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Standardization of 5G-Advanced and 6G

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@qualcomm
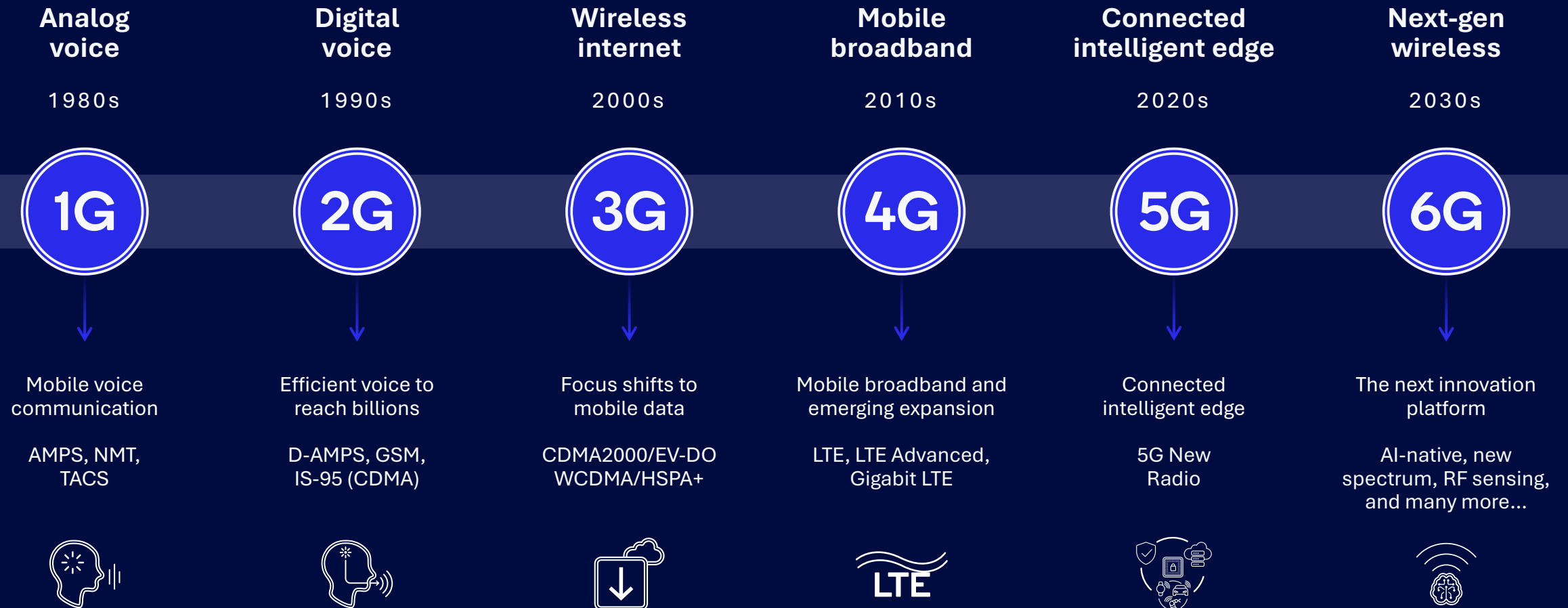
Mobile has made a leap every ~10 years

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...

