Qualcomm @QCOMResearch San Diego, CA January 2024

# What's next in 5G Advanced?

## 3GPP Release 19 is bringing new 5G system capabilities and setting a direction for 6G

1980s

1G

Mobile voice communication

**Analog voice**

AMPS, NMT, TACS

1990s

2G

Efficient voice to reach billions

**Digital voice**

D-AMPS, GSM, IS-95 (CDMA)

2000s

3G

Focus shifts to mobile data

**Wireless Internet**

CDMA2000/EV-DO WCDMA/HSPA+


2010s

4G

Mobile broadband and emerging expansion

**Mobile broadband**

LTE, LTE Advanced, Gigabit LTE

2020s

5G

A unified connectivity platform

**Connected intelligent edge**

5G New Radio

2030s

6G

The next innovation platform

**Next-gen wireless**

AI-native, new spectrum, RF sensing, and many more…

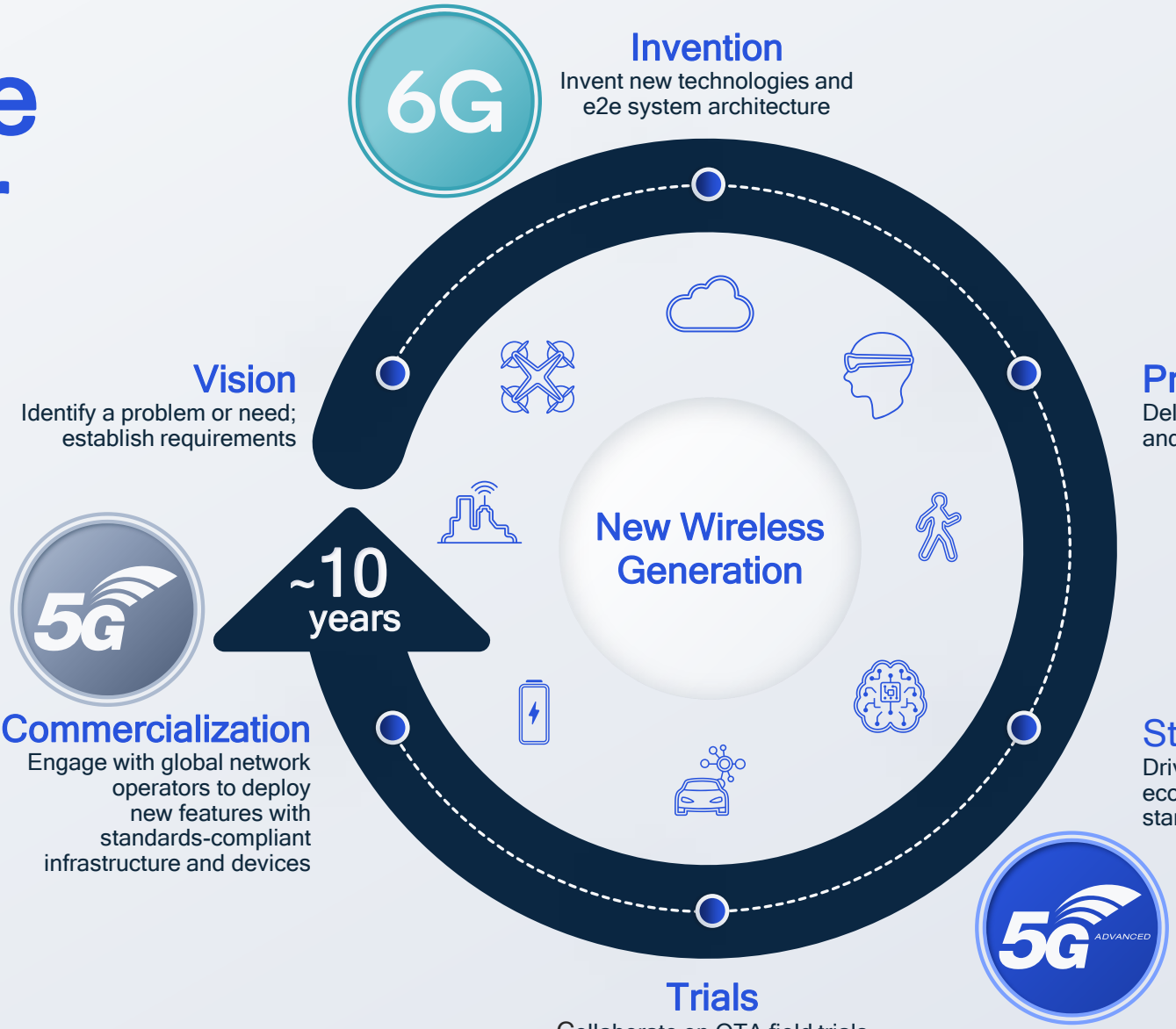
# Mobile has made a leap every ~10 years

# Where are we in the cellular innovation cycle?

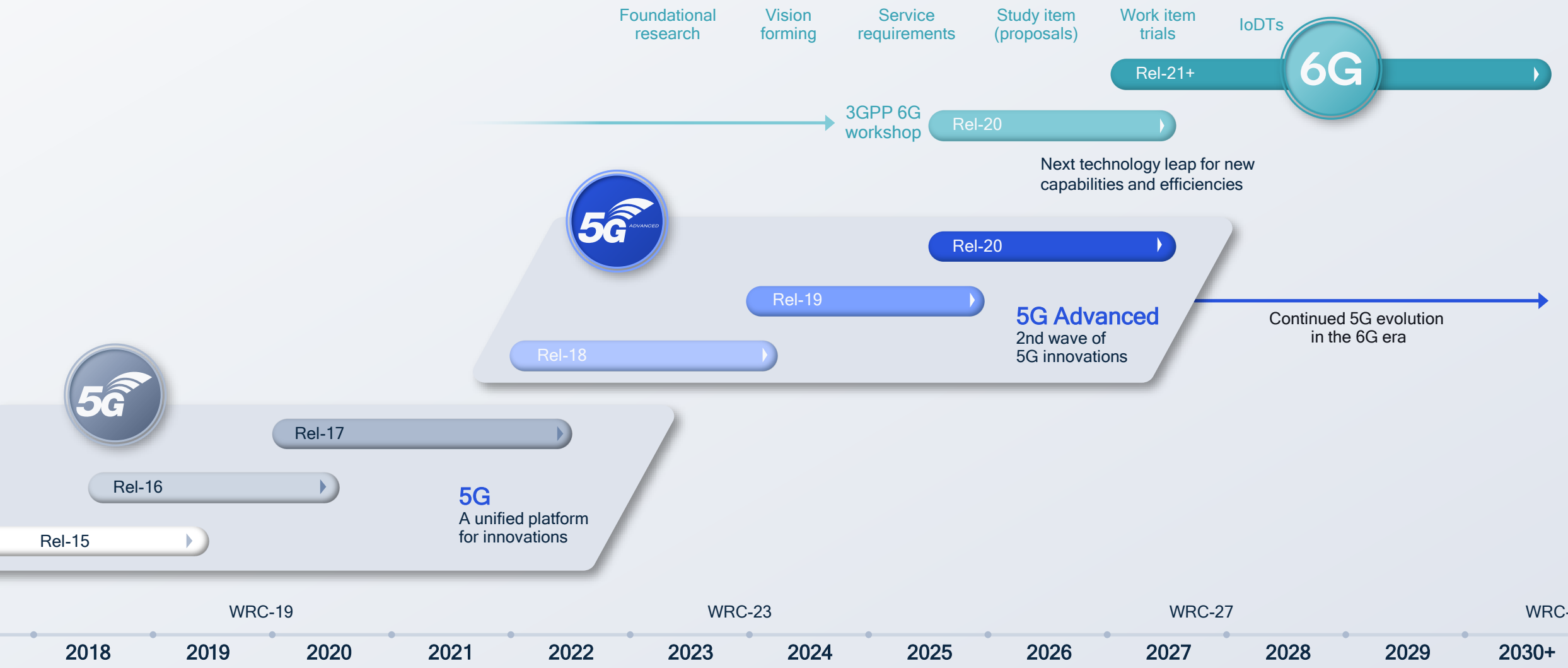
**5G**
Ramping volume and expanding to new use case

