Propelling 5G forward
A closer look at 3GPP Release 16
Mobile has made a leap every ~10 years

1G
Mobile voice communication
1980s
Analog voice
AMPS, NMT, TACS

2G
Efficient voice to reach billions
1990s
Digital voice
D-AMPS, GSM, IS-95 (CDMA)

3G
Focus shifts to mobile data
2000s
Wireless Internet
CDMA2000/EV-DO WCDMA/HSPA+

4G
Mobile broadband and emerging expansion
2010s
Mobile broadband
LTE, LTE Advanced, Gigabit LTE

5G
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
5G momentum accelerating globally

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)
Delivering on the 5G vision

Future-proof platform

Rel-16

Rel-17

Rel-18+

Continue expansion to new verticals, deployments, use cases, spectrum

13GPP 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

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...
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
- **Sidelink**: Advanced safety use cases

5G NR Release 15 technology foundation

- **Flexible slot-based framework**
- **Scalable numerology**
- **Advanced channel coding**
- **Massive MIMO**
- **Mobile mmWave**
3GPP Release 16 elevates 5G to the next level

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

Expanding the reach of 5G

- Automotive
- Industrial IoT
- Positioning
- Sidelink
- Massive IoT
- Satellites
- Broadcast

Driving foundational enhancements

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

Power saving
Unlicensed spectrum
Time synchronization
Private networks
Sidelink
Satellites
Driving foundational enhancements

3GPP Release 16
Enhancing 5G NR massive MIMO performance

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\(^6\)

Release 16 MIMO Enhancements\(^1\)
Improving performance, efficiency, reliability

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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

- **Wakeup signal (WUS)**
  A low-power control channel to indicate activity or lack thereof in the corresponding DRX\(^1\) period

- **Enhanced cross-slot scheduling**
  Such as introducing explicit minimum scheduling offset parameter and better support for BWP\(^2\) switching

- **Adaptive MIMO layer reduction**
  Supporting turning off transmit/receive chains (e.g., from 4 to 2) to save power

- **Rel-16 new power saving techniques**
  Also standardized power model and evaluation methodology

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

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

- **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

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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

Early measurements and faster CA/DC activation

Faster link recovery in dual connectivity

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

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

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

**Coordinated multi-point (CoMP)**
Multi-TRP¹ for redundant communication paths with spatial diversity

**Increased redundancy**
Number of PDCP² packet duplicates increasing to 4 from 2

**Improved HARQ**
Multiple HARQ-ACK feedbacks per slot for latency reduction

**Coordinated multi-point (CoMP)**
Multi-TRP¹ for redundant communication paths with spatial diversity

**Increased redundancy**
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**Inter-device service multiplexing**
Uplink cancellation indicator and power boosting

**Intra-device channel prioritization**
Concurrently supporting differentiated levels of service (e.g., eMBB & mission-critical)

**More flexible scheduling**
Multiple active SPS³ configurations & reduced periodicity, more efficient DL control monitoring, UL repetition with cross-slot boundaries

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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)

- Via reference signals (RIM-RS) over-the-air or in combination with backhaul signaling
- To indicate the presence of interference and whether enough mitigation is in place

Cross-Link Interference (CLI)

- Inter-cell: when devices have semi-static TDD scheduling
- Intra-cell: when devices support dynamic TDD

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

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

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

\(^1\) Integrated Access and Backhaul
Improving uplink performance in higher bands

Single and dual uplink switching

Device with 2 Tx chain

Carrier 2: higher TDD band (e.g., n78 – 3.5 GHz)

Carrier 1: lower FDD band (e.g., n1 – 2.1 GHz)

Device can switch between 2 modes of uplink transmission

- Mode 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

Supporting inter-band aggregation

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

1 Applicable 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 SDU¹ 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

Voice-over-NR (VoNR) is supported in 3GPP Release 15+

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

**Minimization of Drive Testing (MDT)**
Logged and immediate MDT, mobility history information, accessibility & L2 measurements

**Self Organizing Network (SON)**
Mobility robust optimization (MRO), mobility load balancing (MLB), and RACH optimization

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

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

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

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

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

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 V2X sidelink

Release 16 brings new benefits for automotive use cases

- **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 communications**

- Vehicle to vehicle (V2V)
- Vehicle to infrastructure (V2I)
- Other communication modes coming in future releases

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
- Position along circumference based on UL AoA
- Radius based on RTT

New evaluation scenarios
Supporting new channel models for industrial IoT environment

5G Positioning
Enhancing positioning accuracy, latency, and capacity in Rel-17+

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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

- **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).

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\(^1\) 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)

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Wide ecosystem support in 3GPP

List of supporting individual members in RP-193050
Evolving eMTC & NB-IoT for 5G massive IoT

Part of 3GPP Release 16

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

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
3GPP Release 17 accelerates the expansion of 5G

- Continued eMBB enhancements, e.g., mobility, coverage, more
- 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
- Positioning with cm-level accuracy
- Extended reality
- Rel-15 deployment learning, others

Learn more by visiting our OnQ blog post: “3GPP charts the next chapter of 5G standards”
Intelligently connecting our world in the 5G era

A unified connectivity fabric this decade

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