Making 5G NR a Commercial Reality
A unified, more capable 5G air interface
A unifying connectivity fabric for society
Like electricity, you will just expect it everywhere
Designing a unified, more capable 5G air interface

Diverse services

- Enhanced mobile broadband
- Mission-critical services
- Massive Internet of Things

Diverse spectrum

- High-bands: Above 24 GHz (mmWave)
- Mid-bands: 1 GHz to 6 GHz
- Low-bands: Below 1 GHz

Licensed/shared/unlicensed

Diverse deployments

Existing, emerging, and unforeseen services - a platform for future innovation
5G will address the insatiable demand for mobile broadband

Over 60x growth in mobile data traffic from 2013 to 2024

~136B Gigabytes
Monthly global mobile data traffic in 2024

In 2024, ~75% of mobile data traffic from multi-media creation & consumption

In 2024, 25% of mobile data traffic will be carried by 5G networks – 1.3x more than 4G/3G/2G traffic today

Source: Ericsson Mobility Report November 2018
5G is essential for next generation mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- More consistent performance
- Massive capacity for unlimited data
5G will expand the mobile ecosystem to new industries

Powering the digital economy

>$12 Trillion

In goods and services by 2035

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

Rel-15 | Rel-16 | Rel-17+ evolution
---|---|---
Standalone (SA) | Non-Standalone (NSA) | 5G NR Commercialization
Field trials | 5G NR Commercialization | Rel-17+

Rel-15 Commercialization:
- eMBB deployments in both mmWave and sub-6 GHz.

Rel-16 Commercialization:
- New 5G NR technologies to evolve and expand the 5G ecosystem

Expanded ecosystem:
- Smartphone formfactor, Connected laptops, CPE fixed access
- Private networks, Indoor mmW for enterprises, Boundless XR
- Industrial IoT, Private network, 5G NR C-V2X
- Integrated Access and Backhaul, Unlicensed/shared spectrum
- Continued eMBB evolution

Continue to evolve LTE in parallel as essential part of the 5G Platform

5G will be a commercial reality in 2019.
Making 5G NR a commercial reality in 2019

- Industry-leading R&D
- Interoperable global standards
- End-to-end system prototypes
- Network and system simulations
- Interoperability testing and field trials
- Qualcomm® Snapdragon™ X50 5G modem & Snapdragon 855 Mobile Platform
- Commercial 5G NR mmWave networks and products

Qualcomm Snapdragon are products of Qualcomm Technologies, Inc. and/or its subsidiaries.
Our technology inventions drove Rel-15 specifications

Scalable OFDM-based air interface
- Scalable OFDM numerology
- Address diverse services, spectrum, deployments

Flexible slot-based framework
- Self-contained slot structure
- Low latency, URLLC, forward compatibility

Advanced channel coding
- Multi-Edge LDPC and CRC-Aided Polar
- Support large data blocks, reliable control channel

Massive MIMO
- Reciprocity-based MU-MIMO
- Large # of antennas to increase coverage/capacity

Mobile mmWave
- Beamforming and beam-tracking
- For extreme capacity and throughput

Early R&D investments | Best-in-class prototypes | Fundamental contributions to 3GPP
Scalable OFDM-based 5G NR air interface

Scalable numerology

- 2ⁿ scaling of sub-carrier spacing to efficiently support wider bandwidths

Frequency localization

- Windowing¹ can effectively minimize in-band and out-of-band emissions

Lower power consumption

- Single-carrier² OFDM utilized for efficient uplink transmissions

Asynchronous multiple access

- Can co-exist with optimized waveforms and multiple access for IoT UL³

 Qualcomm Research is a division of Qualcomm Technologies, Inc.

1. Such as Weighted Overlap Add (WOLA) utilized in LTE systems today. 2. DFT-Spread (DFT-S) OFDM. 3. Such as non-orthogonal Resource Spread Multiple Access (RSMA)

3GPP Rel-15 specifications aligned with Qualcomm Research whitepaper published Nov 2015 [link]
## Scalable 5G NR OFDM numerology—examples

### Outdoor macro coverage
- e.g., FDD 700 MHz
  - Sub-Carrier spacing, e.g. 15 kHz
  - Carrier bandwidth, e.g. 1, 5, 10 and 20 MHz
- Outdoor macro and small cell
  - e.g., TDD 3-5 GHz
  - Sub-Carrier spacing, e.g. 30 kHz
  - Carrier bandwidth, e.g. 100 MHz
- Indoor wideband
  - e.g., unlicensed 6 GHz
  - Sub-Carrier spacing, e.g. 60 kHz
  - Carrier bandwidth, e.g. 160 MHz
- mmWave
  - e.g., TDD 28 GHz
  - Sub-Carrier spacing, e.g. 120 kHz
  - Carrier bandwidth, e.g. 400 MHz