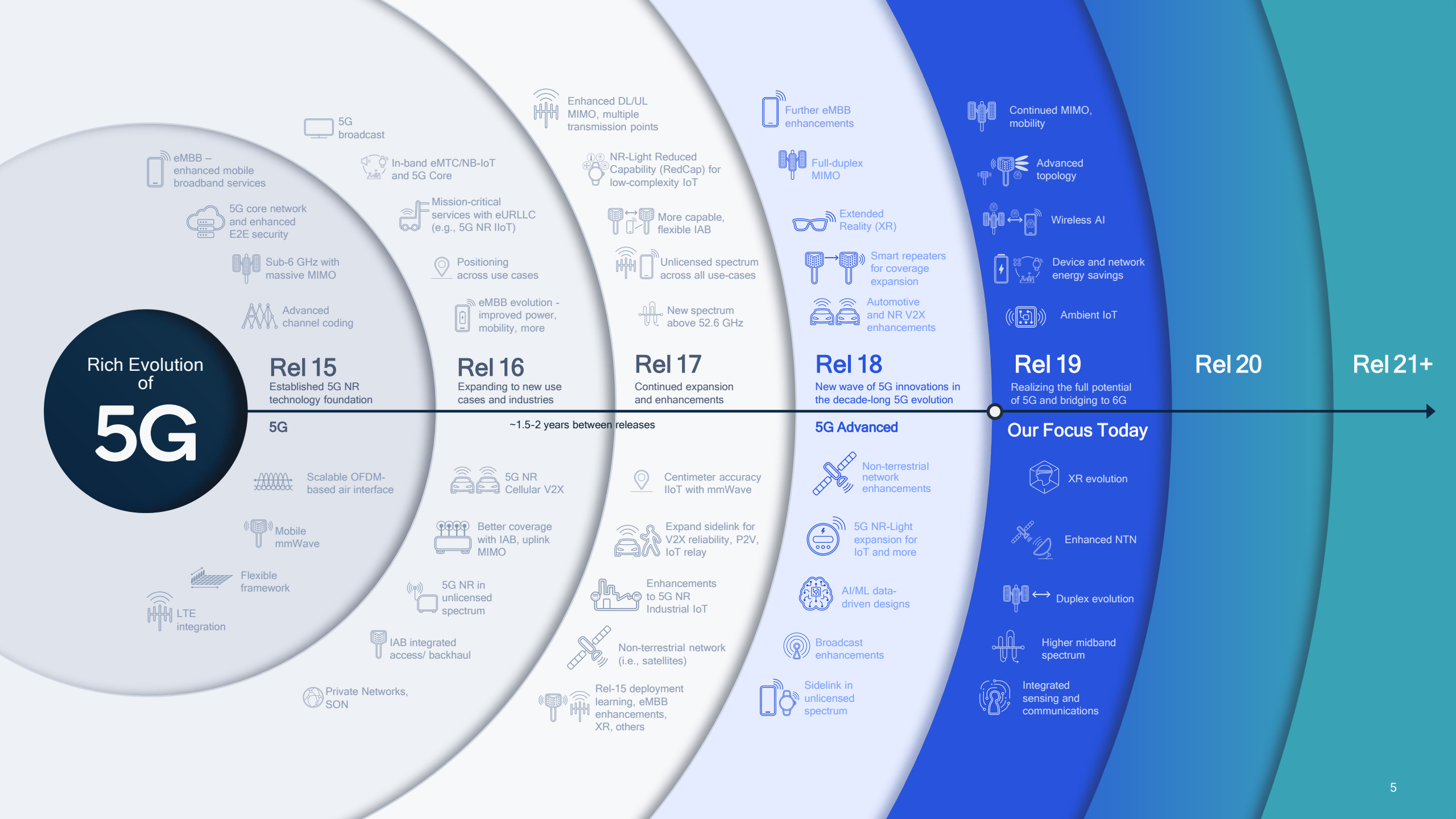
**5G Advanced**
Embarking on the 2nd phase of 5G innovations

**6G**
Aligning on early vision, foundational research, and timeline



# 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

# 5G Advanced Release 19 focus areas

3GPP Release 19

## Realizing the full potential of 5G

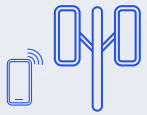
Addressing real and urgent commercial needs

### Mobile broadband evolution and further vertical expansion

Continue to enhance mobile experiences and extend 5G's reach into new areas

### Immediate and longer-term commercial needs

Drive new value in commercialization efforts and efficiently enable advanced deployments



### New and enhanced devices and network evolution

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

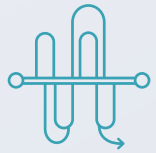
3GPP Release 19

## Bridging to 6G

Establishing the technical foundation

### Revolutionary system innovations

Conduct advanced research to prepare for formal 6G Study Items in Release 20



### New spectrum bands and enabling technologies

Study feasibility of new band ranges and types (e.g., upper mid-band in 7-24 GHz)

5G ADVANCED Release 19

## Continued System Enhancements

DL/U MIMO[1]