Where are we in the cellular innovation cycle?
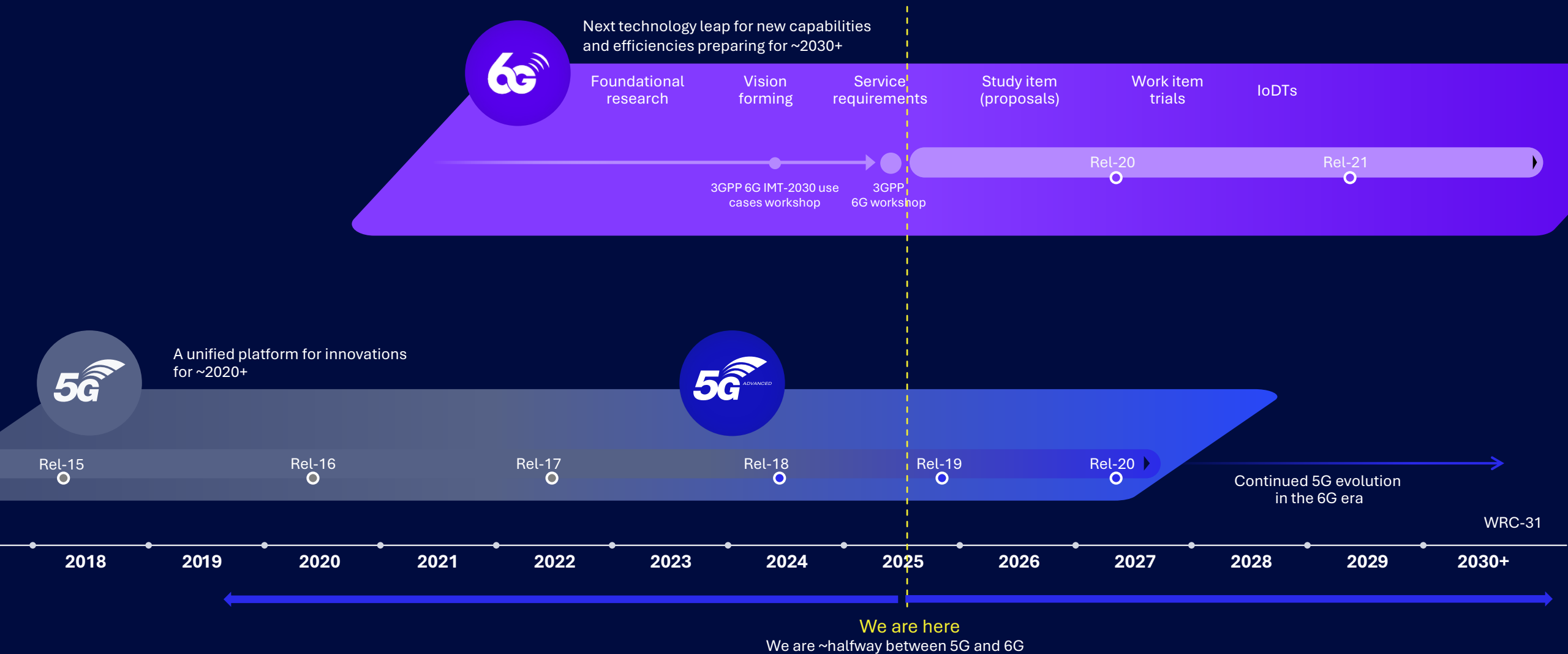
5 G

Ramping volume and expanding to new use case

5 G ADVANCED

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

6 G

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

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

STANDARDIZATION
Drive e2e design with ecosystem and through standards process

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

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On the path to 6G... from 5G and 5G Advanced

6G — Next technology leap for new capabilities and efficiencies preparing for ~2030+

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

3GPP 6G IMT-2030 use cases workshop

3GPP 6G workshop

Rel-20

Rel-21

5G — A unified platform for innovations for ~2020+

5G ADVANCED

Rel-15   Rel-16   Rel-17   Rel-18   Rel-19   Rel-20

Continued 5G evolution in the 6G era

WRC-31

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

We are here
We are ~halfway between 5G and 6G

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Key technology inventions in 5G Advanced Release 18
Leading the innovation pipeline for 5G Advanced and beyond
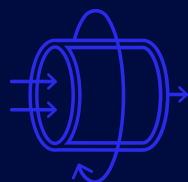
Enhanced Uplink

To optimize device-to-network transmission performance

Enhancements to uplink MIMO, device coverage, mobility, CA power aggregation, and Tx switching

Broadband Evolution

To improve mobile and fixed broadband experiences

Enhancements in MIMO performance, device mobility, DSS, CA enhancements, precise positioning, multi-SIM

IoT Advancement and Expansion

To support new devices and enhanced smart device efficiencies

Improved XR, drone comm., RedCap efficiency, narrowband & sidelink positioning, small data Tx, low-power wakeup receiver

Efficient System Design

To capture energy-saving and flexible deployment opportunities

Network energy saving, network-controlled repeater, full duplex, NR-U sidelink, sidelink relay, mobile IAB, improved NTN, broadcast/multicast

