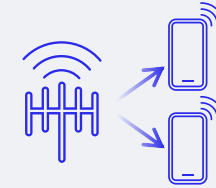
Signaling enhancements to allow shared processing between unicast and multicast / broadcast with the same or different operator

Enhanced resource efficiency for multicast / broadcast reception in RAN sharing scenarios

5G ADVANCED

Establishing the technical foundation for 6G

A Rich Roadmap of **5G** Technology Evolution

Rel 15
Established 5G NR technology foundation

5G

- eMBB — enhanced mobile broadband services
- 5G core network and enhanced E2E security
- Sub-6 GHz with massive MIMO
- Advanced channel coding
- 5G broadcast
- Scalable OFDM-based air interface
- Mobile mmWave
- Flexible framework
- LTE integration

Rel 16
Expanding to new use cases and industries

- 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

~1.5–2 years between releases

Rel 17
Continued expansion and enhancements

- 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

Rel 18
New wave of 5G innovations in the decade-long 5G evolution

5G Advanced

- 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

Rel 19
Realizing the full potential of 5G and bridging to 6G

- 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

Rel 20

Rel 21+

6G

32

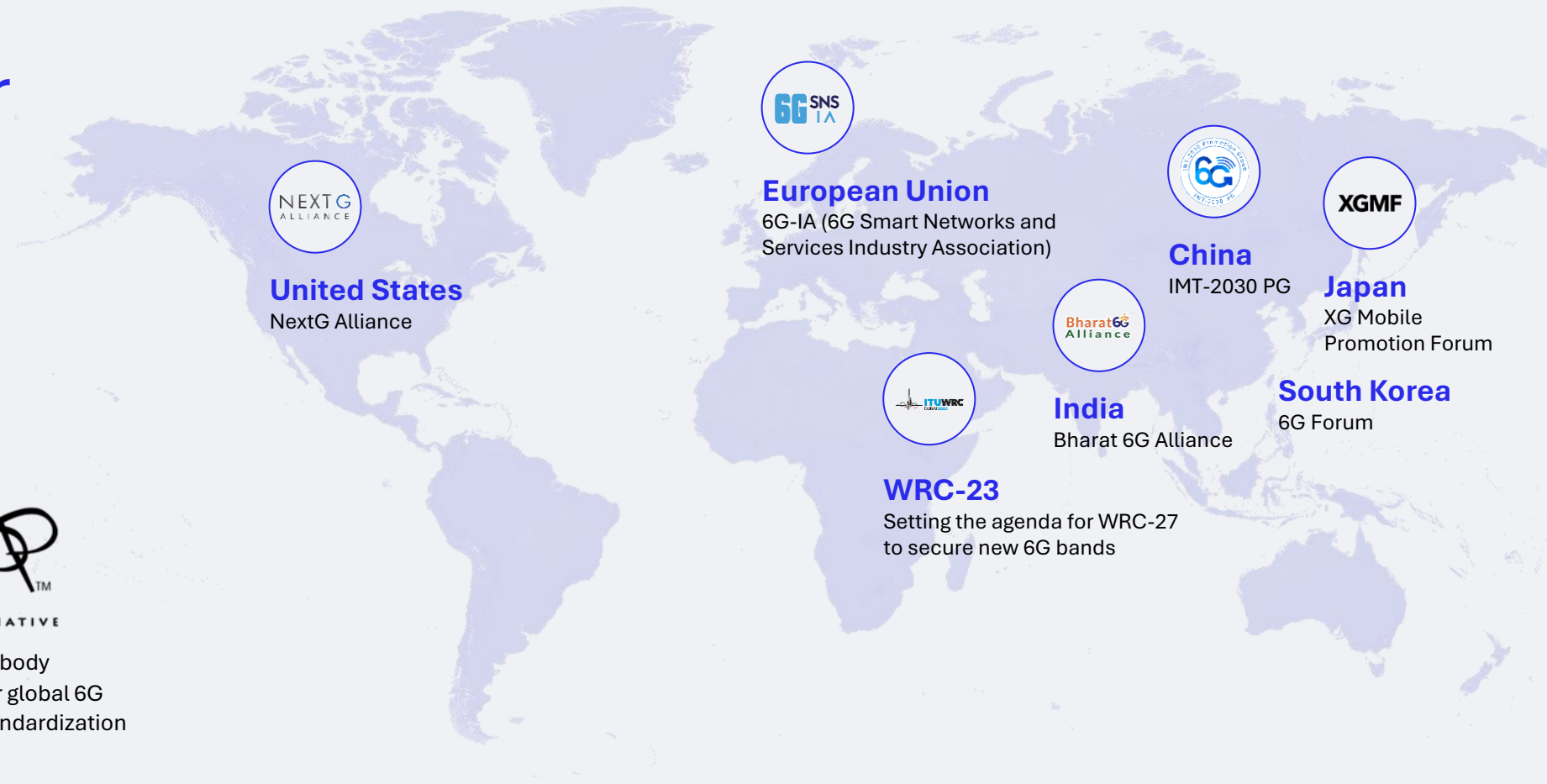# Global Momentum for 6G is growing

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

ITU

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

3GPP
A GLOBAL INITIATIVE

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)

