Qualcomm July 2020 San Diego, CA @qualcomm_tech

Propelling 5G forward

A closer look at 3GPP Release 16

5G

Mobile has made a leap every ~10 years

Mobile voice communication

1G

1980s

Analog voice

AMPS, NMT, TACS

Efficient voice to reach billions

2G

1990s

Digital voice

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

Focus shifts to mobile data

3G

2000s

Wireless Internet

CDMA2000/EV-DO WCDMA/HSPA+,

Mobile broadband and emerging expansion

4G

2010s

Mobile broadband

LTE, LTE Advanced, Gigabit LTE

A unified future-proof platform

2020s

Wireless Edge

5G New Radio (NR)

Delivering on the 5G vision

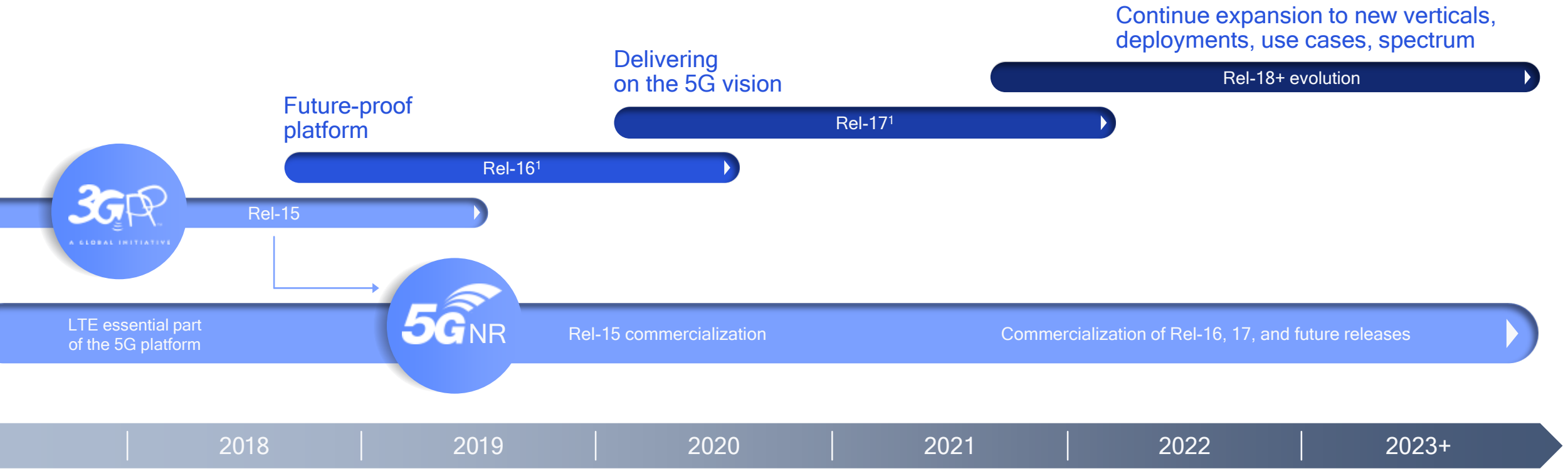
$13.2 Trillion in global economic value by 2035*

* The 5G Economy, an independent study from IHS Markit, Penn Schoen Berland and Berkeley Research Group, commissioned by Qualcomm

Sources - 5G commercial networks and operators investing in 5G: GSA and operator announcements, Apr. '19; 5G device shipment projections: Qualcomm estimates (2020 projection is at mid-point of guidance range), Nov. '19; 5G connection projections: 2023 - GSMA Intelligence (Dec. '19); ABI (Nov. '19); 2025 - ABI (Oct. '19), CCS Insight (Oct. '19), Ericsson (Nov. '19)

5G momentum accelerating globally

Driving the 5G technology evolution



Rel-15 eMBB focus

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

Rel-16 industry expansion

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

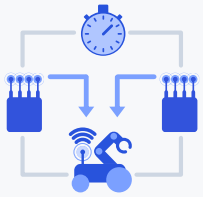
Rel-17+ long-term expansion

- Lower complexity NR-Light
- Boundless extended reality (XR)
- Higher precision positioning and more…

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

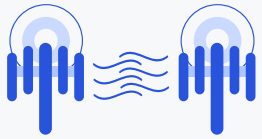
Building on the technology foundation for the 5G expansion

High-precision positioning
Accurate indoor and outdoor positioning



Mission-critical design
Ultra-high reliability of up to 99.9999%

Unlicensed spectrum
Improved capacity and new use cases



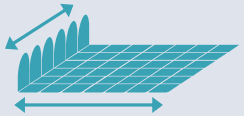
New deployment models
New deployments e.g., IIoT and enterprise

Advanced power saving and mobility
Better device performance and coverage

Expanded 5G foundation in Release 16

Sidelink
Advanced safety use cases

5G NR Release 15 technology foundation

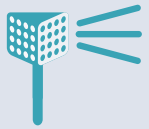


Flexible slot-based framework

Scalable numerology

Advanced channel coding

Massive MIMO



Mobile mmWave

Expanding the reach of 5G

Automotive
Positioning
Massive IoT
Private networks
Unlicensed spectrum
Time synchronization
Broadcast
Industrial IoT
Sidelink
Satellites