Mobility

Topology
(e.g., repeater, sidelink, WAB[2], …)

SON/MDT[3]

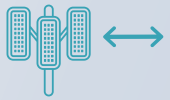
## Further Use Case Diversifications

Ambient IoT

Satellites evolution

XR and metaverse

## New Advanced Capabilities

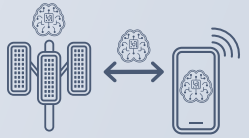


Duplexing evolution

Higher mid-band spectrum
(i.e., 7–16 GHz)

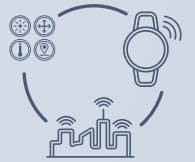
Integrated sensing and communication

## 6G Technical Foundations



Wireless AI/ML

Network energy savings

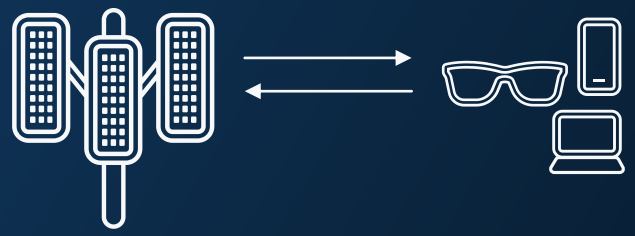


Low-power wakeup receiver

1 Downlink / Uplink Multiple In, Multiple Out; 2 Wireless access/backhaul; 3 Self-organizing network, minimization drive test

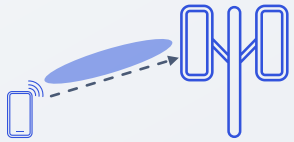
Release 19 Projects

# Delivering continued system enhancements



# Further enhancing 5G MIMO performance

## Continued evolution in 5G Advanced Release 19



### Device-initiated beam management for overhead and latency reduction

With unified TCI while leveraging legacy CSI measurement and reporting configuration frameworks for mmWave & sTRP with intra- and inter-cell beam management

### Channel State Feedback (CSI) framework to support up to 128 CSI-RS ports

Target sub-7 GHz spectrum with enhanced Type I and II codebooks support and hybrid beamforming

### Downlink Coherent Joint Transmission (CJT) multi-TRP enhancements

Target sub-7 GHz FDD and TDD spectrum with under non-ideal synchronization and backhaul for improving device-assisted calibration reporting of delay and offsets

### Improved uplink performance

Enhance simultaneous transmission across multiple panels (e.g., 3Tx UL), without enhancement on uplink full power transmission nor enhancement on SRS resource

### Enhanced asymmetric downlink / uplink

Support improved single-TRP downlink and multi-TRP uplink, assuming intra-band/DU non-co-located mTRP, unified TCI framework, fully reusing legacy spatial relation rules

Source: RP-234007 (NR MIMO Phase 5)

# Continued 5G device mobility enhancements


## Support for inter-CU Layer 2 mobility

Prioritize practical deployment scenarios, e.g., for when the CU acts as the master node (MN) and secondary node (SN) for NR-DC

## Enhanced measurements for Layer 2 mobility

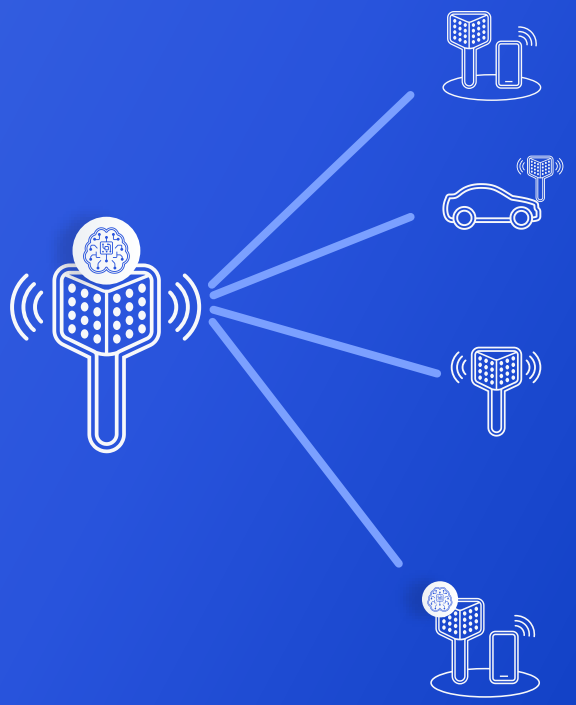
Support event-triggered L1 measurement reporting and CSI-RS based measurement for Layer 2 mobility

## Conditional mobility with short interruption

Specify device evaluated condition to trigger low-layer triggered mobility (LTM), project to prioritize intra-CU LTM

Source: RP-234036 (NR mobility enhancements Phase 4)

## Release 19 to also study wireless AI for device mobility enhancements



# Advanced 5G topology enhancements

## Wireless Access / Backhaul (WAB)

Study architecture and protocol stack of supporting a gNodeB with mobile termination (MT) function providing packet data unit (PDU) session backhaul

Study impact of WAB mobility within an existing radio access network (e.g., inter-gNodeB neighbor relations)

Identify necessary inter-gNodeB and gNodeB to core network signaling to address the support of WAB

Study signaling enhancements on resource multiplexing for WAB

## 5G Femto-cell

Study the overall RAN architecture and required functional and procedural impacts for supporting 5G femto-cell deployments

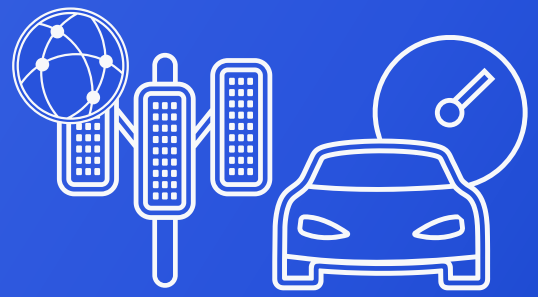
Study how to define the 5G access control mechanism by (re-)using the existing closed access group (CAG) functionality and identify needed enhancements

Clarify the access to local services from the 5G femto-cell via collocated local user plane function and identify issues

## 5G Sidelink

Specification support for multi-hop sidelink relaying operation especially aiming at Public Safety 5G applications

Source: RP-234041 (Additional Topological enhancements);
Source: RP-233998 (SL multi-hop relay);



# Supporting new and enhanced SON and MDT capabilities

5G Advanced Release 19 Work Item to focus on improving Release 17/18 features of commercial interest and technology maturity

## Enhanced mobility robustness optimization (MRO)

Include lower layer triggered mobility (LTM), and conditional handover (CHO) with candidate SCGs[1], subsequent CPAC[2]