### 2^n scaling of Sub-Carrier Spacing (SCS)

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**Efficiently address 5G diverse spectrum, deployments and services**

Scaling reduces FFT processing complexity for wider bandwidths with reusable hardware
<table>
<thead>
<tr>
<th>Band</th>
<th>Licensed</th>
<th>Unlicensed/shared</th>
<th>Existing band</th>
<th>New 5G band</th>
</tr>
</thead>
<tbody>
<tr>
<td>600MHz (2x35MHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600MHz (2x35MHz)</td>
<td></td>
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<tr>
<td>700MHz (2x30 MHz)</td>
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<td>700MHz (2x30 MHz)</td>
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<tr>
<td>700MHz (2x30 MHz)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2.5GHz (LTE B41)</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**Designed for diverse spectrum bands/types**

**Global snapshot of 5G spectrum bands allocated or targeted**
Flexible slot-based 5G NR framework
Efficiently multiplex envisioned and future 5G services on the same frequency

Scalable slot duration
Efficient multiplexing of diverse latency and QoS requirements

Forward compatibility
Transmissions well-confined in time/frequency to simplify adding new features in future

Self-contained slot structure
Ability to independently decode slots and avoid static timing relationships across slots

Nominal traffic puncturing
To enable URLCC transmissions to occur at any time using mini-slots
Scalable 5G NR slot duration for diverse latency/QoS

1. As low as two symbols per mini-slot; 2. Symbols across numerologies align at symbol boundaries and transmissions span an integer # of OFDM symbols

- **14 OFDM symbols per slot with mini-slot (2, 4, or 7 symbols) for shorter transmissions**
- **Supports slot aggregation for data-heavy transmissions**
- **Efficient multiplexing of long and short transmissions**

1. As low as two symbols per mini-slot; 2. Symbols across numerologies align at symbol boundaries and transmissions span an integer # of OFDM symbols
Flexible 5G NR slot structures – Examples

**TDD Self-Contained**
Opportunity for UL/DL scheduling, data and ACK/SRS in the same slot

- **DL**
  - DL Ctrl
  - DL Data
  - Guard
  - UL Ctrl

- **UL**
  - DL Ctrl
  - Guard
  - UL Data
  - UL Ctrl

**Data-centric**
More relaxed TDD timing configurations + FDD operation

- **DL**
  - DL Ctrl
  - DL Data

- **UL**
  - UL Data
  - UL Ctrl

**Mini-slot**
Optimized for shorter data transmissions, e.g. URLLC

- **DL**
  - DL
  - e.g., 2-symbol mini-slot

- **UL**
  - UL
  - e.g., 4-symbol mini-slot

**Blank slot**
Designed in a way not to limit future feature introductions

DL reference signals (DL DMRS) & UL Reference + Sounding (UL DSMR, SRS) not showed for simplicity
Benefits of the 5G NR TDD self-contained slot
Much faster, more flexible TDD switching and turn-around than 4G LTE

- **Flexibility for additional headers**
  E.g., channel reservation header for unlicensed/shared spectrum

- **More adaptive UL/DL**
  Faster TDD switching allows for more flexible capacity allocation

- **Low latency**
  Faster TDD turn-around, with opportunity for UL/DL scheduling, data and ACK in the same slot

- **Efficient massive MIMO**
  Optimized TDD channel reciprocity with opportunity for SRS every slot
5G NR TDD self-contained slot structure in action

Three examples showcasing faster TDD switching for low latency

1. Indoor (sub-6 or mmWave)
   - Shorter guard for indoor deployment
   - Fast turn-around (DL/UL switch per slot)
   - Ultra-low latency possible on every slot
   - Maximum flexibility for UL/DL allocation

2. Outdoor (sub-6 or mmWave)
   - Larger guard for outdoor deployment
   - DL/UL switch per 1ms (5x faster than LTE)
   - Slot 1 opportunity for ultra-low latency
   - Bulk of UL traffic goes on Slot 3

3. Outdoor mmWave
   - Larger guard for outdoor deployment
   - 6:2 configuration every 1ms (120kHz SCS)
   - Slot 3 opportunity for ultra-low latency
   - Bulk of UL traffic goes on Slots 6 & 7

DL reference signals (DL DMRS) & UL Reference + Sounding (UL DSMR, SRS) not showed for simplicity
5G NR flexible FDD slot structure
Delivering low latency, extended coverage, and forward compatibility

FDD baseline for continuous transmission and extended coverage

- FDD full DL Slot: DL Ctrl, DL Data
- FDD full UL Slot: UL Ctrl, UL Data

FDD partial slot for faster DL/UL turn-around and efficient half-duplex FDD implementation

- FDD partial DL Slot: DL Ctrl, DL Data
- FDD partial UL Slot: UL Ctrl, UL Data
Advanced ME-LDPC\(^1\) channel coding is more efficient than LTE Turbo code at higher data rates.

