

# Setting off the 5G Advanced evolution



# 5G

accelerating globally

200

Operators with 5G commercially deployed

285+

Additional operators investing in 5G

1250+

5G designs launched or in development

1B+

5G connections by 2023 – 2 years faster than 4G

750M+

5G smartphones to ship in 2022

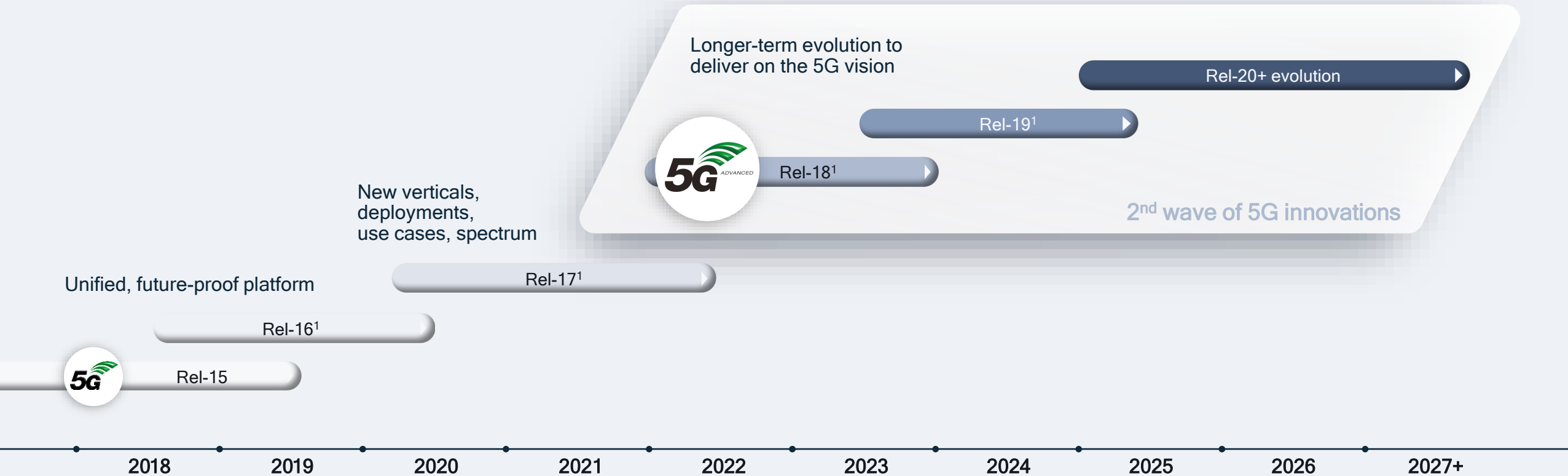
3.8B+

5G smartphones to ship between 2020 and 2024



Sources – 5G commercial networks: operator public announcements. Operators investing in 5G: GSA, Oct 2020. 5G device shipment projections: Qualcomm internal estimates, Nov 2020. 2023 5G connections: avg of ABI (Jun 2020), Ericsson (Jun 2020) and GSMA Intelligence (Oct 2020). Cumulative 5G smartphone shipments - avg of CCS Insight (Sep 2020), CounterPoint Research (Sep 2020), IDC (Aug 2020), Strategy Analytics (Oct 2020).

# Driving the 5G technology evolution in the new decade



## Rel-15 eMBB focus

- 5G NR foundation
- Smartphones, FWA, PC
- Expanding to venues, enterprises

## Rel-16 industry expansion

- eURLLC and TSN for IIoT
- In-band eMTC/NB-IoT
- NR in unlicensed
- Positioning
- 5G V2X sidelink multicast

## Rel-17 continued expansion


- Lower complexity NR-Light
- Non-terrestrial communication (satellites)
- Unlicensed/licensed spectrum in 60 GHz
- Improved IIoT, positioning V2X, IAB, ...


## Rel-18+ 5G-Advanced


- Next set of 5G releases (i.e., 18, 19, 20, ...)
- Rel-18 scope decided in Dec '21
- Rel-18 study/work to start in Q2-2022


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

# Leading 3GPP evolution of 5G

 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

 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

 Further eMBB enhancements

 Full-duplex MIMO

 Extended Reality (XR)

 Smart repeaters for coverage expansion

 Automotive and NR V2X enhancements

**Release 15**  
Established 5G NR technology foundation


**Release 16**  
Expanding to new use cases and industries

**Release 17**  
Continued expansion and enhancements

**Release 18+**  
New wave of 5G innovations in the decade-long 5G evolution

~1.5-2 years between releases

## 5G Advanced

 Non-terrestrial network enhancements


 5G NR-Light expansion for IoT and more

 AI/ML data-driven designs

 Broadcast enhancements

 Sidelink in unlicensed spectrum


 5G NR Cellular V2X


 Better coverage with IAB, uplink MIMO

 5G NR in unlicensed spectrum

 IAB integrated access/backhaul


 Private Networks, SON

 Centimeter accuracy IIoT with mmWave

 Expand sidelink for V2X reliability, P2V, IoT relay

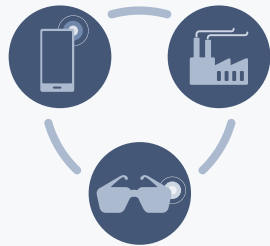
 Enhancements to 5G NR Industrial IoT

 Non-terrestrial network (i.e., satellites)

 Rel-15 deployment learning, eMBB enhancements, XR, others

# Driving a balanced 5G evolution across key technology areas

Mobile broadband evolution vs. further vertical expansion



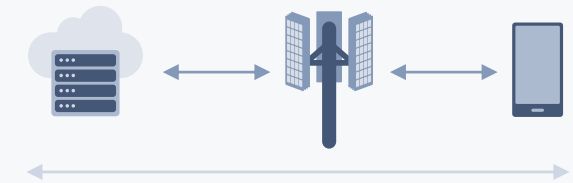
Deliver enhanced mobile broadband experiences and extend 5G's reach into new use cases

Immediate commercial needs vs. longer-term 5G vision



Drive new value in commercialization efforts and fully realize 5G's potential with future deployments