Specify inter-node information exchange, including possible interface enhancements

Identify and specify necessary device reporting to enhance mobility parameter tuning

## Enhanced SON/MDT for new services

Focus on new services including intra-non-terrestrial (NTN) network mobility and network slicing

## Remaining work from Release 18

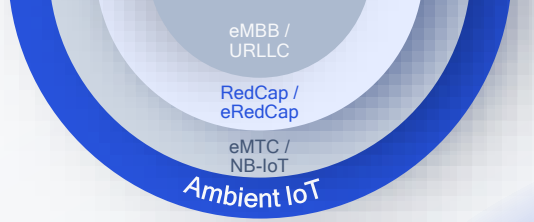
Include random access channel optimization for small data transmission, MHI[3] enhancement for SCG (de)activation, and MRO for MR-DC[4] SCG failure

1 Secondary Cell Groups; 2 Conditional PSCell Addition and Change; 3 Modem host interface; 4 Multi-radio access technology dual connectivity

Source: RP-234038 (SON/MDT for NR/MR-DC Phase 4)

Release 19 Projects

# Driving 5G use case diversifications







## 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



## Logistic tracking

Ambient IoT devices are attached to items, such as pallet containers and individual product, to track and manage inventory



## 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

# Ambient IoT enables diverse use cases that require devices with zero or low maintenance capabilities

Flexible architecture supporting direct and/or indirect device connectivity

# Ambient IoT to further scale down and expand the reach of 5G IoT

## Release 19

### A “Full Stack” Study Item across RAN and SA working groups

with possibility of a conversion into a Work Item within the release

Evaluate assumptions of the study, including deployment scenarios, connectivity topologies, spectrum options, design targets, device architecture, link budget, and coexistence considerations

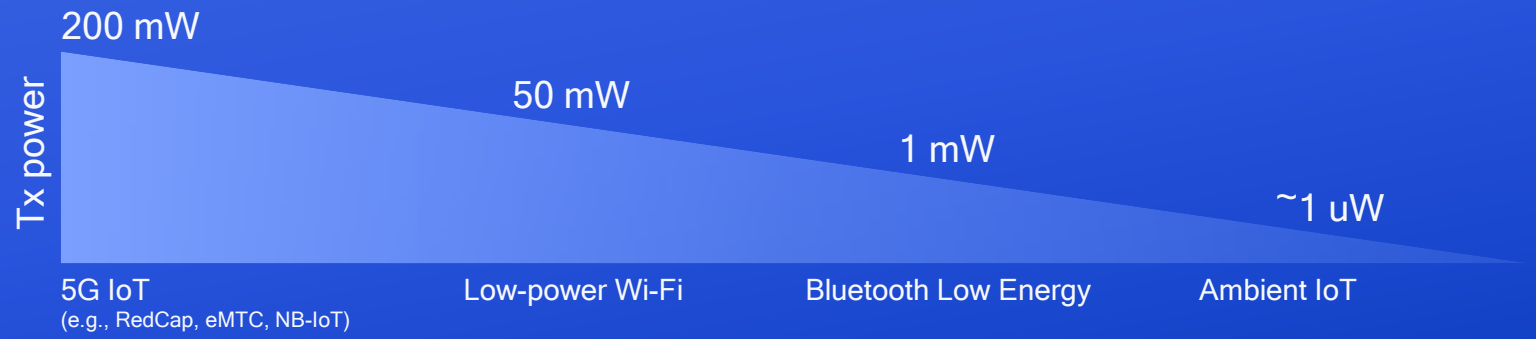
Study ambient IoT design feasibilities across RAN working groups:

**RAN 1:** study air interface design including frame structure, synchronization, timing, random access, numerologies, bandwidths, multiple access, waveforms, modulations, channel coding, …

**RAN 2:** study and decide what’s needed for a compact protocol stack and lightweight signaling procedure including paging, random access, data transmission, upper layer interactions, …

**RAN 3:** identify necessary impacts on CN-RAN interface signaling/procedures to enable paging, device context management, data transport; identify RAN architecture aspects and how to locate an ambient IoT device

**RAN 4:** study coexistence with 5G NR/LTE and RF requirements




Source: RP-234058 (Ambient IoT)

## A harmonized air interface design to enable ambient IoT devices…

From 1 to 100’s µW peak power with energy storage, with or without downlink and uplink amplification, uplink backscattered or generated internally by device

Target 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)

# Delivering enhanced XR experiences over 5G

5G Advanced Release 19 targets to further improve system efficiency and user experiences

## Multi-modality

Enhance intra-device multi-modal flows (i.e., coordinated and synchronized transmissions of different traffic types – video, audio, sensor, etc.), to meet XR QoS requirements (i.e., improved capacity or power consumption)

## Improved scheduling

Enable transmissions and receptions during RRM measurement gaps and scheduling restrictions; for uplink, utilize delay/deadline information to improve XR capacity

## Enhanced user plane

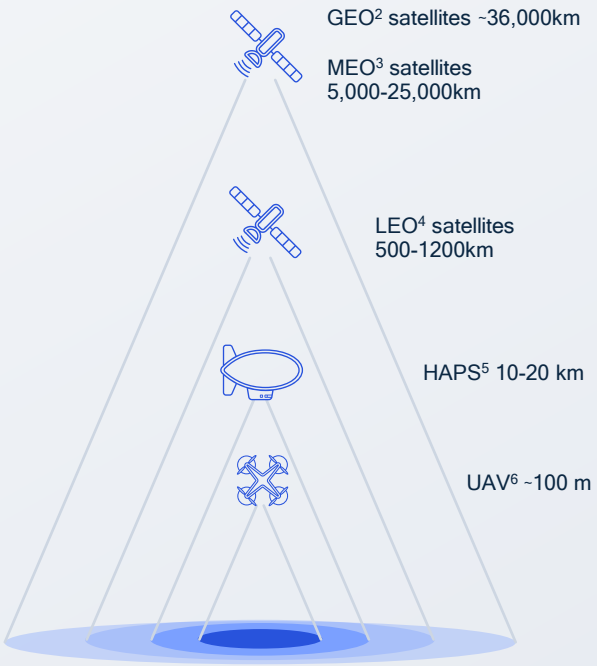
Improve RLC retransmission in Acknowledged Mode (AM) with small packet delay budget, as well as specify a mechanism for transmitter to inform the receiver of SN gap in PDCP

Source: RP-234080 (XR (eXtended Reality) for NR Phase 3)

ADVANCING

# 5G NTN

Release 19 further enhances NR-NTN for ubiquitous broadband access and IoT-NTN for global IoT connectivity