Driving foundational enhancements

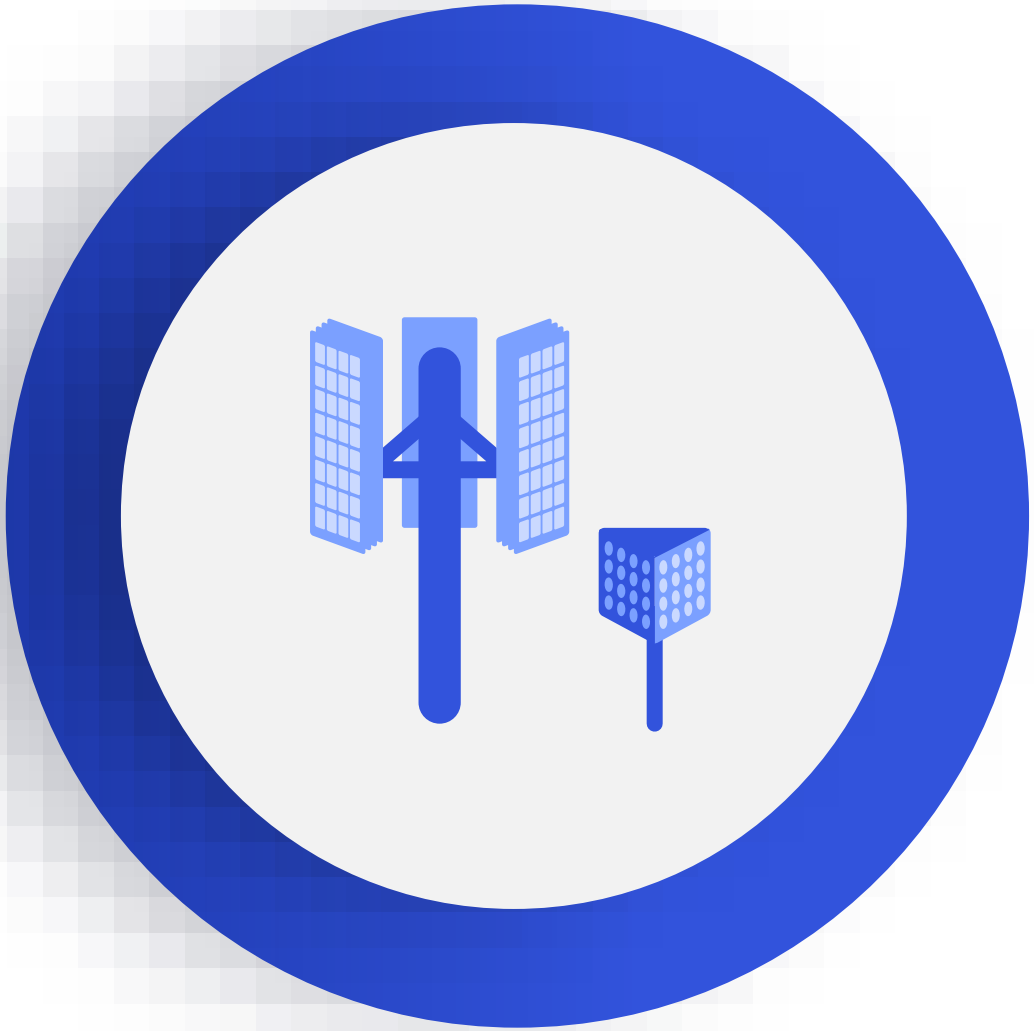
Wider coverage
Higher reliability
More capacity
Lower latency
Better mobility
Interference mitigation
Power saving
Simpler deployment

3GPP Release 16 elevates 5G to the next level

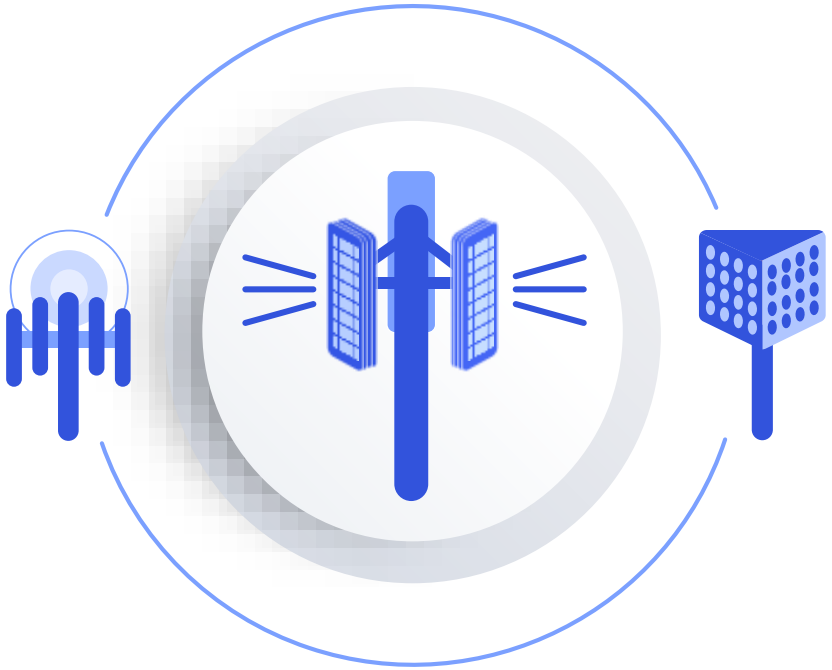
New capabilities, efficiencies, flexibilities, deployments, and spectrum types/bands

Driving foundational enhancements

3GPP Release 16



Enhancing 5G NR massive MIMO performance



Release 16 MIMO Enhancements[1]

Improving performance, efficiency, reliability

Enhanced multi-user MIMO

Reducing overhead and supporting Rank 4 MIMO, finer quantization and PMI[2] granularity by improving Type II CSI[3]

Multi-transmission/reception points

Improving reliability by allowing device to transmit and receive[4] data to/from multiple base stations

Better multi-beam management

Supporting secondary cell beam failure recovery, interference-aware beam selection, overhead reduction

Improved power efficiency

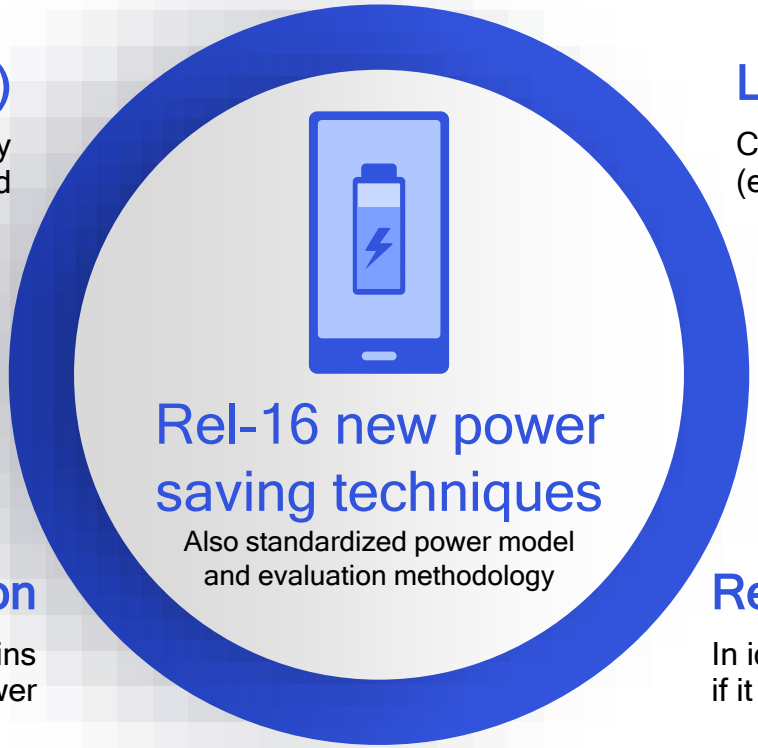
Reducing PAPR (peak-to-average ratio) with improved uplink and downlink reference signal[5]

Extended uplink coverage

Achieving full-power uplink for all MIMO capable devices[6]