New and enhanced devices vs. network evolution

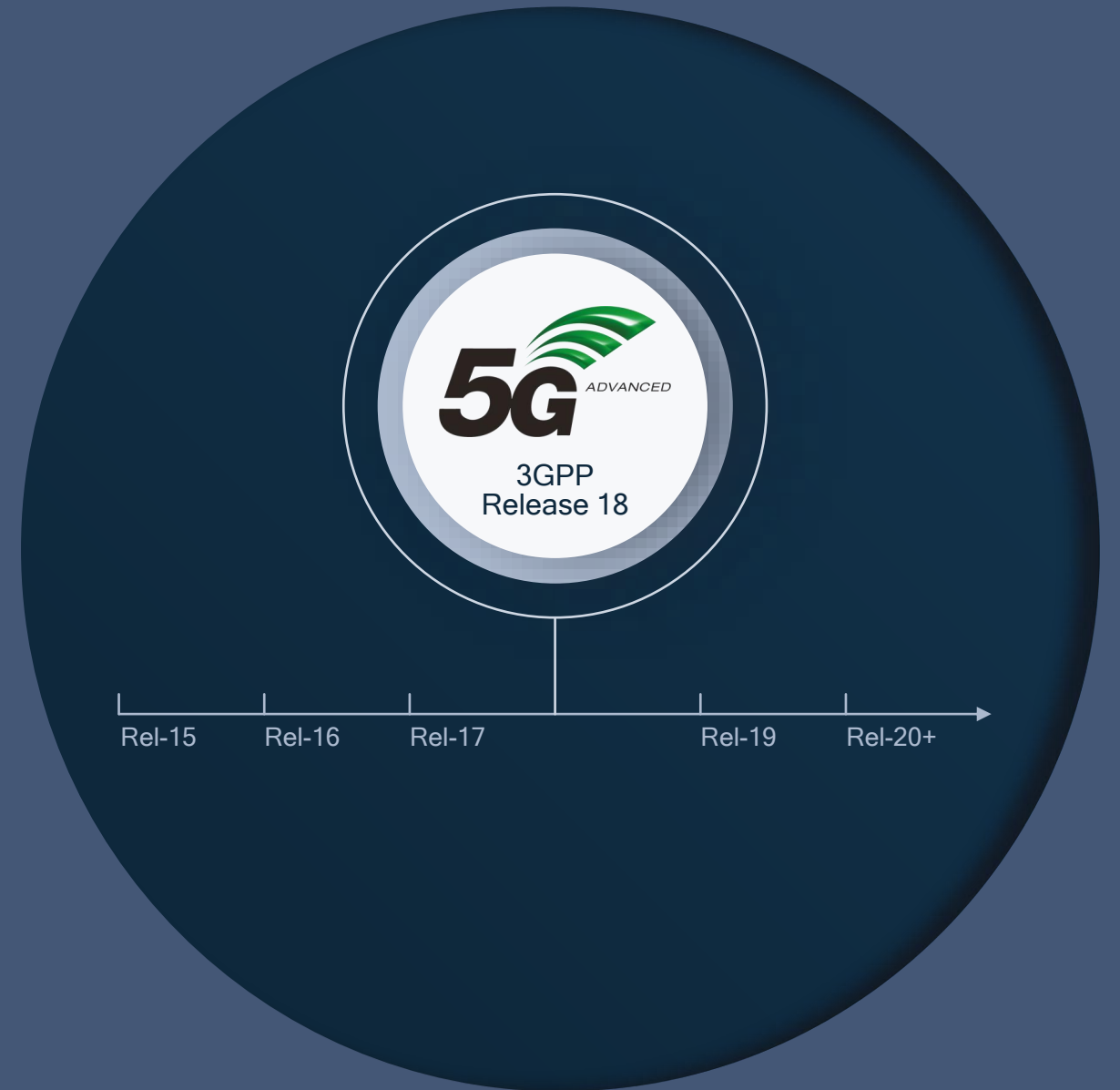


Focus on the end-to-end technology evolution of the 5G system to bring new levels of performance

Release 18 scope takes into consideration of the 5G Advanced evolution in Release 18, 19, and beyond (i.e., many Study Items defined to set up for Work Items in later releases)

# What will be included in Release 18?

The first 3GPP release in 5G Advanced evolution



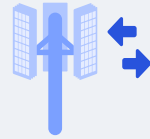


Release 18

# 3GPP Release 18 sets off the 5G Advanced Evolution

Approved package has  
a wide range of projects –  
nominal work to start in  
Q2 2022

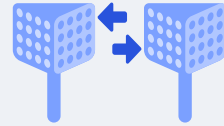
## Strengthen the end-to-end 5G system foundation



Advanced  
DL/UL MIMO



Enhanced  
mobility



Mobile IAB,  
smart repeater



Evolved  
duplexing



AI/ML data-driven  
designs



Green  
networks

## Proliferate 5G to virtually all devices and use cases



Boundless  
extended reality



NR-Light (RedCap)  
evolution



Expanded  
sidelink



Expanded  
positioning



Drones & expanded  
satellites comm.



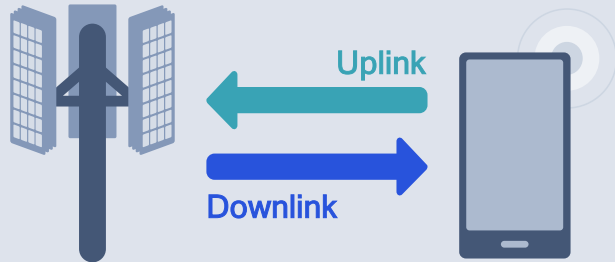
Multicast & other  
enhancements

# Strengthen the end-to-end 5G system foundation

Further enhancing 5G mobile broadband and expanded use cases







# Continuing to evolve 5G MIMO performance and efficiency

## Focus areas for Release 18

CSI<sup>1</sup> and CSI-RS<sup>2</sup> enhancements in high or medium velocities to exploit time-domain correlation or Doppler-domain information

Extending Rel-17 unified TCI<sup>3</sup> framework for multiple downlink/uplink TCI states

Supporting larger number of orthogonal DMRS<sup>4</sup> ports for downlink or uplink multi-user MIMO

Enhanced CSI acquisition for coherent-JT<sup>5</sup> targeting 4 TRPs for both FDD<sup>6</sup> and TDD<sup>7</sup> bands in sub-7 GHz

Supporting uplink DMRS, SRS<sup>8</sup> for 6/8 Tx uplink to support 4+ layers per device targeting CPE<sup>9</sup>, FWA<sup>10</sup>, vehicle, industrial devices

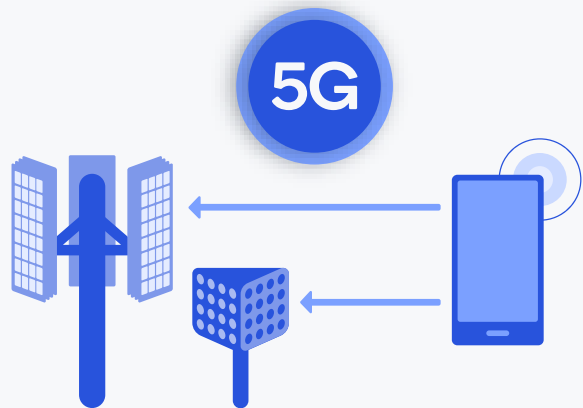
Facilitating simultaneous multi-panel uplink for higher throughput and reliability

Specifying panel-specific timing/power control for uplink multi-TRP<sup>11</sup> or multi-panel setup

Source: RP-213598 (MIMO Evolution)

1 Channel State Information; 2 CSI Reference Signal; Transmission Configuration Indicator;  
4 Demodulation Reference Signal; 5 Joint Transmission; 6 Frequency Division Duplexing;  
7 Time Division Duplexing; 8 Sounding Reference Signal; 9 Customer Premises Equipment;  
10 Fixed Wireless Access; 11 Transmission Reception Points;

# Driving higher 5G uplink performance and efficiency



**Uplink enhancements**  
3GPP Release 18

● **Coverage enhancements** targeting multiple PRACH<sup>1</sup> transmissions with same beam as well as with different beams (for mmWave) targeting 4-step RACH

● **Power domain enhancements**, such as dynamic power aggregation for CA/DC and enhanced transmit power efficiency (e.g., via spectrum shaping, tone reservation)

● **Improved support of UL-MIMO** via dynamic waveform switching between CP-OFDM<sup>3</sup> and DFTS-OFDM<sup>2</sup>

<sup>1</sup> (UL coverage enhancements)

<sup>2</sup> Discrete Fourier Transform Spread Orthogonal Frequency Division Multiplexing;  
<sup>3</sup> Orthogonal Frequency Division Multiplexing.