Wireless AI Foundation

To lay the groundwork for intelligently connected networks and devices

Evaluation of ML-based system design and use cases, e.g., channel feedback, beam management, positioning, mobility optimization
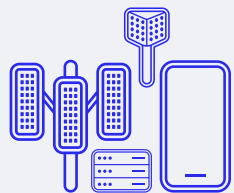
Release 18+
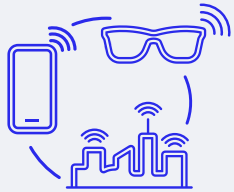
Mobile broadband evolution and further vertical expansion

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
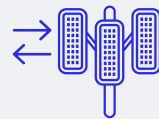
New and enhanced devices and network evolution

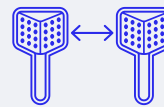Focus on the end-to-end technology evolution of the 5G system to bring new levels of performance

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
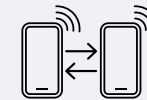
Green networks and devices

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

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
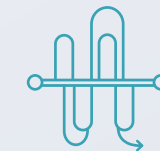
3GPP Release 19
Bridging to 6G
Establishing the technical foundation

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

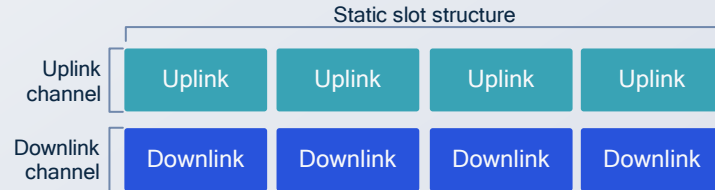| Continued System Enhancements	Further Use Case Diversifications	New Advanced Capabilities	6G Technical Foundations
DL/UL MIMO[1]	Ambient IoT	Wireless AI/ML	Duplexing evolution
Mobility	Satellites evolution	Network energy savings	Higher mid-band spectrum (i.e., 7–16 GHz)
Topology (e.g., repeater, sidelink, WAB[2], …)	XR and metaverse	Low-power wakeup receiver	Integrated sensing and communication
SON/MDT[3]			
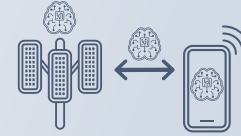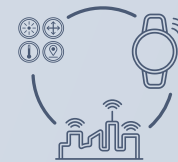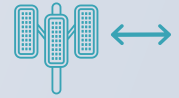
Evolving towards a full duplex wireless system

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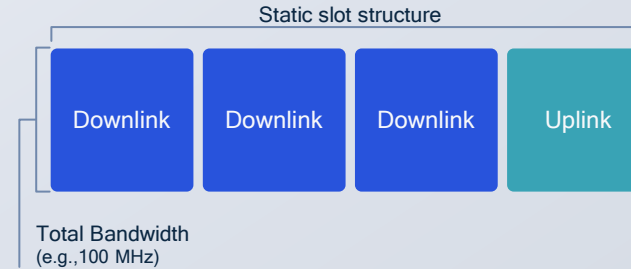
FDD

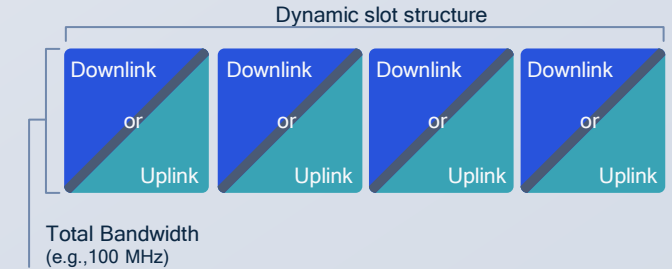Transmit and receive using the same time slot in different frequency channels

Static slot structure

| Uplink channel | Uplink | Uplink | Uplink | Uplink |
| Downlink channel | Downlink | Downlink | Downlink | Downlink |