1 Also includes LTE MIMO enhancements, such as improved SRS capacity and coverage; 2 Precoding Matrix Indicator; 3 Channel State Information, similar overhead yields 15% improvement in CSI performance compared to R15 Type II CSI design; 4 Supporting SDM, FDM, and TDM transmissions with single or multi DCI (DL control information); 5 OFDM for PDSCH & PUSCH and DFT-S for PUSCH & PUCCH; 6 For single layer MIMO, for low-complexity MIMO non-/partially coherent devices

Further enhancing device power efficiency



Rel-16 new power saving techniques

Also standardized power model and evaluation methodology

Wakeup signal (WUS)

A low-power control channel to indicate activity or lack thereof in the corresponding DRX[1] period

Low power mode groups

Carriers can be configured with different DRX duration (e.g., shorter active time for mmWave vs. sub-7 GHz)

Enhanced cross-slot scheduling

Such as introducing explicit minimum scheduling offset parameter and better support for BWP[2] switching

Device-assisted power saving

Devices can request preferred power saving parameters (e.g., DRX, # of carriers, max bandwidth)

Adaptive MIMO layer reduction

Supporting turning off transmit/receive chains (e.g., from 4 to 2) to save power

Relaxed radio resource management

In idle or inactive mode, device can relax measurements if it has low mobility or is not at the cell edge

Low-power carrier aggregation control

Efficient activation and deactivation of secondary cell is controlled by the primary cell

1 Discontinued reception; 2 Bandwidth part; 3 Carrier aggregation

Rel-16 brings 5G NR mobility enhancements

Also further enhancing LTE mobility management

Reduced interruption time

0ms handover enabled by dual active protocol stack with concurrent source/target cell transmissions/reception

Improved mobility robustness

Device-driven conditional handover for single and dual connectivity, and fast handover failure recovery

Sub-7 GHz and mmWave

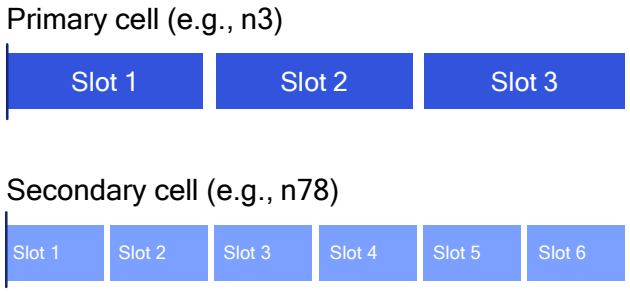
Both inter- and intra-frequency handovers

Beneficial to high-mobility use cases (e.g., train, aerial)

Further improving 5G NR spectrum aggregation

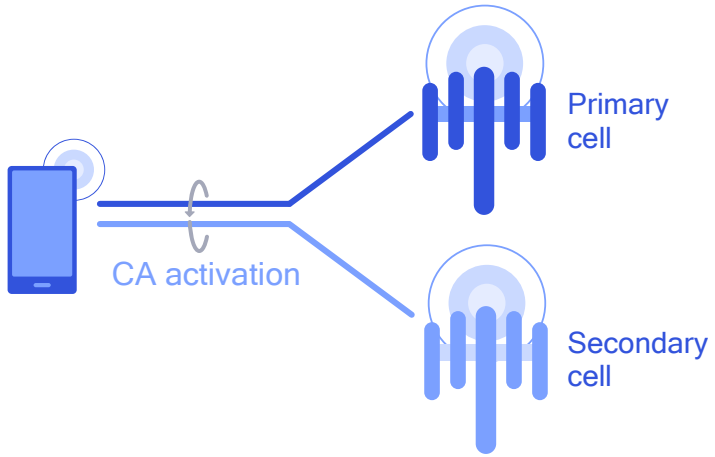
Carrier aggregation (CA) and dual connectivity (DC)

Enhancing Rel-15 CA/DC capability and performance



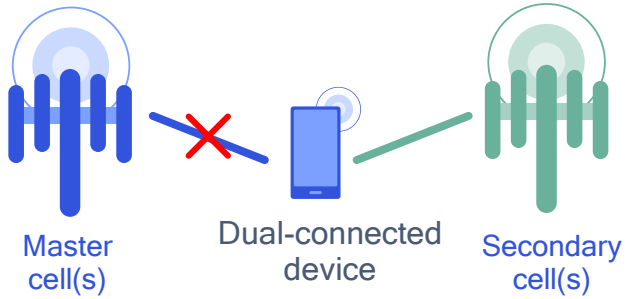
Supporting cross-carrier scheduling & CSI trigger w/ different numerologies, enhanced single Tx switching, async DC with NR power sharing, and unaligned CA

Early measurements and faster CA/DC activation



Defining configuration, signaling, reporting procedure for early measurement, and blind resume, faster activation for secondary cell(s)

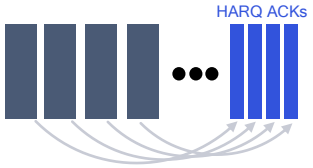
Faster link recovery in dual connectivity



Improving robustness in case of master cell(s) failure when link to secondary cell(s) is still available

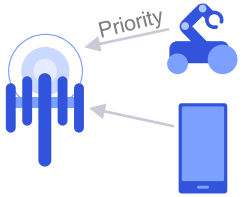
Enhancing ultra-reliable, low-latency communication

Rel-16 eURLLC builds on Rel-15 URLLC foundation



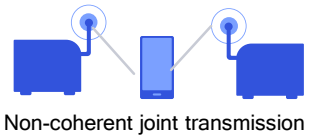
Improved HARQ

Multiple HARQ-ACK feedbacks per slot for latency reduction



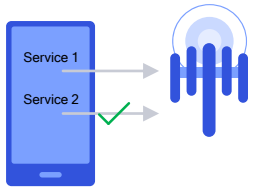
Inter-device service multiplexing

Uplink cancellation indicator and power boosting



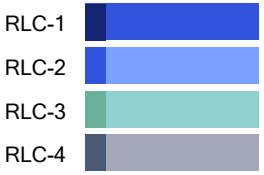
Coordinated multi-point (CoMP)

Multi-TRP[1] for redundant communication paths with spatial diversity



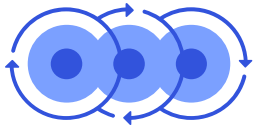
Intra-device channel prioritization

Concurrently supporting differentiated levels of service (e.g., eMBB & mission-critical)