# Further optimizing 5G device mobility management

Work Item targeting operations in both sub-7 GHz and mmWave bands



5G NR Release 18 project is proposed to address different deployment configurations

Source: RP-213565 (Mobility enhancements)

Dual Connectivity; 2 Primary Cell of Secondary Cell Group (SCG); 3 Secondary Cell Group; Master Cell Group; 5 Secondary Cell.

## Layer 1 / 2 based inter-cell mobility

Configuration and maintenance of multiple candidate cells, dynamic switching among those, and other L1 enhancements (e.g., L1 measurement reporting / mobility command)

## NR-DC<sup>1</sup> with selective activation of cell groups via L3 enh.

Conditional PSCell<sup>2</sup> Addition and Change among multiple candidate SCGs. One SCG<sup>3</sup> active at a time.

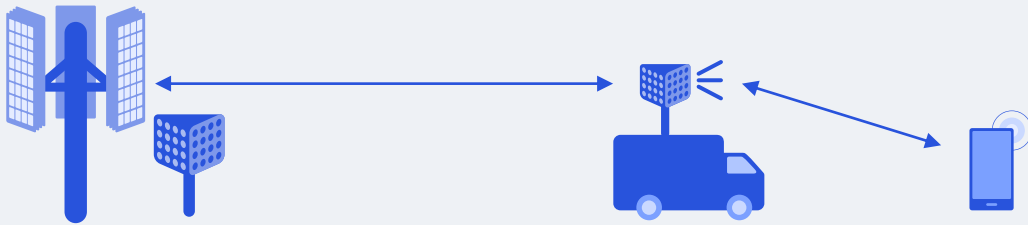
## Conditional Handover enhancements

Conditional configuration including target MCG and target SCG or target MCG<sup>4</sup> and target SCGs for Conditional PSCell Addition and Change.

## FR2 enhancements

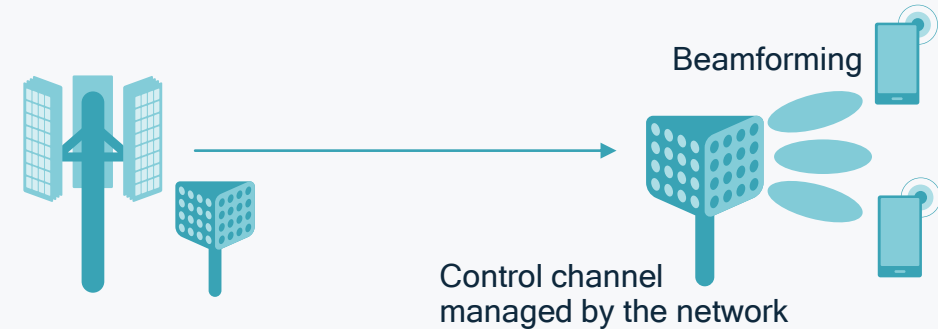
SCell<sup>5</sup>/SCG setup delay improvement. New early UE measurements procedure.

## Mobile integrated access/backhaul (IAB) and vehicle mounted relay (VMR)



Focus on the mobile IAB mounted on vehicles providing 5G coverage/capacity enhancement supporting single hop in-band, out-of-band backhauling, device handover and dual connectivity

## Smart repeaters with side control information



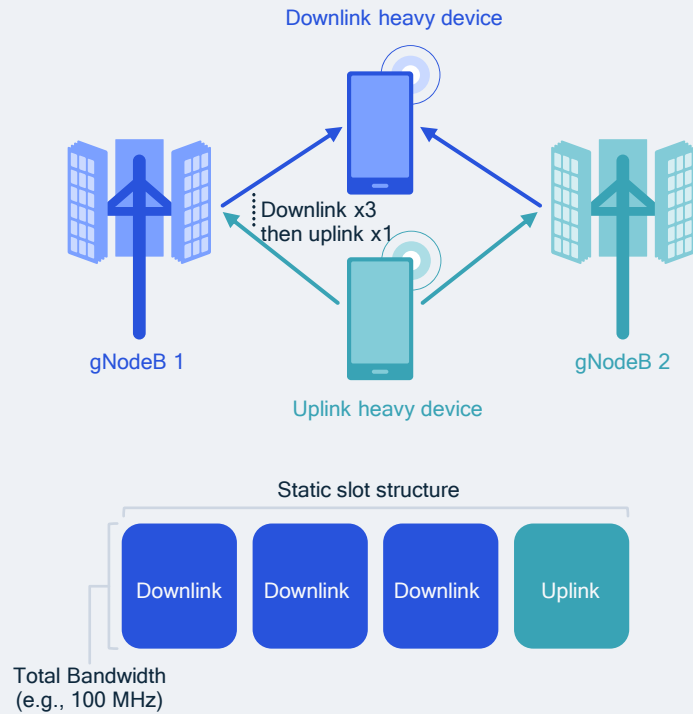
Focus on single-hop operation that is transparent to the device, supporting identification/authorization of smart repeaters, with side control information including max Tx power, beamforming, timing, TDD configurations, and on/off

# Cost-efficient expansion of 5G coverage and capacity

New Release 18 project focuses on new 5G deployment topologies

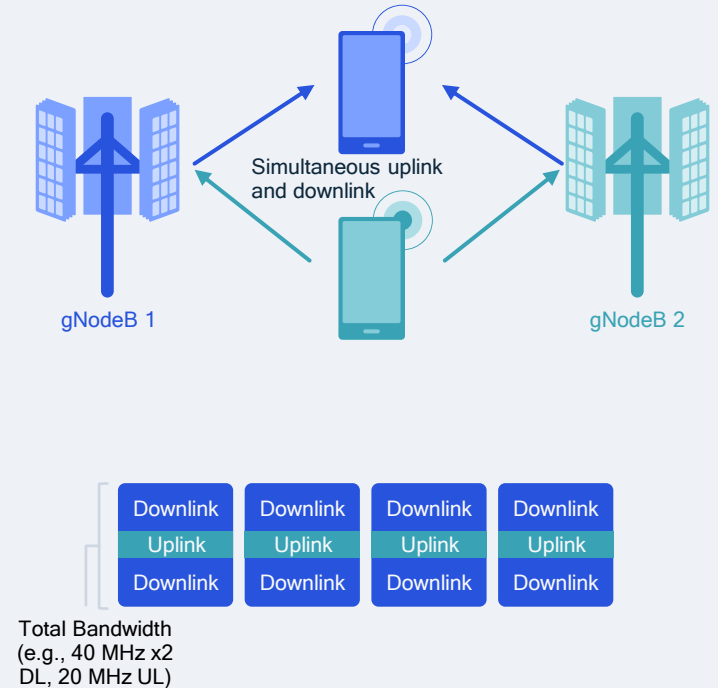
## Static TDD

Time aligned to avoid inter-site interference  
Time separation to avoid self-interference