## 5G NR-NTN

Complementing terrestrial networks in underserved areas

- Enhanced downlink coverage (e.g., additional reference satellite payload parameters)
- Regenerative payload with full gNodeB
- Improved uplink capacity and throughput
- 5G RedCap and eRedCap devices support
- Signaling of intended service area for 5G broadcast

## 5G IoT-NTN

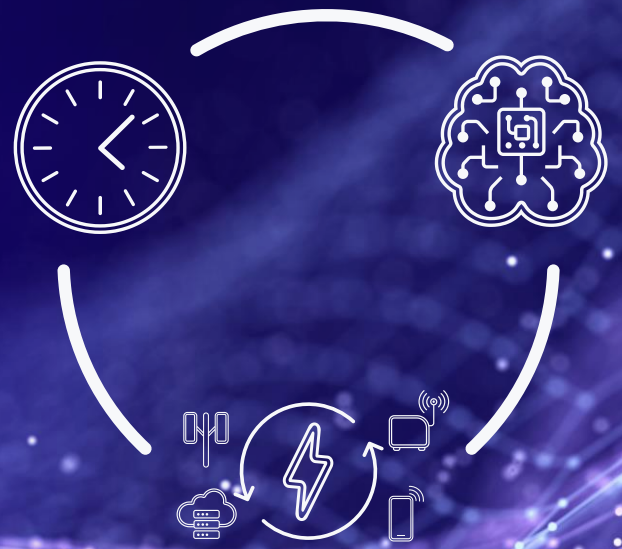
Expanding addressable market for the 5G massive IoT

- Store and forward of data packets with full eNodeB as regenerative payload
- Uplink capacity enhancements (e.g., increased multiplexing within same time/frequency resources, signaling reduction)

Source: RP-234078 (NTN for NR Phase 3); RP-234077 (NTN for IOT Phase 3)

Release 19 Projects

# Supporting new advanced 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

# Applying AI to solve difficult wireless challenges

Deep wireless domain knowledge is required to optimally use AI capabilities

A KEY PILLAR OF THE
5G ADVANCED ERA

# Wireless AI

3 projects in Release 19

## Study on AI/ML for Next-Gen Radio Access Network[1]

New use cases including network slicing and coverage and capacity optimization (CCO)

Continued studies on mobility optimization for NR-DC, split architecture support, enhanced energy saving, continuous MDT, and multi-hop device trajectory

## Study on AI/ML to enhance 5G NR mobility[2]

Focusing on L3 device mobility, including RRM measurement & event prediction, device assistance information for network-side model, enhanced LCM, evaluation on testability, interoperability, impacts on RRM requirements and performance

1 RAN 3 led; 2 RAN 2 led; 3 RAN 1 led; 4 Continued study with corresponding checkpoints in RAN#105 (Sept '24)

Source: RP-234039 (AI/ML for NR air interface); RP-234054 (Study on AI/ML for NG-RAN); RP-234055 (Study on AI/ML for mobility in NR)

# Work on AI/ML Air Interface[3]

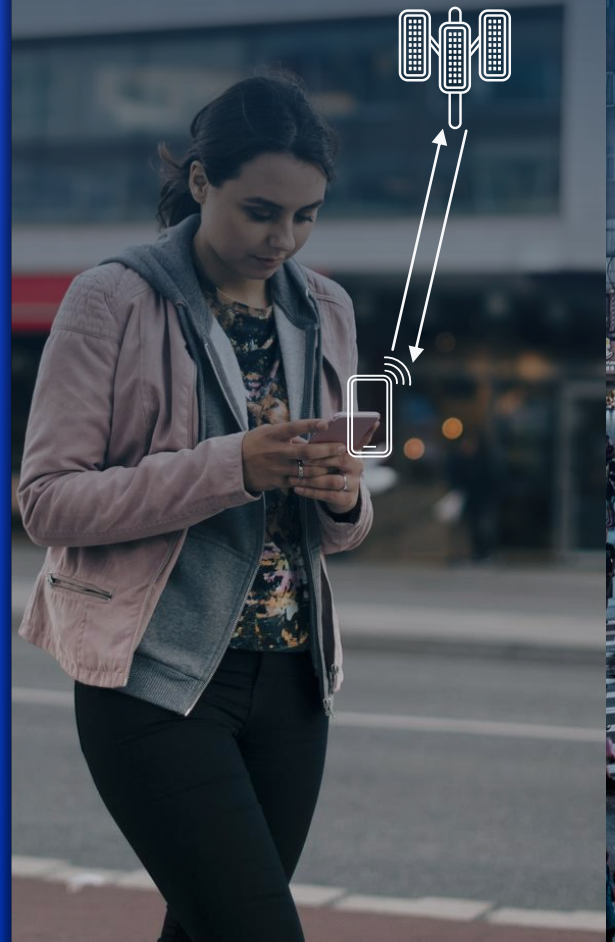
## General Wireless AI Framework

Support Life Cycle Management (LCM) of one-sided (i.e., device or network) AI/ML models

### Channel feedback[4]

Further study 2-sided CSI compression, 1-sided CSI prediction, model transfer/deliver, …

Improve user downlink throughput and reduce uplink overhead



### Beam management

Support device/network-sided beam prediction model in time/spatial domain

Reduce overhead, latency, and improve beam selection accuracy

### Precise positioning

Support single-sided model for both AI-direct and AI-assisted positioning

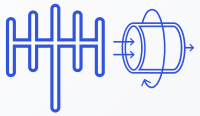
Improve positioning accuracy for different indoor/outdoor scenarios

# 5G Advanced introduces new techniques to improve network energy savings

## Release 19 builds on the study and work completed in Release 18


### On-demand SSB transmission for devices in CONNECTED MODE with intra-/inter-band CA

Specify triggering based on device uplink wake-up signal (WUS), cell on/off indication via backhaul, Scell activation/deactivation signaling



### On-demand SIB1 transmission for devices in IDLE / INACTIVE mode

Study triggering based on uplink WUS

Study WUS configuration provisioning to device

Study information exchange between gNodeBs for the configuration of WUS

### Common signal / channel transmissions

Specify adaptation of PRACH and SSB in time domain (e.g., periodicity)

Study adaptation of PRACH in spatial domain (e.g., non-uniform resources)

Specify adaptation of paging occasions


## Extending power efficiency innovations to the network

1 Analysis is based on the network power model and evaluation methodology defined in TR38.864 for FR1

Source: RP-234065 (Network Energy Savings Enhancements)

# Release 19 begins work on low-power Wake-up Signal / Receiver

Support on-off keying (i.e., OOK-1, OOK-4) with overlaid OFDM sequence(s) over OOK symbol, commonly applicable to both IDLE / INACTIVE and CONNECTED modes