Increased redundancy

Number of PDCP[2] packet duplicates increasing to 4 from 2



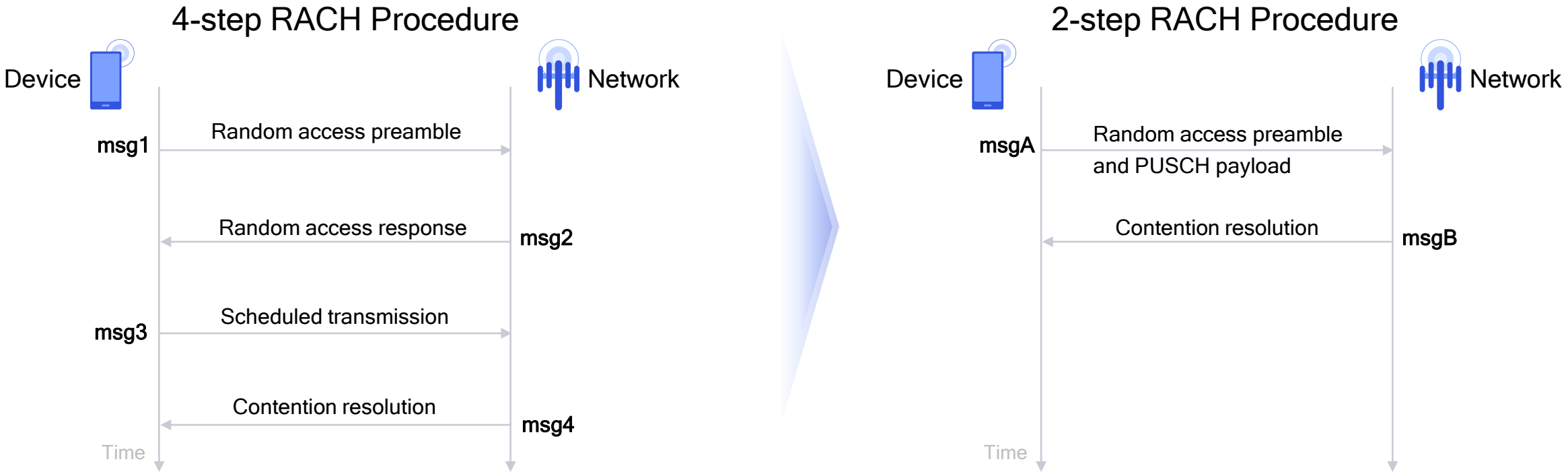
More flexible scheduling

Multiple active SPS[3] configurations & reduced periodicity, more efficient DL control monitoring, UL repetition with cross-slot boundaries

1. Multiple transmission and reception points; 2 Packet Data Convergence Protocol; 3 Semi-persistent scheduling

Two-step random access (RACH) procedure enhances efficiency

Over existing 5G NR Rel-15 four-step RACH procedure



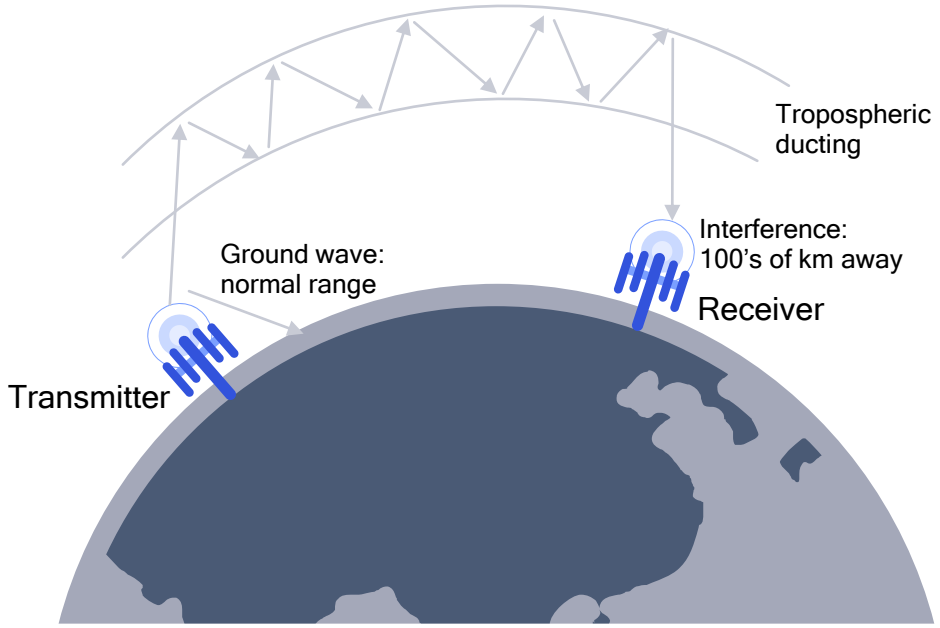
Reduces signaling overhead and latency

Improves capacity and power efficiency

Supports small grant-free uplink

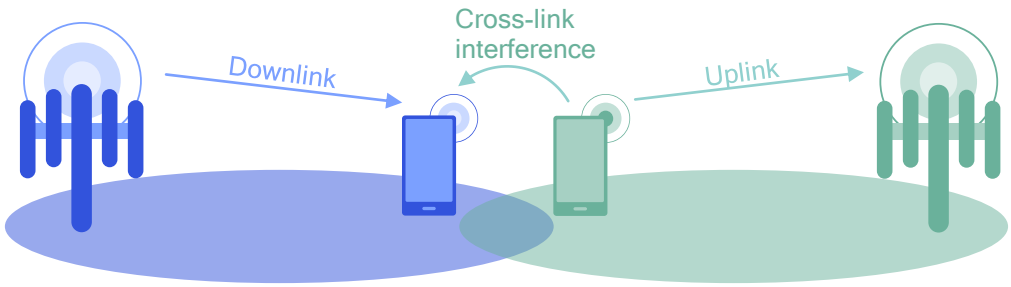
Addressing interferences to improve system reliability

Remote Interference Mitigation (RIM)



Base stations can communicate and coordinate[1] mitigation of base station TDD DL-to-UL ducting interferences[2]

Cross-Link Interference (CLI)