## Sub-band Full Duplex (SBFD)

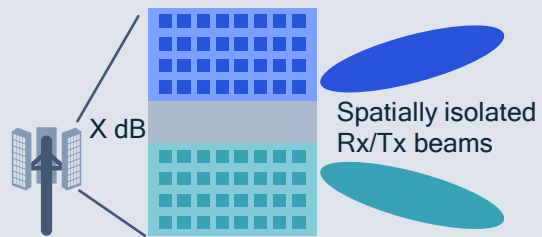
Frequency aligned to avoid inter-site interference  
Frequency separation and interference cancellation to avoid self-interference  
gNodeBs are full-duplex capable, devices are half-duplex



# Evolving towards a full duplex wireless system

Improving perceived user throughput, latency, uplink coverage – path to single-frequency full duplex (SFFD)

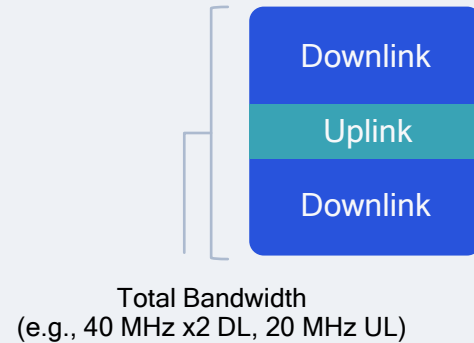
## Spatial/beam isolation/duplexer



Two separate antenna panels for simultaneous Tx/Rx

80 to 90 dB isolation between 2 panels based on lab measurement in mmWave

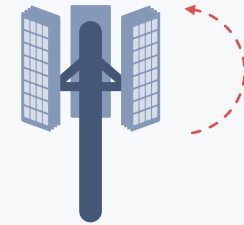
## Frequency isolation (for SBFD)



Subband “frequency” multiplexing uplink and downlink (FDM)

Y dB isolation ( $Y > 40$  dB)

## Digital/analog self-interference mitigation



Tx/Rx processing including potential nulling

Z dB from mitigation technique

# Key enablers for a full duplex air interface

Working to define suitable parameter values for X, Y and Z to enable full duplex operations

# Release 18 lays the foundation for the future of full duplex

Identify and evaluate potential enhancements to support duplex evolution for 5G NR TDD spectrum

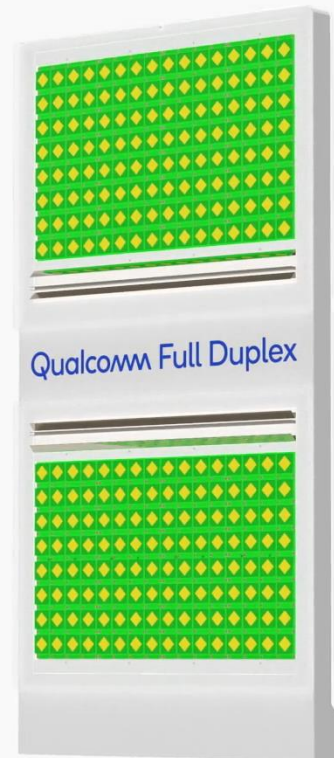


Identify applicable and relevant deployment scenarios and use cases

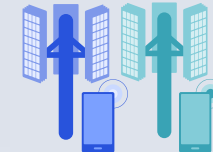


Study subband non-overlapping full duplex and potential enhancements on dynamic TDD

Future study may include partial overlapping and full overlapping subband



Develop evaluation methodology for duplex enhancement



Study inter-gNodeB, inter-device CLI<sup>1</sup> management and impact on RF requirements considering adjacent-channel coexistence with legacy operation



## Network architecture enhancements

Allowing for machine learning to run over different HW/SW and future RAN function split to improve flexibility and efficiency



## AI/ML procedure enhancements

Optimizing system for model management, training (e.g., federated and reinforced learning), and inference



## Data management enhancements

Standardizing ML data storage/access, data registration/discovery, and data request/subscription



## New and expanded use cases

Supporting traffic/mobility prediction, coverage/capacity optimization, massive MIMO, SON, CSI feedback, beam management, and other PHY/MAC and upper layer improvements



**5G Advanced (Rel-18+) targets to expand wireless machine learning to the end-to-end system across RAN, device, and air interface**





Wireless ML  
Rel-18

# 3GPP Release 18

## Scope for wireless ML projects

Source: RP-213599 (AI/ML for NR Air Interface),  
RP-213602 (AI/ML for NG-RAN)

1 Quality of Experience

## AI/ML-enabled air interface design



### Use cases

Including enhanced channel state information (CSI) feedback, beam management, and positioning accuracy (including heavy non-line-of-sight conditions)



### AI/ML models

Identifying collaboration models, from no collaboration to cross-node ML, life cycle management of models, characterizing model generation/inference algorithms



### Evaluation methodology

Utilizing existing 3GPP framework for evaluations and field data to assess performance in real-world environments, as well as identifying common KPIs



### Impact assessment

Evaluating specification changes needed to support identified use cases, covering PHY layer, protocol, interoperability and testability aspects

## AI/ML framework for next-generation radio access network



### Network optimization

Specify enhanced data collection and signaling support for AI/ML-based network energy saving, load balancing and mobility optimization



### Future study

Study new use cases (e.g., AI/ML for slicing, QoE<sup>1</sup>), as well as network functionality and interface procedures (e.g., multi-vendor interoperability)

# Driving towards greener 5G networks

## Release 18 project scope

Define a base station energy consumption model

Define an evaluation methodology and KPIs

Study techniques on the base station and device side to improve network energy savings

Target system-level studies with various scenarios:

- Urban micro in sub-7 GHz, including TDD massive MIMO
- mmWave beam-based deployments
- Urban/rural macro in sub-6 GHz with/without DSS<sup>1</sup>
- Dual connected macro with FDD anchor and TDD on higher sub-7 GHz
- Other scenarios, e.g., small cell deployment



# Proliferate 5G to virtually all devices and use cases

Continued expansion  
to new device types  
and tiers – fulfilling  
the 5G vision



# Purpose-built system enhancements for XR over 5G



Release 18 focuses on capacity considerations as well as power savings for XR use cases

Source: RP-213587 (Enhancements for XR)

1 Quality of Service; 2 Key Performance Indicators; 3 Radio Access Network;  
4 Connected Discontinued Reception; 5 Semi-Persistent Scheduling



## KPIs<sup>1</sup> and QoS<sup>2</sup>

Enhancing RAN<sup>3</sup> support for enhanced granularity for QoS and XR-specific parameters