Static TDD

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

Static slot structure
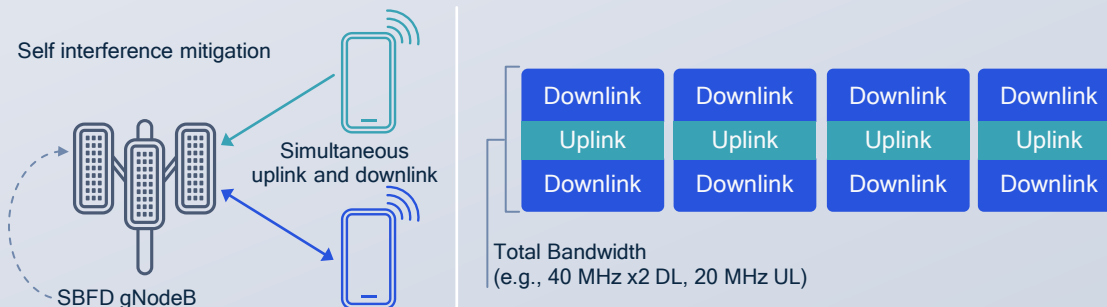
| Downlink | Downlink | Downlink | Uplink |

Total Bandwidth
(e.g.,100 MHz)

Dynamic TDD

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

Dynamic slot structure

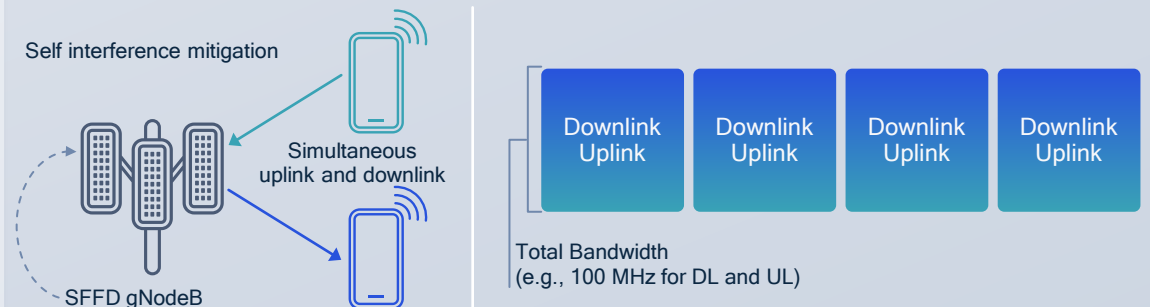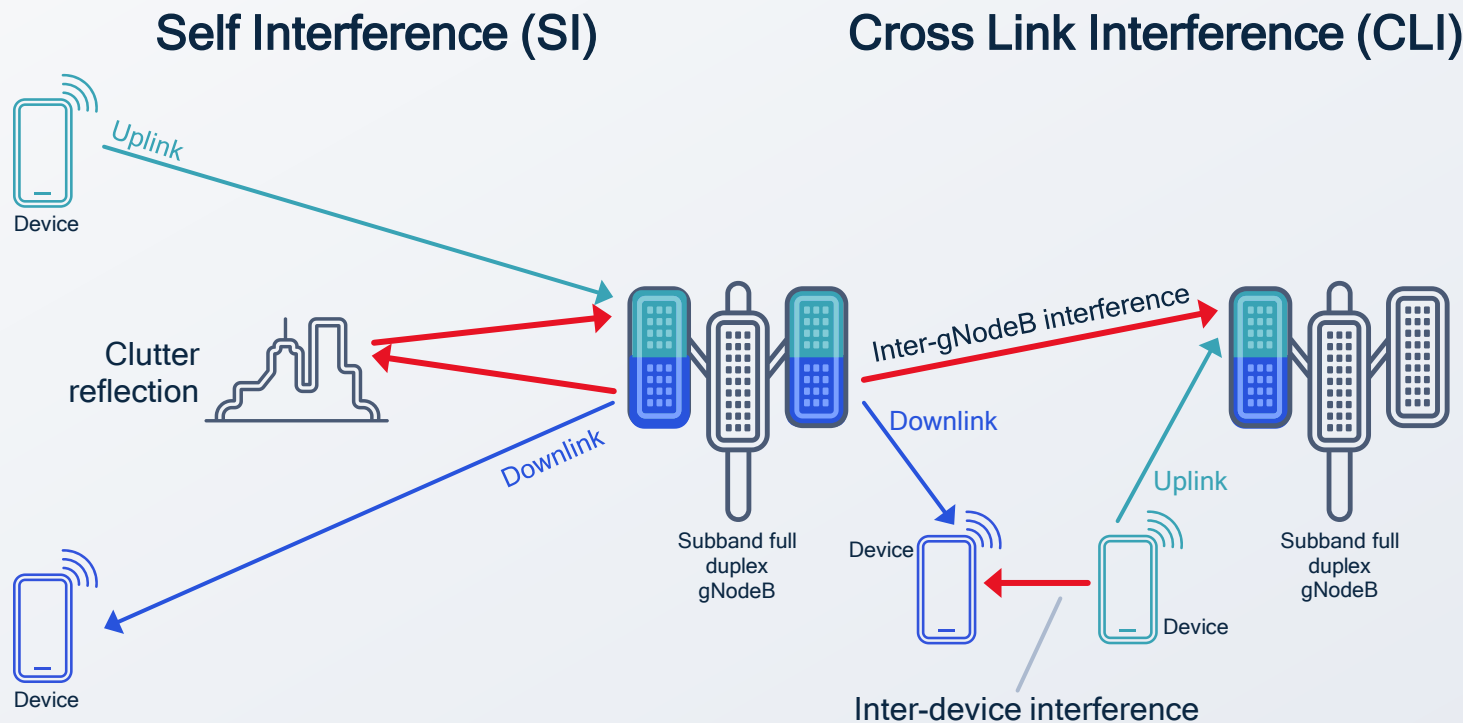| Downlink or Uplink | Downlink or Uplink | Downlink or Uplink | Downlink or Uplink |