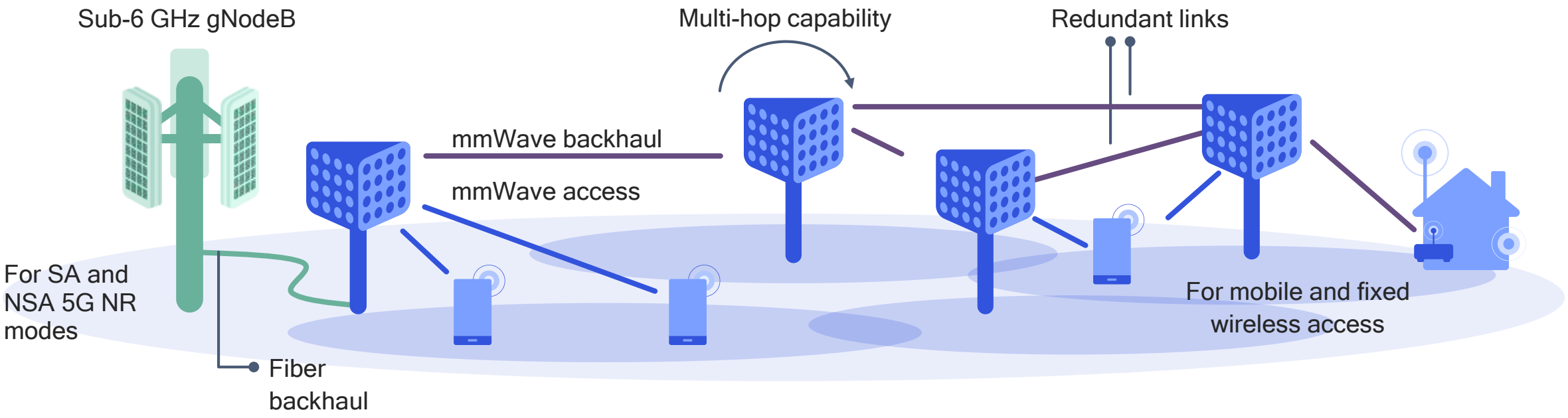


Devices can measure and report inter-/intra-cell interferences[3] caused by neighboring devices with different TDD configurations

1 Via reference signals (RIM-RS) over-the-air or in combination with backhaul signaling; 2 To indicate the presence of interference and whether enough mitigation is in place; 3 Inter-cell: when devices have semi-static TDD scheduling, Intra-cell: when devices support dynamic TDD

5G NR mmWave IAB[1] for cost-efficient dense deployments

Improves coverage and capacity, while limiting backhaul cost



1 Integrated Access and Backhaul

Traditional fiber backhaul can be expensive for mmWave cell sites

- mmWave access inherently requires small cell deployment
- Running fiber to each cell site may not be feasible and can be cost prohibitive
- mmWave backhaul can have longer range compared to access
- mmWave access and backhaul can flexibly share common resources

Improving uplink performance in higher bands

Single and dual uplink switching

Device can switch between 2 modes of uplink transmission

- Mode 1[1]: 1 Tx on carrier 1 and 1 Tx on carrier 2
- Mode 2: 0 Tx on carrier 1 and 2 Tx on carrier 2

Rel-16 Single/dual Uplink Switching

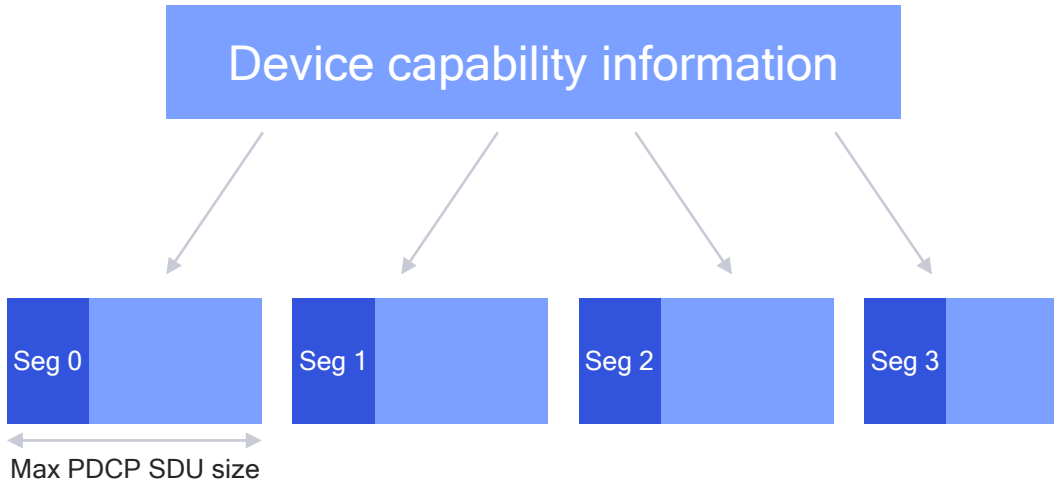
Supporting inter-band aggregation

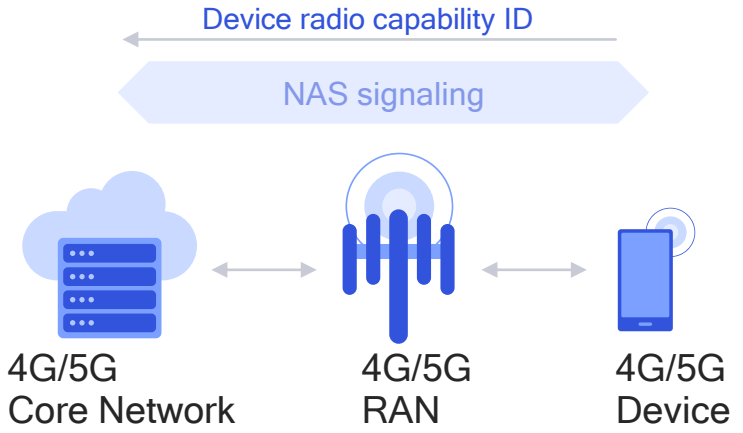
- Uplink carrier aggregation
- Supplemental uplink (SUL) without LTE/NR DC
- LTE/NR DC without SUL

1 Applicatble to UL CA and LTE/NR DC; for SUL, 1 Tx in carrier 1 and 0 Tx in carrier 2

Improving efficiency of radio access capability signaling

To address rapid increase in device capability size due to more band combinations and features





Uplink RRC message segmentation

Overcoming the maximum PDCP SDU[1] size (i.e., 9kB defined in 5G NR) by dividing device capability information into multiple smaller segments

Device radio capability ID

Identifying device's radio capability, stored in the network, which can be assigned by device manufacturer or serving network

1. Packet Data Convergence Protocol Service Data Unit

Maintaining call continuity with circuit-switched fallback

Defining fallback procedures from 5G NR to circuit-switched 3G FDD network

Applying to also emergency (E911) calls

Excludes 3G TDD network support, packet switched and video service continuity

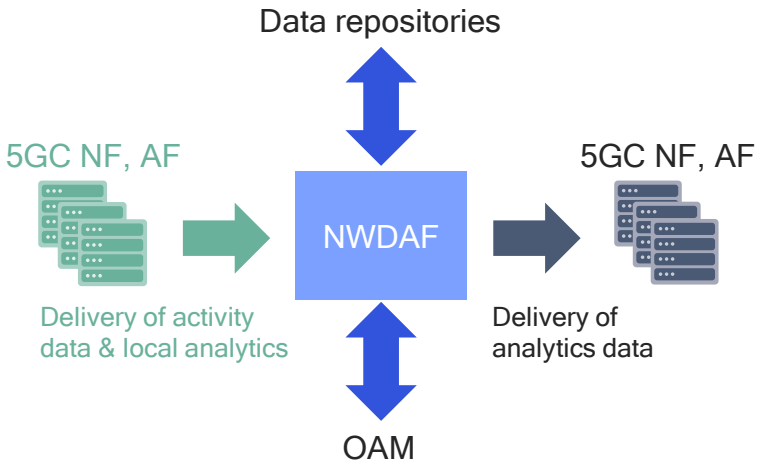
For VoNR deployments with limited or no VoLTE coverage