Selected as 5G NR eMBB data channel as part of 3GPP Release-15

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**High efficiency**
Significant gains over LTE Turbo—particularly for large block sizes suitable for MBB

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**Low complexity**
Easily parallelizable decoder scales to achieve high throughput at low complexity

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**Low latency**
Efficient encoding/decoding enables shorter transmission time at high throughput

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1. Multi-Edge Low-Density Parity-Check
Performance gains of CRC-Aided Polar channel coding led to its adoption across many 5G NR control use cases

5G NR CRC-Aided (CA-Polar) design
Efficient construction based on single Cyclic Redundancy Check (CRC) for joint detection and decoding

<table>
<thead>
<tr>
<th>Effective payload size (bits)</th>
<th>Required SNR (dB) for BLER = 0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>5</td>
</tr>
<tr>
<td>48</td>
<td>4</td>
</tr>
<tr>
<td>64</td>
<td>3</td>
</tr>
<tr>
<td>80</td>
<td>2</td>
</tr>
<tr>
<td>120</td>
<td>1</td>
</tr>
</tbody>
</table>

1. Parity-Check Polar channel coding
5G NR optimized design for massive MIMO
Key enabler for using higher spectrum bands, e.g. 4 GHz, with existing LTE sites

- Exploit 3D beamforming with up to 256 antenna elements
- Accurate and timely channel knowledge essential to realizing full benefits
- Mitigate UL coverage with 5G NR massive MIMO + HPUE

Enabled through an advanced 5G NR end-to-end Massive MIMO design (network and device)

- Optimized design for TDD reciprocity procedures utilizing UL SRS
- Enhanced CSI-RS design and reporting mechanism
- Advanced, high-spatial resolution codebook supporting up to 256 antennas
- New features, such as distributed MIMO

5G NR optimized design for TDD reciprocity procedures
5G NR slot structure and enhanced Ref Signals enable fast/accurate feedback

Step 1:
UL SRS\(^1\) → Precoding decision → DL Precoded CSI-RS\(^2\)

Step 2:
CSI-RS → UE CQI\(^3\) feedback

Step 3:
Precoding + CQI → Final scheduling decision

MIMO rate prediction latency reduced from >10 ms in LTE to 1 ms in 5G NR

*Sub-6 GHz, macro cell numerology, 30 kHz tone spacing; Channel sounding opportunity increases from <= 200 Hz with LTE to 2 kHz with 5G NR.
Faster, more uniform data rates throughout cell

**5G NR Massive MIMO increases coverage & capacity**

**Median Burst Rate**
- **5G NR Massive MIMO**: 195 Mbps
- **4x4 MIMO**: 52 Mbps

**Cell-edge Burst Rate**
- **5G NR Massive MIMO**: 79 Mbps
- **4x4 MIMO**: 27 Mbps

Assumptions: carrier frequency 4GHz; 200m ISD, 200MHz total bandwidth; base station: 256 antenna elements (x-pol), 48dBm Tx power; UE: 4 Tx/Rx antenna elements, 23dBm max. Tx power; full buffer traffic model, 80% indoor and 20% outdoor UEs.
Frankfurt Simulation
5G NR Sub-6 GHz Non-standalone (NSA)

Industry-first simulation of real world performance reveals immense 5G user experience gains over 4G

![Diagram showing performance gains]

Median burst rate
- 4G device in 4G network: 56 Mbps
- 4G device after 5G is deployed: 102 Mbps
- 5G device in 5G network: 493 Mbps

Cell-edge burst rate
- 4G device in 4G network: 20 Mbps
- 4G device after 5G is deployed: 39 Mbps
- 5G device in 5G network: 184 Mbps

Assumptions: Actual Frankfurt city layout; Max LTE bandwidth 80 MHz (carrier frequencies ranging from 700 MHz to 2.7 GHz); 5G NR total bandwidth 100 MHz (carrier frequency 3.5 GHz); Mix of macro and small cell base stations; Bursty Poisson traffic model; 50% indoor and 50% outdoor UE4; 75% LTE only devices / 25% 5G NR capable devices; NR TDD 3:1 DL/UL slot configuration. Burst rate comparisons are between LTE Cat-9 mainstream devices and 5G NR devices.
Industry-first simulation of 5G NR Standalone network