Total Bandwidth
(e.g.,100 MHz)

Subband full duplex

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

Self interference mitigation

Simultaneous uplink and downlink

SBFD gNodeB

Downlink	Downlink	Downlink	Downlink
Uplink	Uplink	Uplink	Uplink
Downlink	Downlink	Downlink	Downlink

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

Single frequency full duplex

Interference cancellation to avoid self-interference

Self interference mitigation

Simultaneous uplink and downlink

SFFD gNodeB

| Downlink Uplink | Downlink Uplink | Downlink Uplink | Downlink Uplink |

Total Bandwidth
(e.g., 100 MHz for DL and UL)

Self Interference (SI)

Device

Uplink

Clutter reflection

Downlink

Device

Cross Link Interference (CLI)

Subband full duplex gNodeB

Inter-gNodeB interference

Downlink

Uplink

Device

Device

Inter-device interference

Subband full duplex gNodeB

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

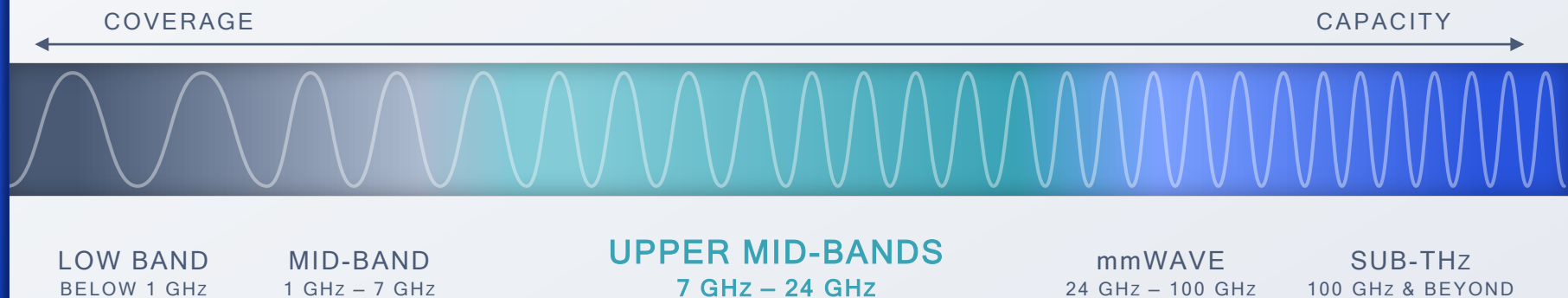# Addressing interferences in a full duplex wireless system