## Application awareness

Optimizing DL/UL XR traffic in the network to improve user experience and network efficiency



## Power optimization

Specifying XR-specific power saving techniques such as enhanced C-DRX<sup>4</sup> and control channel monitoring



## Capacity enhancement

Supporting resource allocation and scheduling specifically for XR traffic profile, such as enhanced SPS<sup>5</sup> and dynamic grants

# Sidelink enhancements



**Unlicensed spectrum**  
Supporting optimized sidelink operations in unlicensed 5 and 6 GHz bands

**Multi-beam operation**  
Supporting sidelink beam management by reusing and enhancing existing framework and concepts

**Sidelink carrier aggregation**  
Supporting enhanced use cases that can benefit from wider bandwidths

# Sidelink relay enhancements



**Device-to-device relay**  
Allowing single-hop operation for unicast with forward compatibility for more hops

**Service continuity enhancements for UE-to-NW relay**  
Supporting inter-gNodeB mobility and intra-gNodeB indirect-to-indirect path switching

**Multipath relay & UE Aggregation/Switching**  
Enhancing reliability and throughput for 1 direct (Uu) + 1 indirect (PC5 or ideal link) path within the same cell

**Remaining Rel-17 work**  
Completing features such as discontinued reception (DRX) for sidelink relay operations

# Expanding 5G Sidelink capabilities in Release 18

For public safety, IoT, commercial use cases and beyond – Study and Work Item project scope



Low-end industrial sensors



Surveillance cameras



Industrial sensors



Smart city (e.g., meters)



Health monitors



Agriculture sensors

eMBB/URLLC

Highest performance



High-end logistic trackers



High-end wearables



Low-end asset trackers



Smart grid



Low-end wearables

NR-Light (RedCap)

Lower complexity<sup>2</sup> and power

NR-Light (RedCap) Evolution



Utility meters

eMTC/NB-IoT<sup>1</sup>

Lowest complexity<sup>3</sup>, delay tolerant

Passive IoT

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

<sup>1</sup> Also including satellite access; <sup>2</sup> Data rate of 150 Mbps DL / 50 Mbps UL, latency of 10-30 ms, 10-3 to 10-5 reliability, coverage MCL of 143 dB; <sup>3</sup> Data rate of 1Mbps, MCL of 155.7 dB (eMTC) and 164 dB (NB-IoT)

# 5G eMBB/URLLC

Highest performance

Rel-15+



Surveillance cameras



Industrial sensors



Health monitors



Lower-tier mobile devices



High-end wearables



Smart grid



## Device coexistence

With Rel-17 NR-Light reduced capability and eMBB/URLLC devices



## Low-power WUS<sup>2</sup>/WUR<sup>3</sup>

Enhanced low-power operations targeting IoT use cases

# 5G NR-Light (RedCap)

Lower complexity and power

Rel-17

## Lower device complexity

Reduced bandwidth (e.g., 5 MHz), peak data rate, and relaxed device processing timeline



## Power savings

Enhanced DRX<sup>1</sup> in inactive mode (>10.24s) and lower device power class

# Further scaling down 5G NR-Light

for reduced capability devices

Release 18

# Supporting 5G NR devices with 5 MHz or lower bandwidth

3 to 5 MHz bandwidth in dedicated  
FDD sub-7 GHz spectrum

15 kHz SCS<sup>1</sup> with normal CP<sup>2</sup>

PSS/SSS<sup>3</sup> without puncturing,  
PBCH<sup>4</sup> based on current design

For 5G NR deployments  
for specific applications

Source: RP-213603 (<5 MHz NR in dedicated spectrum)

1 Subcarrier Spacing; 2 Cyclic Prefix; 3 Primary/Secondary Synchronization  
Signals; 4 Physical Broadcast Channel





## Precise device class definition

Supporting ultra-low power consumption and energy-harvesting capabilities

## Potential use cases

Such as identification, tracking, monitoring, sensing for logistics, transportation, healthcare

## Deployment scenarios

Such as public/private, indoor/outdoor, macro/small cells, direct/relay, traffic models, spectrum



## Existing solutions

Competing technologies such as RFID or other proprietary connectivity platforms

## Design targets

Such as link budget, data rate, power, energy harvesting techniques, positioning accuracy

## Coexistence

With existing 3GPP devices, infrastructure, and spectrum

# Further scaling down 5G NR IoT support

Continued 3GPP discussions focusing on key interest areas to refine future project scope



# 5G positioning evolution

## Release 16

### Establishing foundation

Achieving accuracy of 3m/10m (indoor/outdoor) for 80% of time

Supporting RTT<sup>1</sup>, AoA/AoD<sup>2</sup>, TDOA<sup>3</sup>, single-cell positioning

Including new evaluation scenarios, i.e., industrial IoT

## Release 17

### Enhancing performance

Meeting centimeter-level absolute accuracy requirement of down to 0.3m

Reducing positioning latency to as low as 10 ms

Scaling to higher capacity for millions of simultaneous devices (e.g., IoT, automotive)

## 5G Advanced in Release 18

Improving performance, expanding to new devices and deployments



### Sidelink positioning and ranging

Defining methodologies, reference signals, measurements, procedures for absolute and relative (e.g., ranging) sidelink positioning in licensed and ITS<sup>4</sup> spectrum



### Improved positioning performance

Specifying higher layer solutions for RAT<sup>5</sup> dependent positioning techniques, accuracy improvement based on PRS/SRS<sup>6</sup> bandwidth aggregation, and carrier phase measurements



### NR-Light<sup>7</sup> positioning

Setting performance requirements, evaluating performance for R17 positioning procedures, and identifying potential enhancements

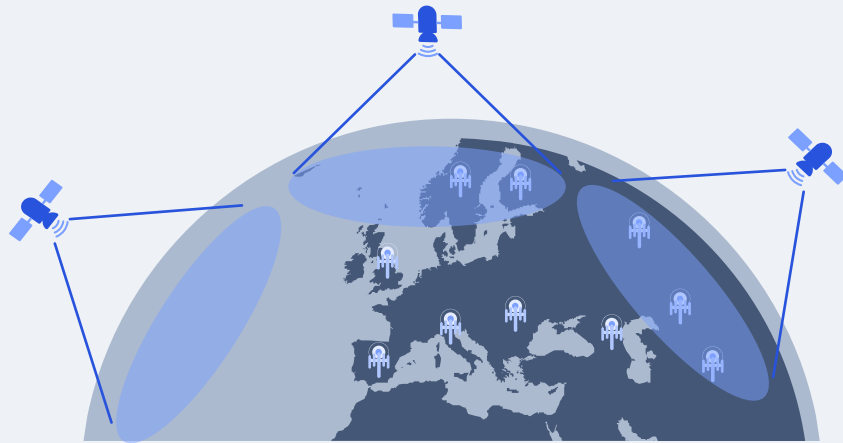
# Pushing forward with the 5G positioning technologies

Source: RP-213588 (Expanded and improved Positioning)