6G IMT-2030

China
IMT-2030 PG

XGMF

Japan
XG Mobile Promotion Forum

Bharat 6G Alliance

India
Bharat 6G Alliance

South Korea
6G Forum

ITU WRC

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

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CONTINUED TECHNOLOGY EVOLUTION

KEY MARKET TRENDS
AND TECHNOLOGY DRIVERS

Leading the way to 6G
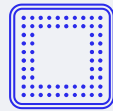
Core technology advancements

Environmental and societal sustainability

Enhanced and new experiences

Fixed and mobile broadband evolution

Critical services expansion

Collaborative robots, real-time command and control

Hologram telepresence

Ultra-wide area to micro connectivity

Smarter verticals

Enhanced boundless XR experiences

Wireless sensor fusion

Human augmentation and digital twins

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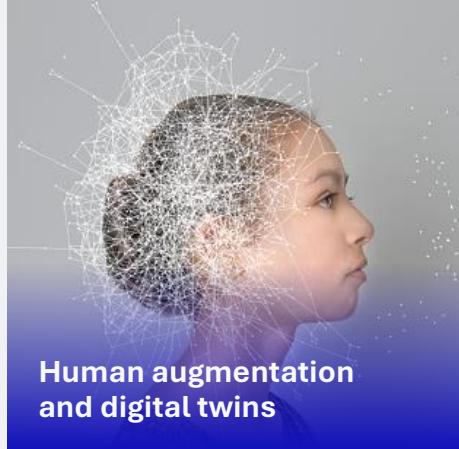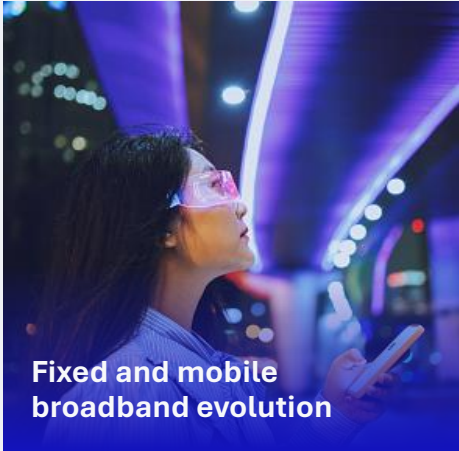
Propelling next-level experiences and innovative use cases in the new era of the connected intelligent edge for 2030 and beyond