Specify procedures and configurations indicating triggered page monitoring, low-power sync (LP-SS) with periodicity, and further relaxed RRM measurements in IDLE / INACTIVE modes

Specify procedures to allow device PDCCH monitoring triggered by low-power wake-up signal including activation and deactivation procedure in CONNECTED MODE

Design optimization for idle / inactive mode is prioritized over connected mode

## New energy saving design to enable additional efficiency

Suitable for small form-factor IoT devices such as sensors and wearables

Source: RP-234056 (LP-WUS/WUR)

Release 19 Projects

# Establishing the technical foundation for 6G


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

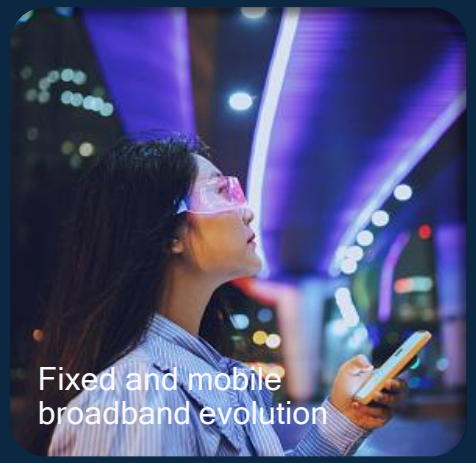
Bharat6G Alliance

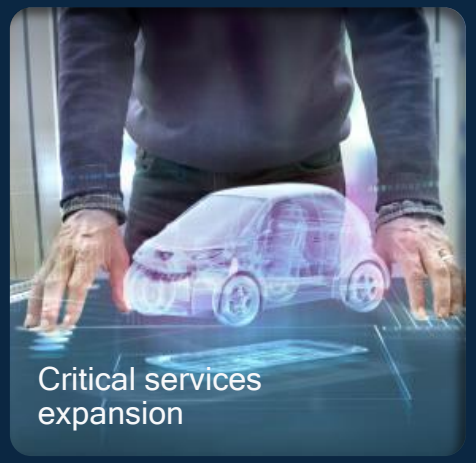
**India**
Bharat 6G Alliance

**South Korea**
6G Forum

ITU WRC DUBAI 2023

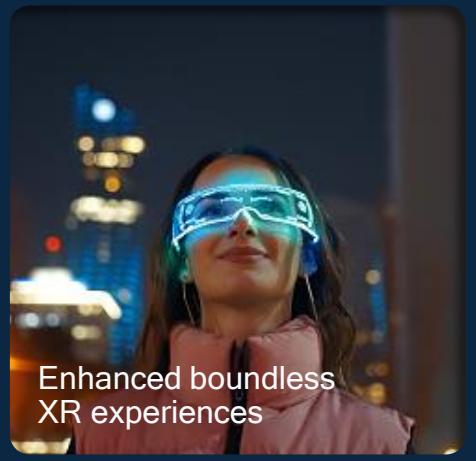
**WRC-23**
Setting the agenda for WRC-27 to secure new 6G bands



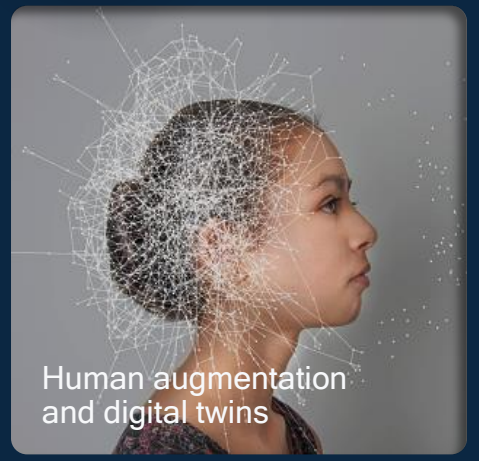



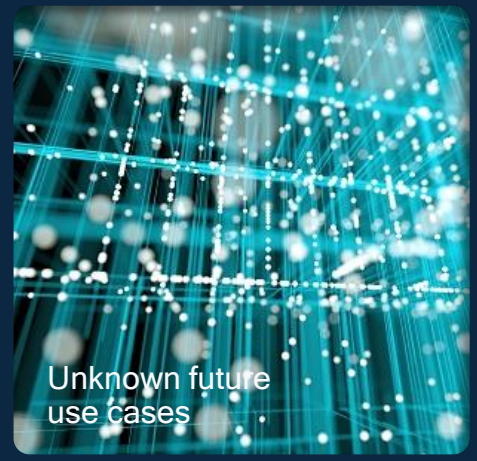









6G

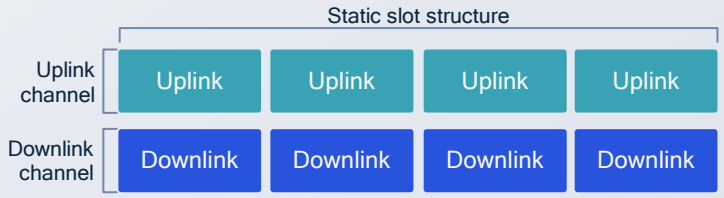
# Propelling next-level experiences and innovative use cases in the new era of the connected intelligent edge for 2030 and beyond