1 Roundtrip Time; 2 Angle of Arrival, Angle of Departure; 3 Time Difference of Arrival; 4 Intelligent Transport System; 5 Radio Access Technology; 6 Positioning Reference Signal, Sounding Reference Signal; 7 aka. RedCap

## 5G NR for NTN

Complementing terrestrial networks  
in underserved areas



Network verified  
device location  
based on satellites  
network

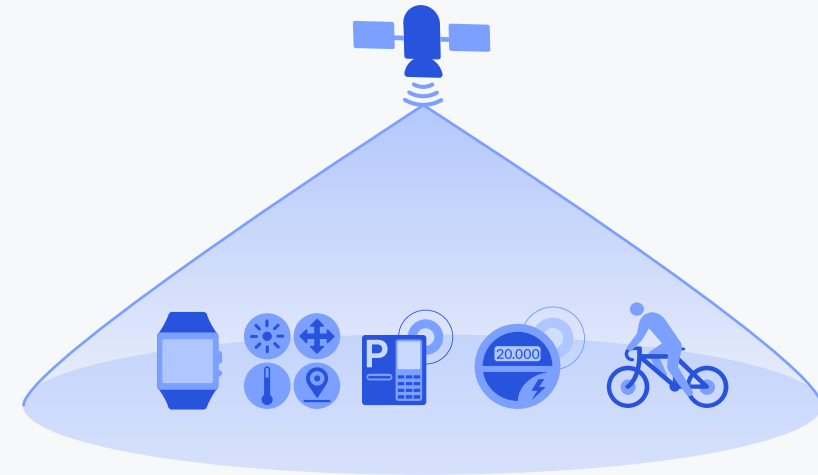
Coverage  
enhancements for  
voice and low-data  
rate services

Mobility  
enhancements for  
satellite and  
terrestrial networks

Deployment in  
10+ GHz bands  
and support for  
VSAT<sup>1</sup>/ESIM<sup>2</sup>

## 5G IoT for NTN

Expanding addressable market  
for the 5G massive IoT



Addressing remaining Rel-  
17 issues (e.g., disabling  
HARQ<sup>3</sup> feedback to  
mitigate impact of HARQ  
device data rate stalling)

Enhanced mobility  
such as neighbor cell  
measurements and  
extending to mMTC

Enhanced GNSS  
operation for longer  
connections and  
reduced power  
consumption

Study possible  
enhancements  
to Rel-17 for  
discontinuous  
coverage

# Expanding the 5G NR support for satellites communication

5G Advanced will further enhance the non-terrestrial networks (NTN) foundation



# 5G drones are getting ready to take off

Release 18 leverages the cellular drones work in Rel-15 LTE-A Pro

## Measurement reports

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

## Signaling to support subscription-based aerial device identification

## Support for broadcast/groupcast of drone identification

## Beam management enhancements (e.g., device directional antenna)

## Improved DSS<sup>1</sup>

Enabling NR-PDCCH<sup>2</sup> reception in symbols with LTE CRS. Allow two overlapping CRS rate matching patterns regardless of support of multiple TRPs.

## Low-power WUS<sup>3</sup>

Study the feasibility of a very low-power WUS design not necessarily using existing signals and aiming at substantial gains compared to R15/R16/R17 mechanisms.

## Multi-SIM<sup>4</sup>

Enhance support for simultaneous network connections (i.e., 2) and more seamless switching

## In-device coexistence

Improve interference management of 5G and other technologies focusing on enhanced FDM<sup>5</sup> and TDM<sup>5</sup> solution

## Small data transmission

Support mobile terminated triggered transmissions in inactive state for e.g., enhanced paging



## SON/MDT<sup>6</sup> enhancements

Add IRAT<sup>7</sup> handover voice fallback, enhanced random access procedure, and expanded use cases (e.g., NPN)

## Improved QoE<sup>8</sup>

Support new service types (e.g., AR, broadcast), QoE in NR-DC (e.g., reporting via Secondary Node)

## gNodeB CU<sup>9</sup> resiliency

Study and agree possible failure scenarios associated with the Control Plane of the gNB-CU

## Multicast enhancements

Support reception in inactive mode, UE indication/signaling for "shared processing", enhanced RAN sharing

## CA<sup>10</sup> enhancements

Support multi-cell scheduling and improve multi-carrier uplink focusing on Tx switching for 3 or more bands

Source: RP-213575 (DSS enhancements); RP-213645 (Low-Power WUS); RP-213584 (MUSIM Enhancements); RP-213589 (IDC Enhancements); RP-213583 (Small data transmission); RP-213553 (SON/MDT enhancements); RP-213594 (QoE Enhancements); RP-213677 (gNodeB CU resiliency); RP-213568 (MBS enhancements); RP-213577 (CA enhancements);

1 Dynamic Spectrum Sharing; 2 5G NR Physical Downlink Control Channel; 3 Wakeup Signal; 4 Subscriber Identity Module; 5 Frequency Division Multiplexing, Time Division Multiplexing; 6 Self Organizing Network/Minimization of Drive Test; 7 Inter Radio Access Technology; 8 Quality of Experience; 9 Central Unit; 10 Carrier Aggregation



### AI/ML

Air interface (cross-node channel state feedback, beam management, positioning)  
Study Item in **Rel-18** and Work Item in **Rel-19+**



### Full Duplex

Full Duplex in TDD bands, sub-6/mmWave, enhanced crosslink interference, coexistence with legacy and other operators  
Study Item in **Rel-18** and Work Item in **Rel-19+**



### Network Power Savings

**Rel-18:** Techniques on the gNodeB and device side to improve network energy savings in terms of both transmission and reception

**Rel-19+:** Further enhancements for system power saving



### XR

**Rel-18:** Application-aware RAN (frame-level QoS, multi-streams), power enhancements, capacity enhancements

**Rel-19+:** Further enhancements for capacity and power



### Enhanced RedCap/IoT

**Rel-18:** Reduced complexity/cost (5MHz devices), power savings, sidelink support, enhancements for narrow band positioning

**Rel-19+:** Low-power Wake Up Signal, passive IoT (energy harvesting)



### Enhanced Non-terrestrial network

**Rel-18:** Coverage enhancements, deployment above 10 GHz bands, mobility and service continuity enhancements, enhancements for IoT-NTN

**Rel-19+:** Possible further enhancements



### Sidelink/V2X

**Rel-18:** Enhancements for unlicensed, mmWave enhancements, device-to-device relay, coexistence of LTE/NR V2X, enhanced CA

**Rel-19+:** Enhancements for sidelink MIMO, enhancements for power savings, etc.



### eMBB enhancement

**Rel-18:** Rel-18: MIMO enhancements, enhanced uplink coverage, smart repeater, enhanced mobility, network energy savings