Data collection for network performance enhancements

Part of 3GPP Release 16

Enhanced Network Automation (eNA)

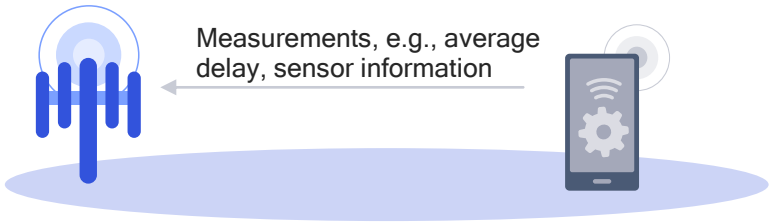
New enhanced core network function for data collection and exposure



Expanding NWDAF[1] from providing network slice analysis in Rel-15 to data collection and exposure from/to 5G core NF, AF, OAM[2], data repositories

Minimization of Drive Testing (MDT)

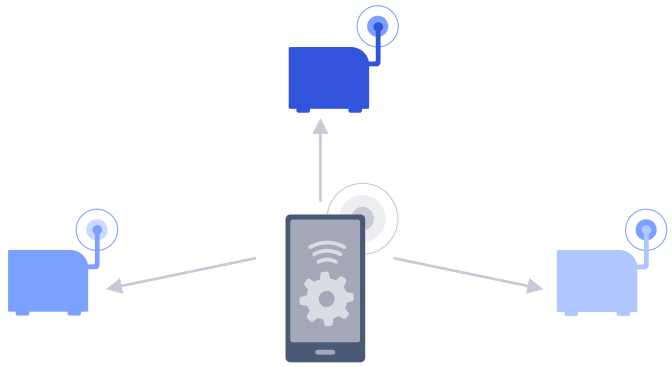
Logged and immediate MDT, mobility history information, accessibility & L2 measurements[3]



Specifying features for identified use cases, including coverage, optimization, QoS verification, location information reporting, sensor data collection

Self Organizing Network (SON)

Mobility robust optimization (MRO), mobility load balancing (MLB), and RACH optimization



Specifying device reporting needed to enhance network configurations and inter-node information exchange (e.g., enhancements to interfaces like N2, Xn)

1 NWDAF – Network Data Analytics Function; 2 Network Function, Application Function, Operations Administration and Maintenance; 3 For standalone and dual connected 5G NR systems

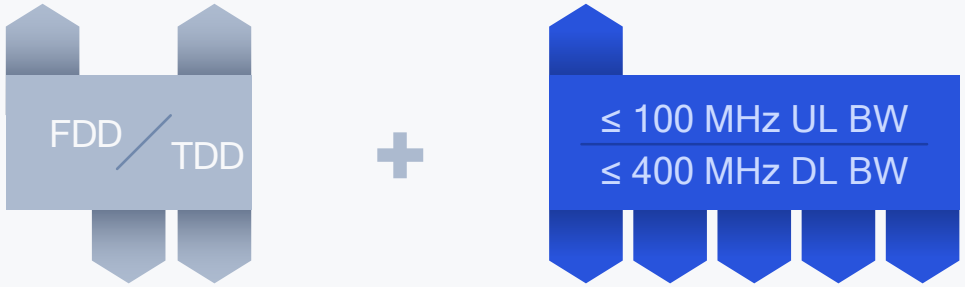
Expanding the reach of 5G

3GPP Release 16

Rel-16 introduces NR in unlicensed spectrum

Anchored NR-U

Unlicensed spectrum is combined with other licensed or shared spectrum as anchor



Licensed or shared anchor spectrum

Unlicensed NR-U spectrum*

Standalone NR-U

Only unlicensed spectrum is used

Unlicensed NR-U spectrum*

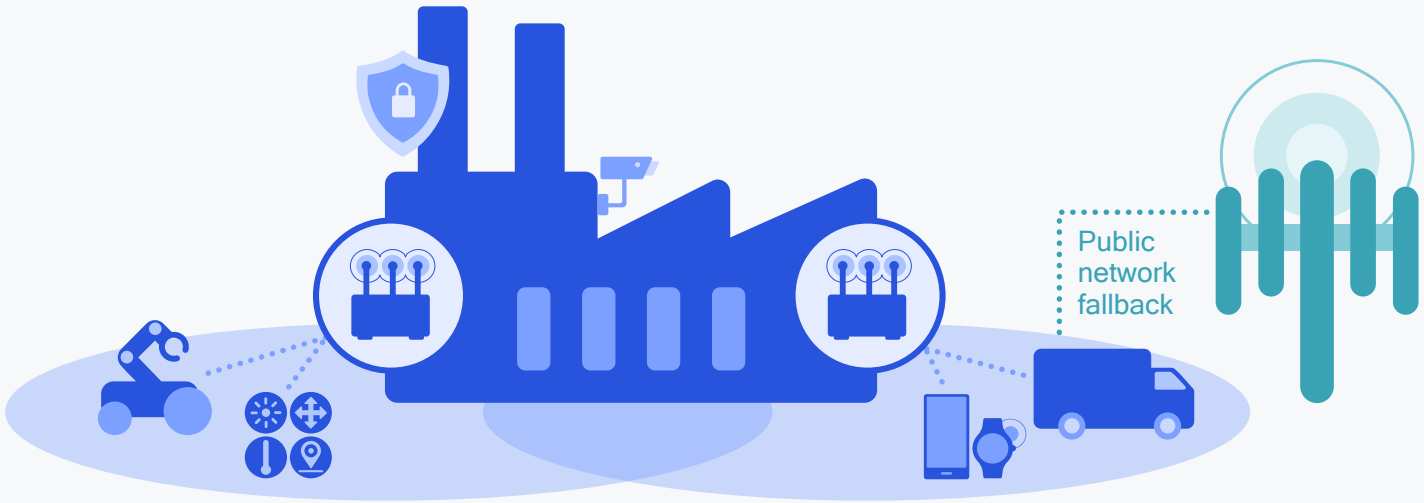
* Still under discussion in Rel-16

Unlock more spectrum globally

New markets and verticals

New deployment scenarios

5G private networks brings benefits to industrial IoT



Private network[1]

Dedicated

Local network, dedicated resources, independently managed

Secure

Cellular grade security, sensitive data stays on-premise

Optimized

Tailored performance for local applications, e.g., low latency, QoS[2], APIs for managed 3rd party access

5G

Coverage, capacity, and, mobility

Outdoor/indoor, high data speeds, seamless handovers, public network fallback

Reliability and precise timing

Industrial grade reliability, latency and synchronization (eURLLC[3] and TSN[4])