6G vision from ITU-R — Usage scenarios and capabilities

Enhanced Capabilities

Security resilience

Reliability
- 5G: $1-10^{-5}$
- 6G: ↑ $1-10^{-5} - 1-10^{-7}$

Latency
- 5G: 1
- 6G: ↓ $0.1 - 1$ ms

Mobility
- 5G: 500
- 6G: ↑ $500 - 1,000$ km/h

Connection density
- 5G: 10^6
- 6G: ↑ $10^6 - 10^8$ devices/km²

Area traffic capacity

Spectrum efficiency

User experience data rate

Peak data rate
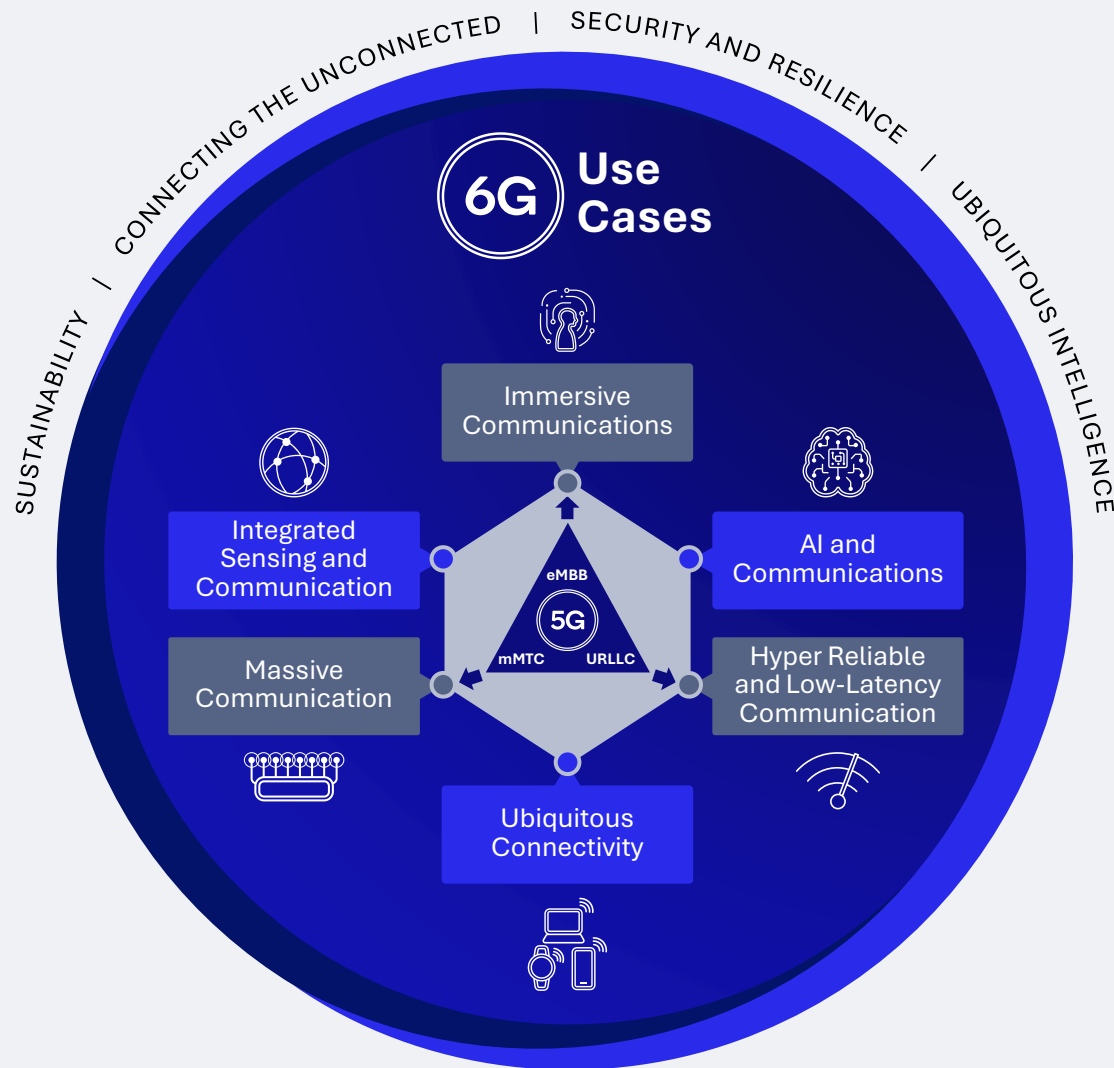
Capabilities

New Capabilities
- Coverage
- Sensing-related capabilities
- AI-related capabilities
- Sustainability
- Interoperability
- Positioning (1-10 cm)

6G Use Cases
- Immersive Communications
- AI and Communications
- Hyper Reliable and Low-Latency Communication
- Ubiquitous Connectivity
- Massive Communication
- Integrated Sensing and Communication

5G: eMBB, mMTC, URLLC

SUSTAINABILITY | CONNECTING THE UNCONNECTED | SECURITY AND RESILIENCE | UBIQUITOUS INTELLIGENCE

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

Expanding into new spectrum bands

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

Merging of worlds

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

Scalable network architecture

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

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

Communications resiliency

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

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Driving Technology Innovation on the Path to 6G

At Mobile World Congress Barcelona 2024

5G Advanced

6G

Foundational Wireless Innovations

Advanced mmWave Deployment

Multi-user MIMO, enhanced mobility, WAB, IS, RIS, simple repeater, NCR

Wireless AI Interoperability

Cross-node channel feedback
Nokia collab.

AI-enabled Beam Management

Device-side spatial-domain beam prediction

Giga-MIMO System Enabling Upper Midband

World's First Giga-MIMO antenna prototype operating at 13 GHz

Digital Twin Network

Precise network coverage validation, mobility, capacity planning

On the Path to Sub-THz

Single-to-multi-point, data center comm., multi-object sensing

5G Beyond Mobile Broadband

Advanced Automotive Connectivity

Large-scale VRU alerts OTA
Coverage prediction

Boundless eXtended Reality (XR)

Boundless AR over 5G/Wi-Fi
Hololight collab.

Wide-area IoT RedCap Evolution

Capacity simulation
Low-power wakeup signal

5G from Space (5G NTN)

TN-NTN, NTN-NTN mobility
Ericsson, Keysight collab.

5G Broadcast Readiness

Commercial readiness
Rohde & Schwarz collab.

Thank you

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