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

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

LOW BAND
BELOW 1 GHz

MID-BAND
1 GHz – 7 GHz

UPPER MID-BANDS
7 GHz – 24 GHz

mmWAVE
24 GHz – 100 GHz

SUB-THz
100 GHz & BEYOND

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
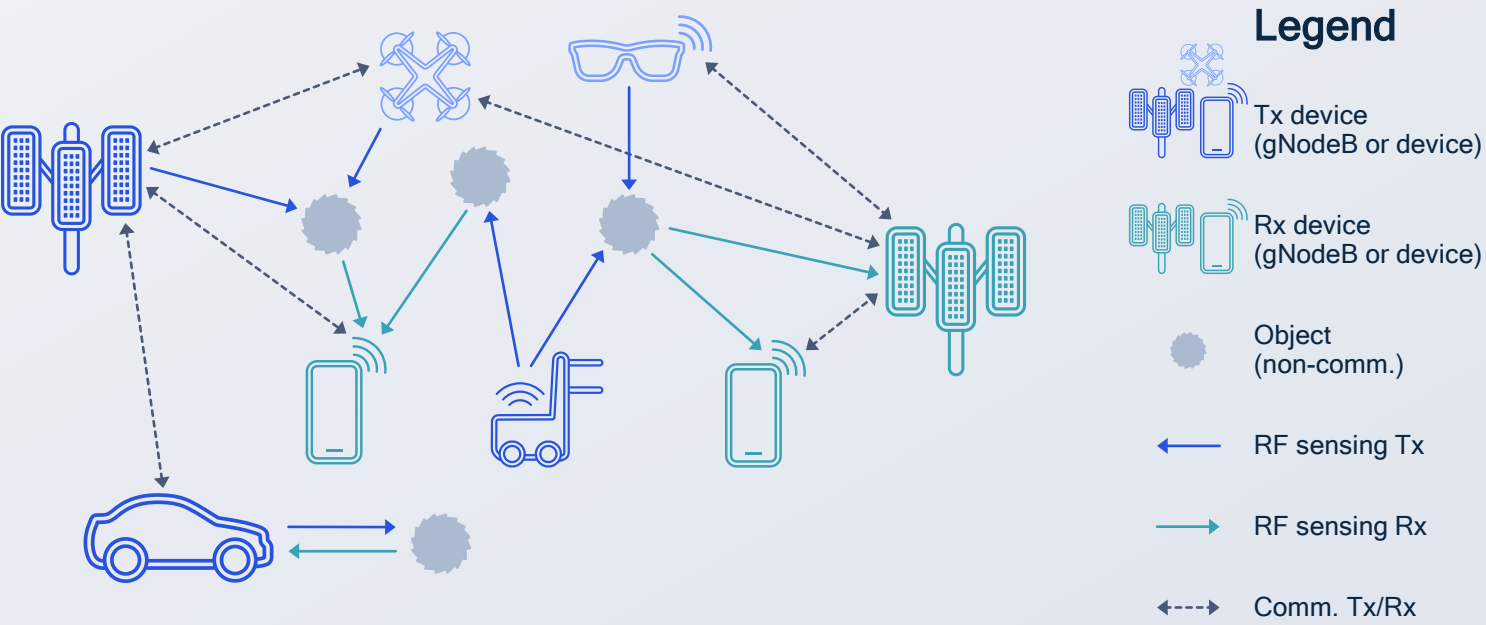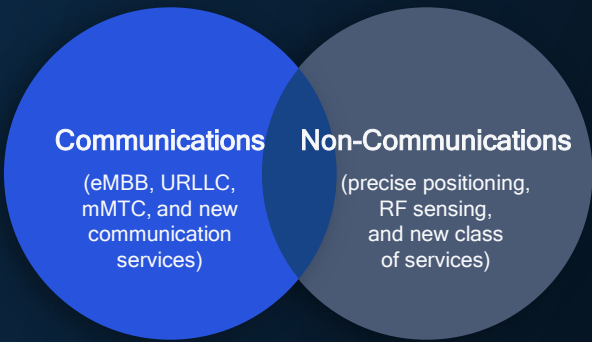
3GPP Release 19 Study

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

Communications
(eMBB, URLLC, mMTC, and new communication services)

Non-Communications
(precise positioning, RF sensing, and new class of services)

Unmanned aerial vehicles (UAVs)

Humans indoors and outdoors

Automotive vehicles

Automated guided vehicles (AGVs)

Objects creating hazards on roads / railways

Legend

Tx device (gNodeB or device)

Rx device (gNodeB or device)

Object (non-comm.)