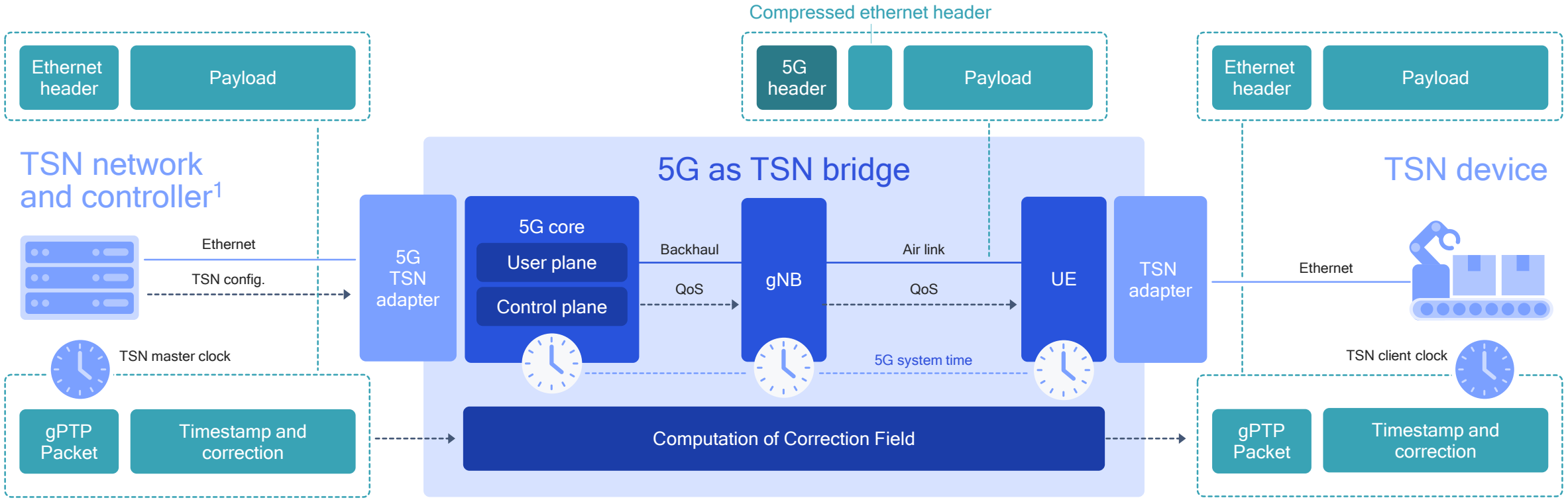
Interoperability

Global standard, vast ecosystem, future proof with rich 5G roadmap

1. Also referred to as non-public network (NPN); 2. Quality of service; 3. Enhanced ultra-reliable low-latency communication; 4 Time sensitive network

5G brings support for Time Sensitive Networking (TSN)

A requirement for industrial automation and many other industrial IoT applications



1 The TSN network is controlled by a Central Network Controller (CNC). TSN and CNC are defined in a set of standards specified by IEEE 802.1.

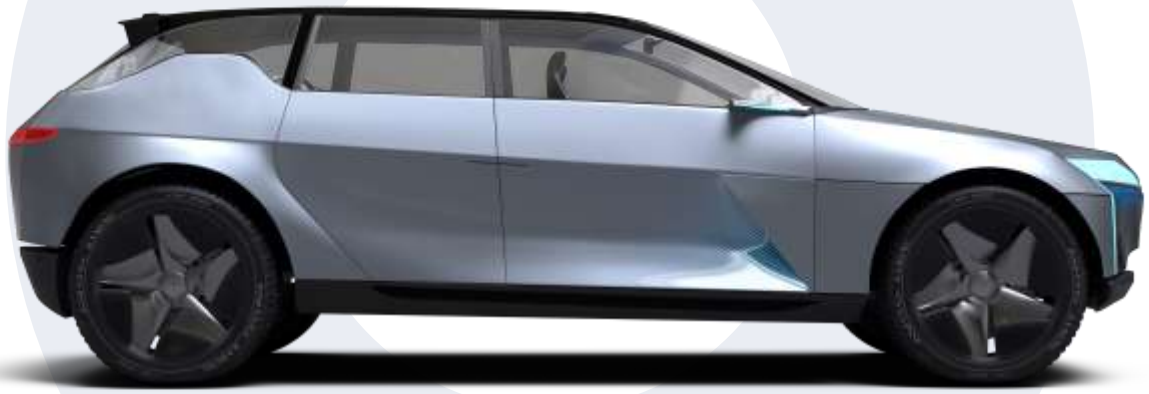
5G TSN adapters allow the 5G system to act as a TSN bridge with Ethernet connectivity

Mapping of TSN configurations to 5G QoS framework for deterministic messaging and traffic shaping

Precise time synchronization with generalized Precision Time Protocol (gPTP) at microsecond level

5G V2X sidelink

Release 16 brings new benefits for automotive use cases



Sidelink communications

Vehicle to vehicle (V2V)

Vehicle to infrastructure (V2I)

Other communication modes coming in future releases

Enhanced autonomous driving

Real-time situation awareness and sharing of new kinds of sensor data enhances autonomous driving

Faster travel / energy efficiency

More coordinated driving for faster travel and lower energy usage

Accelerated network effect

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

Sidelink also essential for other use cases such as public safety, data offload

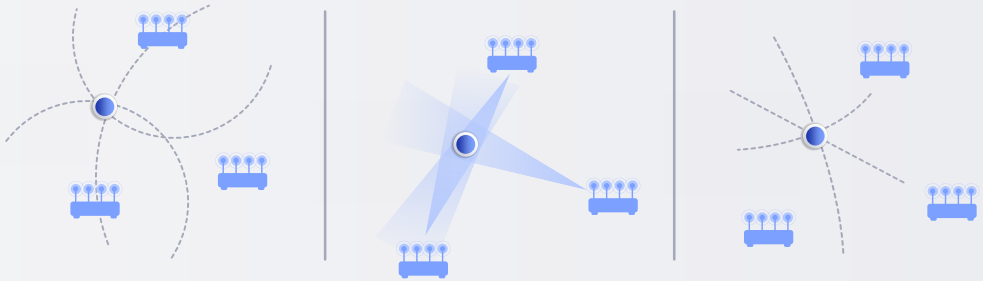
Rel-16 established the baseline for 5G-based positioning

New PRS[1] for devices to detect/measure more neighboring TRPs[2]

Meeting initial 5G positioning accuracy requirements[3]