# Evolving towards a full duplex wireless system

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

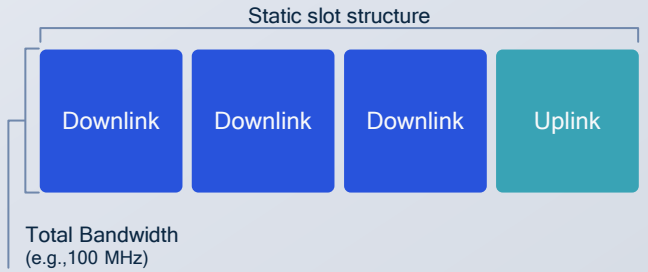
## FDD

Transmit and receive using the same time slot in different frequency channels



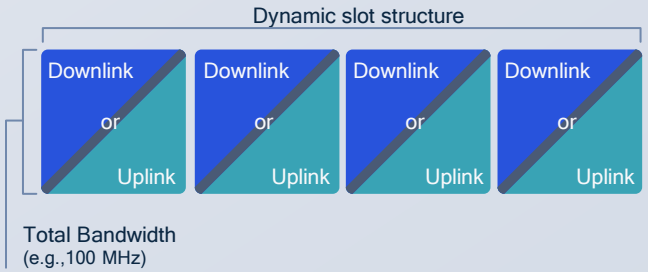

## Static TDD

Transmit and receive using the same frequency channel in different time slots



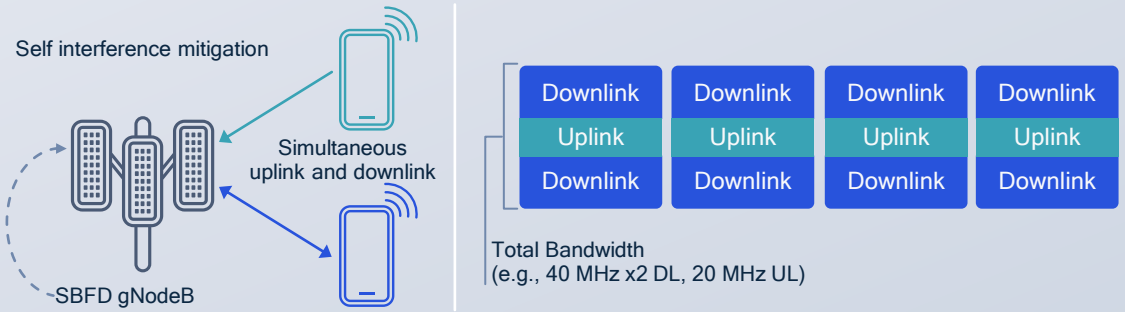

## Dynamic TDD

Transmit and receive can be configured dynamically for all time slots in the same frequency channel



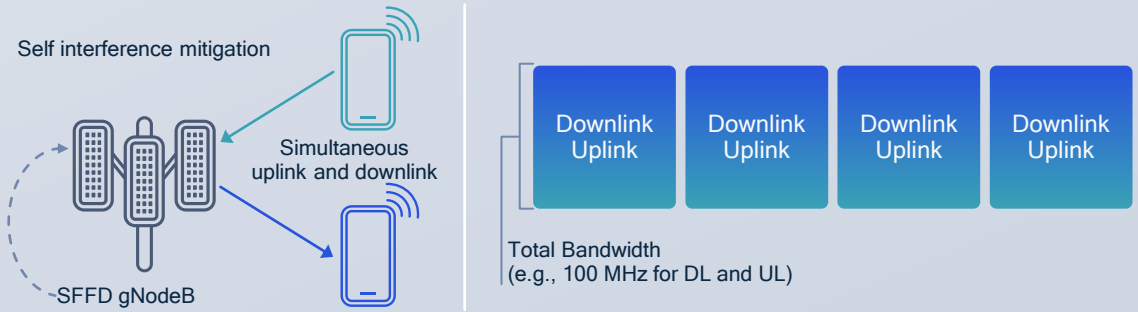

## Subband full duplex

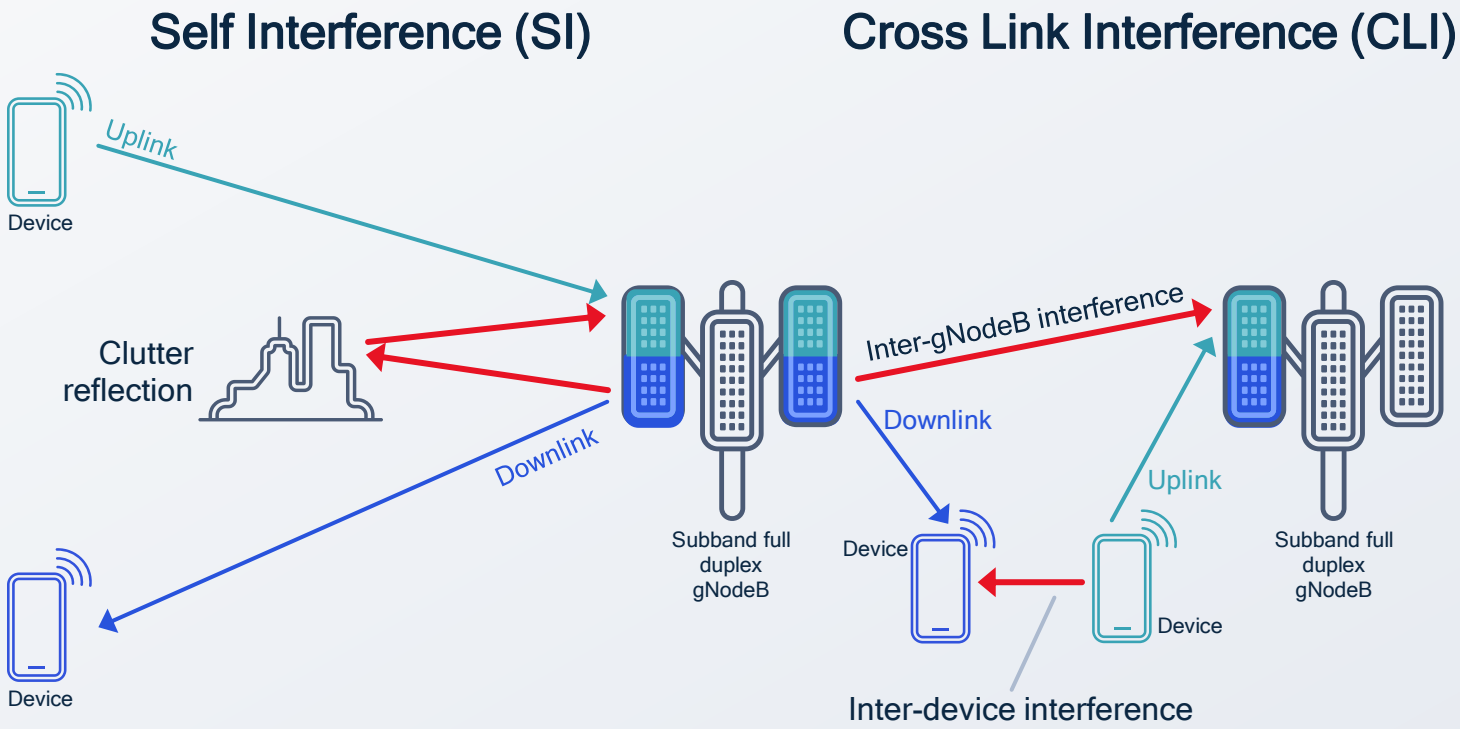
Frequency aligned to avoid inter-site interference; Frequency separation + interference cancellation to avoid self-interference




## Single frequency full duplex

Interference cancellation to avoid self-interference






## Release 19 Work Item Scope

For subband non-overlapping full duplex operation at gNodeB within a TDD carrier:

Specify semi-static indication of time/frequency location of subbands to devices in connected mode

Specify SBFD operation to support random access in SBFD symbols by devices in connected mode