RF sensing Tx

RF sensing Rx

Comm. Tx/Rx

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

Global Momentum for 6G is growing

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

ITU

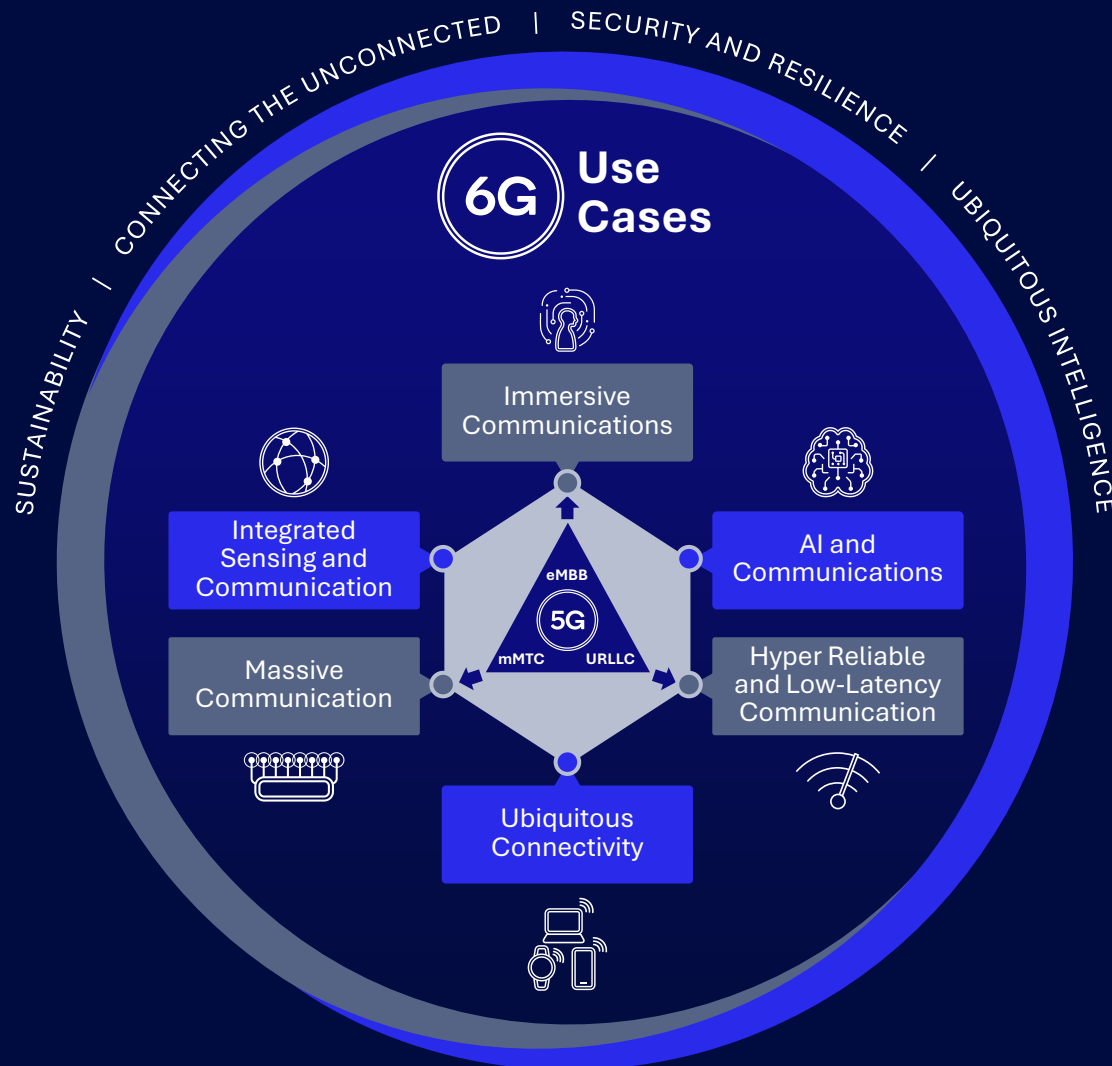IMT-2030 defines next-gen mobile system requirements for 2030 and beyond