**Rel-19+:** MIMO enhancements (CSF time domain compression, etc.), enhancements for network energy savings

Release 18

Release 19

Release 20

Release 21

2022

2023

2024

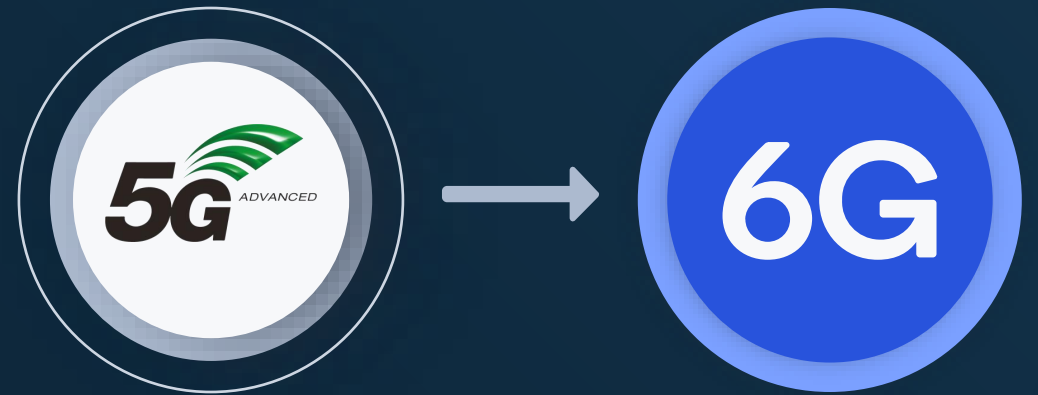
2025

2026

# Release 18 is just the start of the 5G Advanced evolution

## Further 5G NR enhancements in R19, R20, and beyond

How will 5G  
evolve in the  
new decade?



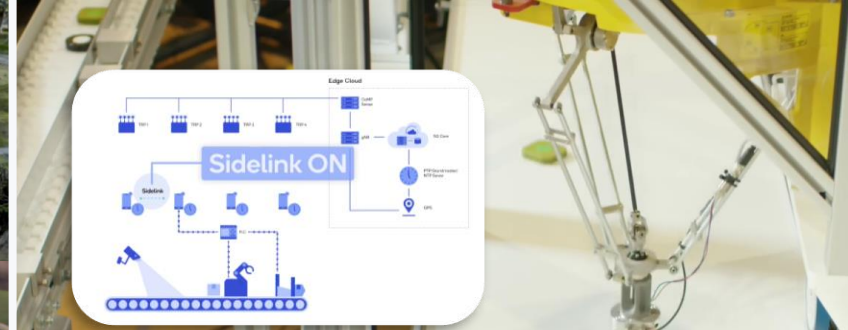
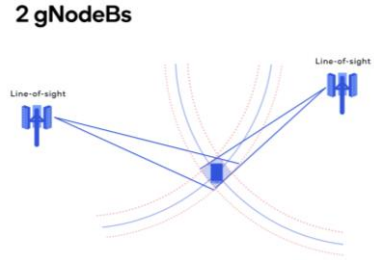
Continued evolution towards 6G

# Advancing 5G to fulfill its full promise

Enhanced mobile experiences, new capabilities,  
and expansion to diverse verticals

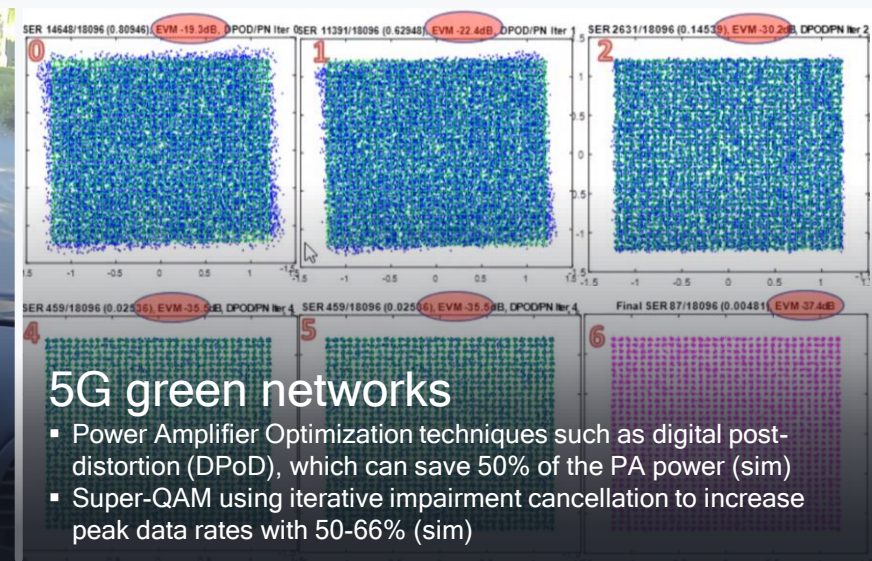






## Industrial IoT expansion

- Ultra-high reliability, time sensitive networking, and sidelink (OTA)
- Centimeter-level indoor positioning for asset tracking (OTA)
- Complementary sidelink for improved network capacity (sim)