Study and specify, if justified, SBFD operation to device in idle/inactive mode for random access

Specify device transmission, reception, measurement behavior and procedures in SBFD symbols and/or non-SBFD symbols

Specify enhancements for inter-gNodeB/device CLI handling

Specify RF requirements for SBFD operation at gNodeB

Specify RRM core requirements for co-channel CLI handling mechanisms and SBFD operations

# Addressing interferences in a full duplex wireless system

Subband operation allows SI/CLI to be more manageable due to uplink/downlink frequency separation

Source: in RP-234035 (Evolution of NR duplex operation: SBFD)

3GPP Release 19 Study

# Pioneering new spectrum for wireless communications

Focusing on 7–24 GHz that can become the wide-area coverage band for 6G


Wide bandwidths (e.g., 500 MHz) will be key to success of next-generation wireless systems

Studies on new bands need to begin today in preparation for WRC-27 (e.g., focused on 7.1–15.3 GHz range)

## Release 19 Scope

Validate using measurements the channel model of TR38.901 for 7–24 GHz

Adapt and extend, as necessary, the channel model of TR38.901 for at least 7–24 GHz, also include scenarios of near-field propagation and spatial non-stationarity

Source: RP-234018 (Study on channel modelling enhancements for 7-24GHz for NR)

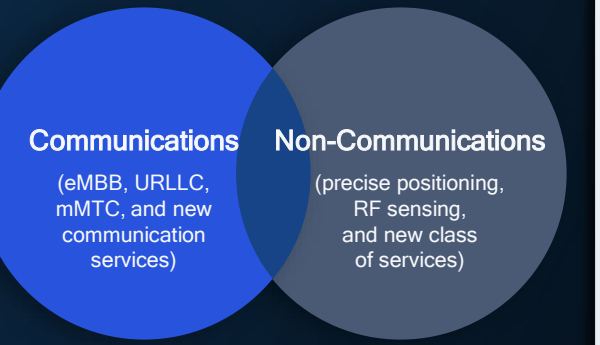
3GPP Release 19 Study

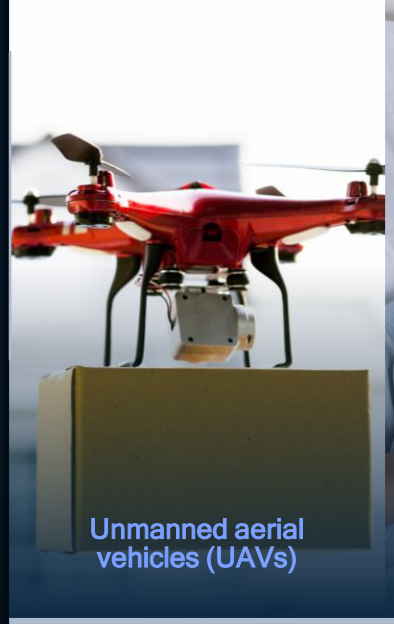
# Channel modeling for integrated sensing and communications

Primary focus on 0.5 – 52.6 GHz, scalable to 100 GHz

Identify deployment details of the selected use cases

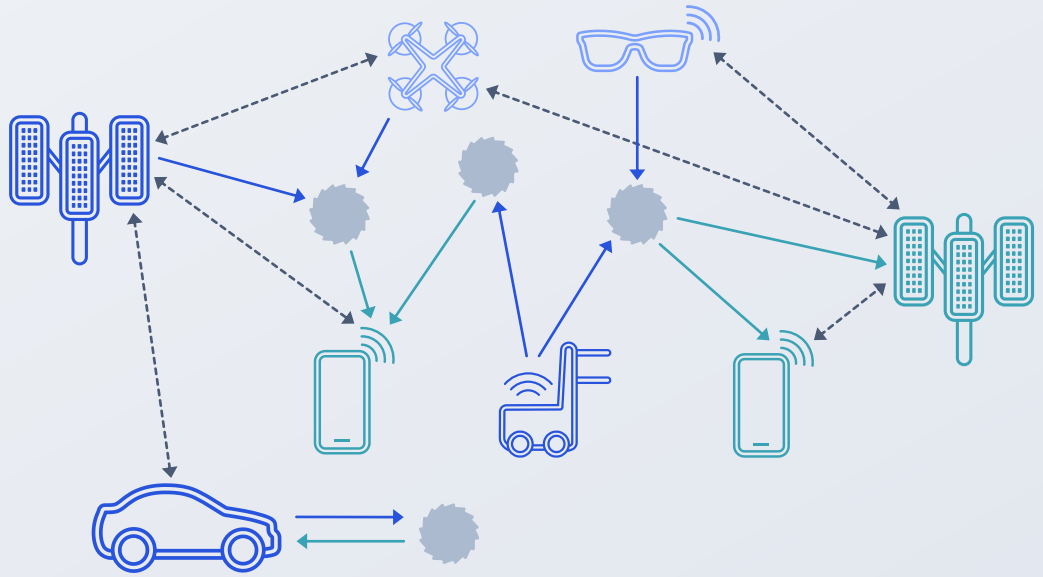
Define channel modelling details, e.g., modelling of sensing targets and background environment (radar cross-section, mobility, clutter/scattering patterns) and spatial consistency

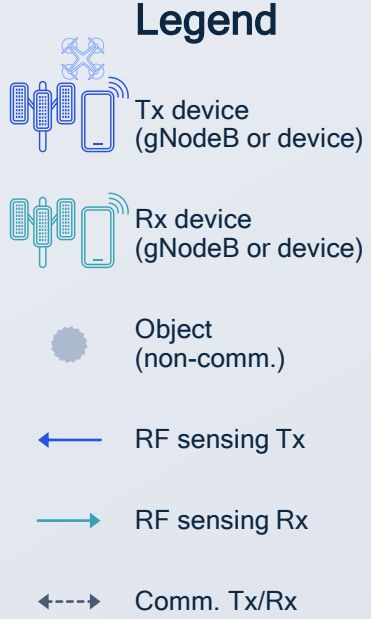









Multiple sensing modes to be evaluated in this study project, including TRP-TRP bistatic, TRP monostatic, TRP-UE bistatic, UE-TRP bistatic, UE-UE bistatic, UE monostatic

Source: RP-234069 (Study on channel modelling for Integrated Sensing And Communication (ISAC) for NR)

Continuing the 5G Advanced evolution with 3GPP Release 19 standardization starting in 2024

Delivering system enhancements and use case diversification building on previous releases

Supporting advanced capabilities and establishing technical foundation that bridges to 6G


# Leading the 5G Advanced Evolution Towards 6G

# Thank you

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