3GPP
A GLOBAL INITIATIVE

The standards body responsible for global 6G technology standardization

United States
NextG Alliance

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

China
IMT-2030 PG

India
Bharat 6G Alliance

Japan
XG Mobile Promotion Forum

South Korea
6G Forum

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

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

6G Use Cases (outer ring): SUSTAINABILITY | CONNECTING THE UNCONNECTED | SECURITY AND RESILIENCE | UBIQUITOUS INTELLIGENCE

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

5G inner triangle: eMBB, mMTC, URLLC

Enhanced Capabilities

Capability	5G	6G
Security resilience		
Reliability	$1\text{-}10^{-5}$	$1\text{-}10^{-5} - 1\text{-}10^{-7}$
Latency	1	$0.1 - 1$ ms
Mobility	500	$500 - 1{,}000$ km/h
Connection density	10^6	$10^6 - 10^8$ devices/km^2
Area traffic capacity		
Spectrum efficiency		
User experience data rate		
Peak data rate		

6G Capabilities

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

BACK TO THE
WIRELESS FUNDAMENTALS

What do we expect from the next era of wireless connectivity?

Technology exploration
for next-generation
wireless system design

FOUNDATIONAL EVOLUTION
Continued enhancements to
core wireless system design

OPERATIONAL OPTIMIZATION
New tools to maximize
wireless system efficiency

EMERGING SERVICES
Scalable, next-generation
user experiences

FOUNDATIONAL EVOLUTION

Ubiquitous
coverage

Massive
capacity

NEW SYSTEM CAPABILITIES
FOR WIRELESS

Voice / data
connectivity

Artificial
intelligence

Integrated
sensing

Digital
twin

System
resiliency

Green network
& devices

6G · 5G ADVANCED · Bluetooth · ((UWB))

Augmented
perception

Real-time
efficiency

EMERGING SERVICES

OPERATIONAL OPTIMIZATION

Immersive
communication

Adaptive
intelligence

Advanced technology exploration to bring in the next era of wireless connectivity

Qualcomm

Wireless research directions & priorities

6G | 5G ADVANCED | (WiFi) | Bluetooth | (((UWB)))

FOUNDATIONAL EVOLUTION

Ubiquitous coverage

Lower-band spectrum design for 6G

5G non-terrestrial network (NTN) evolution

Massive capacity

New wide-area capacity with 6G Giga-MIMO

Super-QAM in upper midband

Flexible wireless augmented data center

OPERATIONAL OPTIMIZATION

Real-time efficiency

Network slicing with digital twins and gen AI

Digital twin hybrid beamforming

Adaptive intelligence

AI-native wireless system design for 6G

Wireless AI model LCM

AI-enhanced wireless efficiency (w/ Nokia)

Wireless AI performance verification (w/ R&S)

EMERGING SERVICES

Immersive communication

Delivering immersive experiences with distributed spatial compute

Augmented perception

Sensing-enhanced communication

Wireless sensing for aerial drone detection

TECHNOLOGY EXPLORATION AREAS

OUR INNOVATIONS CAN...

FOUNDATIONAL EVOLUTION

Massive capacity

Enabling new wide-bandwidth spectrum

| New wide-area capacity with 6G Giga-MIMO | Super-QAM in upper midband | Flexible wireless augmented data center |

Address the growing data demand of human and machine communications

Ubiquitous coverage

Enhancing low band and addressing coverage gaps

| Lower-band spectrum design | 5G NTN evolution |

Provide seamless wireless services everywhere that everyone has come to expect

OPERATIONAL OPTIMIZATION

Real-time efficiency

Advancing network operations with digital twins

| Network slicing with digital twins and gen AI | Digital twin for hybrid beamforming |

Realize sustained user experience benefits and maximize resource utilization

Adaptive intelligence

Evolving towards an AI-native system design

| AI-native wireless system design | Wireless AI model LCM | AI-enhanced wireless efficiency (w/ Nokia) | Wireless AI performance verification (w/ R&S) |

Derive tangible full-stack benefits from the maturation of wireless AI

EMERGING SERVICES

Immersive communication

Improving experiences with dynamic spatial compute

Delivering immersive experiences with distributed spatial compute

Revolutionize the way we connect to everyone and the world

Augmented perception

Integrating wireless sensing for new efficiency and use

| Sensing-enhanced communication | Wireless sensing for aerial drone detection |

Enable novel use cases through new and enhanced wireless capabilities

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Thank you

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