3m (indoor) to 10m (outdoors) for 80% of time

Multi-cell positioning

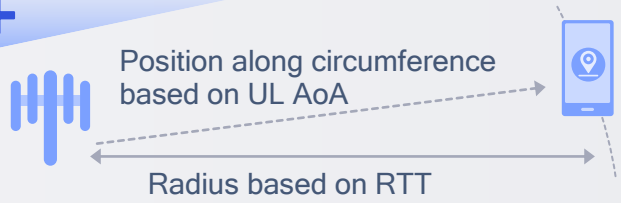


Roundtrip time (RTT)

Angle of arrival / departure (AoA/AoD)

Time difference of arrival (TDOA)

Single-cell positioning



New evaluation scenarios

Supporting new channel models for industrial IoT environment

Enhancing positioning accuracy, latency, and capacity in Rel-17+

1 Positioning Reference Signal; 2 Transmission Points; 3 5G positioning requirements defined in TS 22.261

enTV is evolving in Rel-16 to become 5G broadcast

Fulfilling all 5G requirements[1] defined for broadcast

enTV evolution timeline

2017	2018	2019	2020	2021+
Rel-14 completed new broadcast design that met many 5G requirements	5G broadcast included as part of the Rel-16 project package in RAN#78	Rel-16 Study Item – a gap analysis – was completed in March	Rel-16 Work Item was completed in June	Rel-17+ will further broaden 5G broadcast / multicast capabilities

Rel-16 enTV – 5G Broadcast – focuses on supporting more diverse deployments

- Add support for MPMT[2] and HPHT[3] deployments with rooftop reception (CP[4] of 300µs)
- Enhance support for high speed (~250km/h) in car-mounted LPLT[5] deployment (CP of 100µs)
- Other potential enhancements are captured in TR 36.776 (SI) and RP-190732 (WI).

1 Defined in 3GPP TS 38.913; 2 Medium Power Medium Tower (50km ISD, 60 dBm, 100m height); 3 High Power High Tower (125km ISD, 70 dBm, 300m height); 4 Cyclic Prefix; 5 Low Power Low Tower (15km ISD, 46 dBm, 35m height)

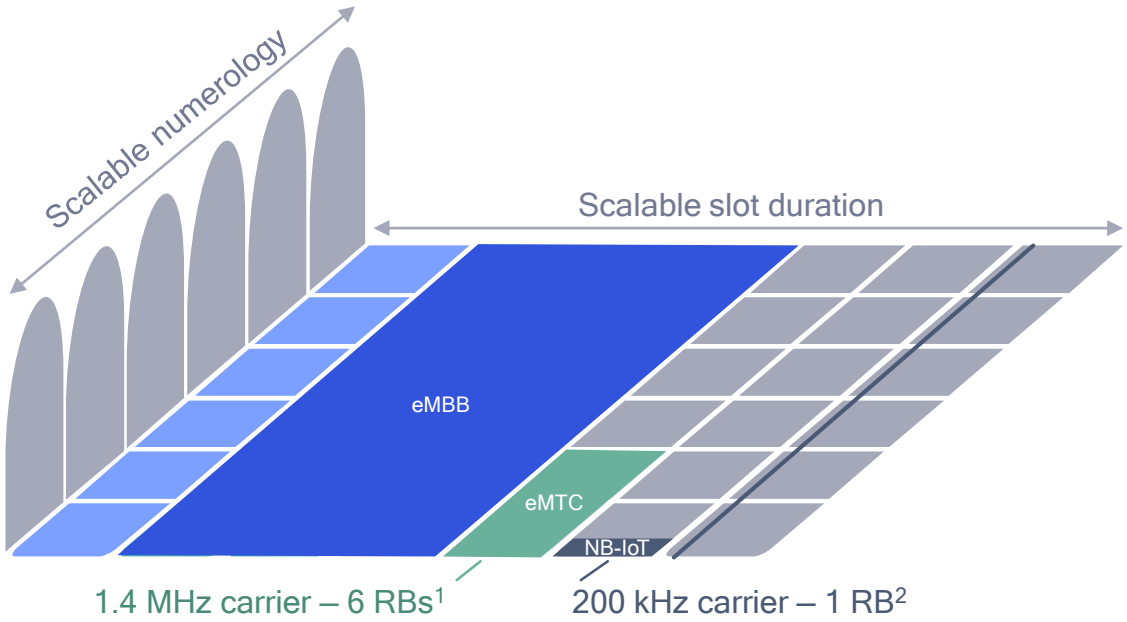
Wide ecosystem support in 3GPP

List of supporting individual members in RP-193050

Academy of Broadcasting Science, BBC, Bittium Wireless, BMWi, British Telecom, Cellnex Telecom, CHTTL, Dish, European Broadcast Union, European Space Agency, ENENSYS Technologies, Expway, Fraunhofer IIS, Fraunhofer HHI, IRT, Nomor, Nokia, Nokia Shanghai Bell, One2many, Qualcomm, Rohde & Schwarz, Samsung, Shanghai Jiao Tung University, Telstra, University of the Basque Country

Evolving eMTC & NB-IoT for 5G massive IoT

Part of 3GPP Release 16



In-band eMTC / NB-IoT in 5G carrier

5G NR 2^n scaling of 15 kHz subcarrier spacing is natively compatible with eMTC and NB-IoT numerologies

5G core network support

For deploying eMTC and NB-IoT in networks operating in 5G NR standalone mode (SA) with a common core network

Further enhanced efficiency

Group wakeup signal, preconfigured uplink, multi-block scheduling, early data transmission, mobility enhancements

1. Cat-M1 uses 6 Resource Blocks (RBs) with 12 tones per RB at 15 kHz SCS; 2. Cat-NB1 uses 1 Resource Block (RB) with 12 tones with 12 tones per RB at 15 kHz SCS, single-tone option also available

Flexible framework designed to support future evolution addressing even broader IoT use cases

3GPP Release 17 accelerates the expansion of 5G

Continued eMBB enhancements, e.g., mobility, coverage, more[1]

New spectrum above 52.6 GHz

More capable, flexible IAB

Enhancements to 5G NR IIoT

Expanded sidelink, e.g., V2X reliability, P2V

Unlicensed spectrum across all use cases

NR-Light for wearables, industrial sensors, and enhanced massive IoT[2]

Positioning with cm-level accuracy

Extended reality

Rel-15 deployment learning, others[3]

1. Further improvements to capacity, power consumption, spectral efficiency; 2. Including eMTC and NB-IoT in 5G NR; 3. mixed-mode multicast, small data transmission, multi-SIM, satellite, multimedia

Learn more by visiting our OnQ blog post:
"3GPP charts the next chapter of 5G standards"
https://www.qualcomm.com/news/onq/2019/12/13/3gpp-charts-next-chapter-5g-standards

Intelligently connecting

our world in the 5G era

A unified connectivity fabric this decade

5G

Strong 5G momentum sets the stage for the global expansion

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

Historically 10 years between generations

Qualcomm

Thank you!

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