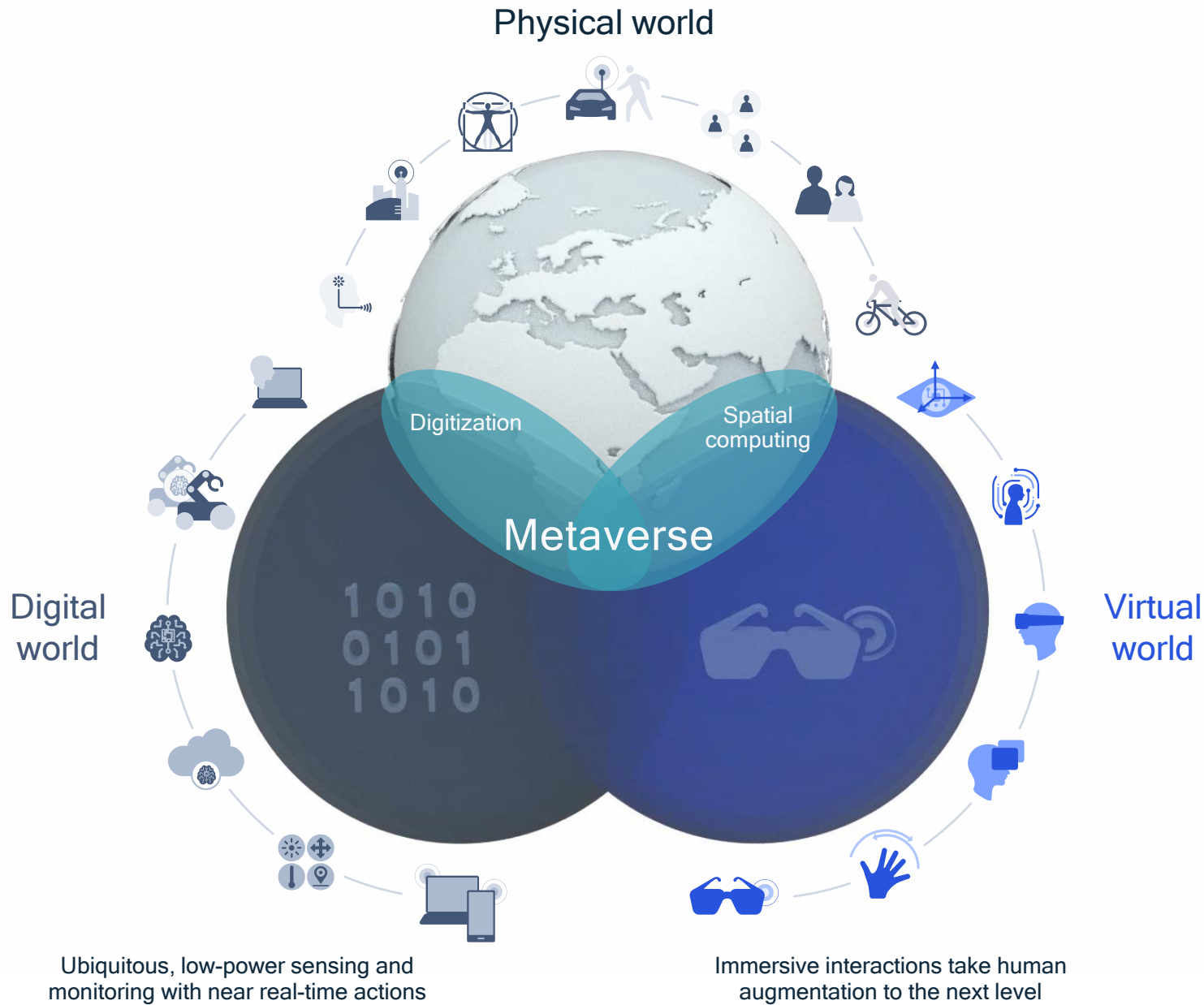


# Accelerating the 5G expansion and paving the path to 6G

## A heavyweight lineup of advanced wireless R&D demonstrations for MWC Barcelona 2021



[YouTube Playlist](#)



New interface opportunities through

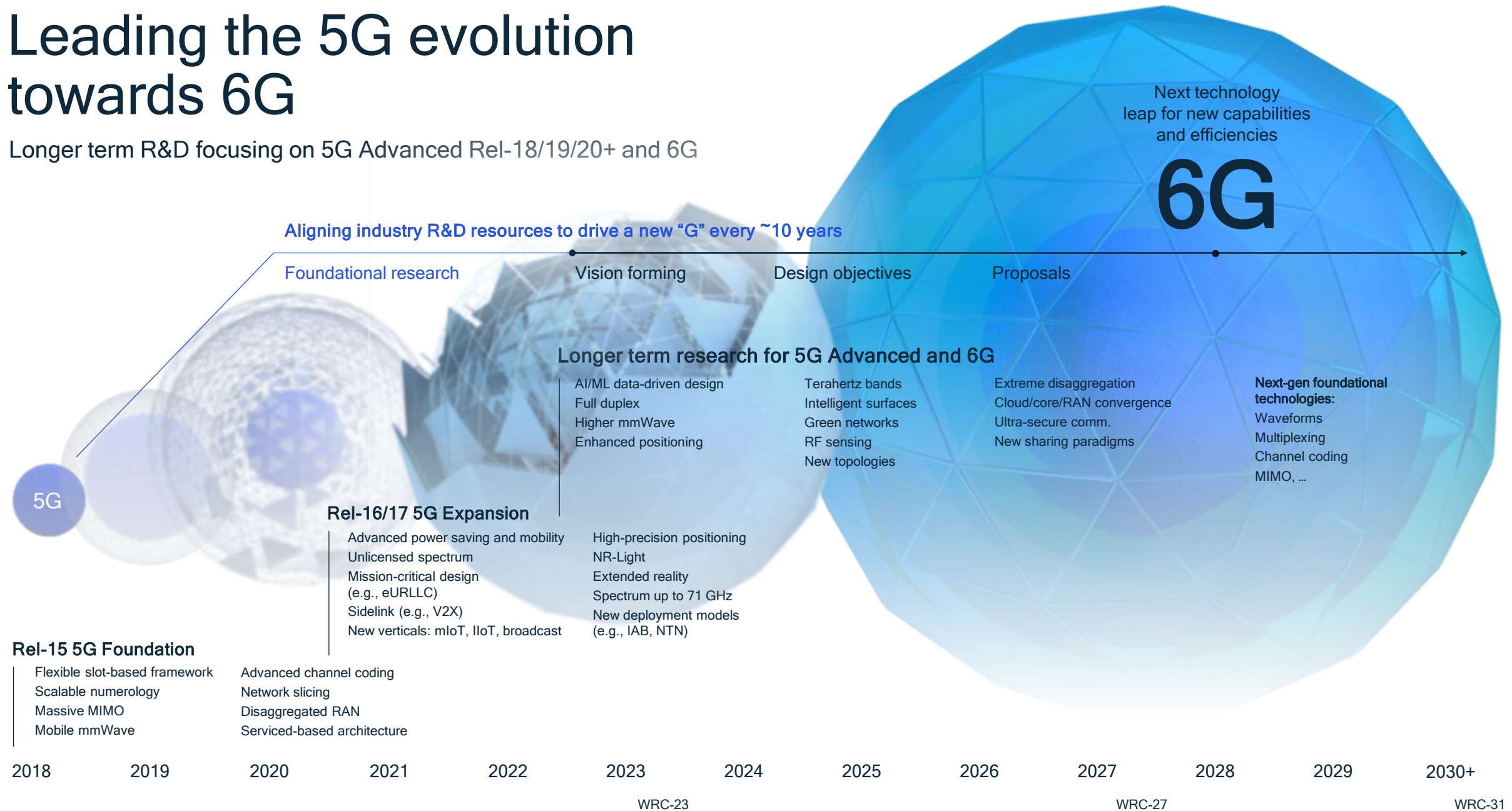
# Merging worlds

The

# New human interface

# Leading the 5G evolution towards 6G

Longer term R&D focusing on 5G Advanced Rel-18/19/20+ and 6G



# Key research vectors enabling the path towards 6G



## AI/ML powered E2E communications

Data-driven communication and network design, with joint training, model sharing and distributed inference across networks and devices



## Spectrum expansion & sharing

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



## New radio designs

Evolution of duplexing schemes, large-scale MIMO, mmWave evolution, reconfigurable intelligent surfaces, non-terrestrial communications, waveform/coding for MHz to THz, system energy efficiency



## Merging of worlds

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



## Scalable network architecture

Disaggregation and virtualization at the Connected Intelligent Edge, use of advanced topologies to address growing demand



## Communications resiliency

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



## Design goals & performance vectors

Capacity	Latency	Spectral efficiency	User experience	Ease of onboarding		
Data rate	Reliability	Mobility	Security	Scalability	Intelligence	Cost efficiency
Coverage	Energy efficiency	Connection density	Positioning capability	And others.		

# Innovating to pave the path to 6G

A unified connectivity fabric for this decade



## Continued evolution

Rel-15  
eMBB focus

Rel-16 and 17 expanding  
to new industries



Rel-18, 19, 20 and beyond  
Continued 5G proliferation







Next technology leap  
for new capabilities  
and efficiencies

Strong 5G momentum sets  
stage for global expansion

Historically 10 years  
between generations



# Thank you

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