**DL median burst rate**

<table>
<thead>
<tr>
<th>4G device in 4G network</th>
<th>4G device after 5G is deployed</th>
<th>5G device in 5G network</th>
</tr>
</thead>
<tbody>
<tr>
<td>88 Mbps</td>
<td>102 Mbps</td>
<td>332 Mbps</td>
</tr>
</tbody>
</table>

**DL cell-edge burst rate**

<table>
<thead>
<tr>
<th>4G device in 4G network</th>
<th>4G device after 5G is deployed</th>
<th>5G device in 5G network</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 Mbps</td>
<td>51 Mbps</td>
<td>171 Mbps</td>
</tr>
</tbody>
</table>

**UL median burst rate**

<table>
<thead>
<tr>
<th>4G device in 4G network</th>
<th>4G device after 5G is deployed</th>
<th>5G device in 5G network</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Mbps</td>
<td>9 Mbps</td>
<td>122 Mbps</td>
</tr>
</tbody>
</table>

**UL cell-edge burst rate**

<table>
<thead>
<tr>
<th>4G device in 4G network</th>
<th>4G device after 5G is deployed</th>
<th>5G device in 5G network</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4 Mbps</td>
<td>1 Mbps</td>
<td>17 Mbps</td>
</tr>
</tbody>
</table>

Assumptions: Actual Tokyo city layout: Max LTE bandwidth 60 MHz in 2.5 GHz; 5G NR total bandwidth 100 MHz (carrier frequency 3.5 GHz). Mix of macro and small cell base stations; Bursty Poison traffic model; 50% indoor and 50% outdoor UEs; 75% LTE only devices / 25% 5G NR capable devices; NR TDD 3:1 DL/UL slot configuration. Burst rate comparisons are between LTE Cat-9 mainstream devices and 5G NR devices.
Significant 5G NR 3.5 GHz outdoor & indoor coverage via co-siting

Simulations based on over-the-air testing and channel measurements

Assuming minimum spectral efficiency of 0.3 bps/Hz over 100 MHz = ~30 Mbps at cell edge. With LTE, outdoor/indoor coverage for Korea city: 100%/96%, Japan city 100%/87%, Europe city 100%/80%
New frontier of mobile broadband – mobilizing mmWave

Vast amount of bandwidth that is ~25x more than what's being used for 3G/4G today

- Sub-6 GHz (e.g., 3.5 GHz)
- Millimeter wave (mmWave) (e.g., 24.25-27.5 GHz, 27.5-29.5 GHz)
- 6 GHz
- 24 GHz
- 100 GHz

Multi-Gbps data rates
With large bandwidths (100s of MHz)

Much more capacity
With dense spatial reuse

Lower latency
Opening up new opportunities
We are overcoming the mobile mmWave challenge
Proving the skeptics wrong about mmWave can never be used for mobile

**Significant coverage with co-siting**
Analog beamforming w/ narrow beam width to overcome path loss. Comprehensive system simulations reusing existing sites.

**Operating in LOS and NLOS**
Pioneered advanced beamforming, beam tracking leveraging path diversity and reflections.

**Overcoming the mobile mmWave challenge**

**Supporting robust mobility**
Robustness and handoff with adaptive beam steering and switching to overcome blockage from hand, head, body, foliage.

**Commercializing smartphone**
Announced modem, RF, and antenna products to meet formfactor and thermal constrains, plus device innovations.

1 LOS: Line of sight, NLOS: Non-line-of-sight
Mobilizing mmWave with 5G NR technologies

Key properties for robust mmWave operation in a NLOS mobile environment

- Very dense network topology and spatial reuse (~150-200m ISD)
- Fast beam steering and switching within an access point
- Architecture that allows for fast beam switching across access points
- Tight integration with sub-6 GHz (LTE or NR)
Empowering the 5G ecosystem

Advanced 5G Simulations

for network planning based on our extensive over-the-air testing and channel measurements

Collaborating with global operators to demonstrate significant 5G NR mmWave capacity & coverage

- Significant outdoor coverage, user experience and capacity gains utilizing existing LTE infrastructure (including LAA small cells for Gigabit LTE)
- Outdoor coverage only; frees up sub-6 GHz resources for out-to-indoor capacity
- Dual connectivity with LTE or aggregation with sub-6 GHz 5G NR ensures complete coverage

<table>
<thead>
<tr>
<th>Outdoor coverage</th>
<th>Increase in capacity</th>
<th>Cell edge burst rate</th>
<th>Median burst rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>62%</td>
<td>5x</td>
<td>320 Mbps</td>
<td>1.4 Gbps</td>
</tr>
</tbody>
</table>

1 Compared to Gigabit LTE only with additional 800 MHz spectrum in 28 GHz; 2 Cell edge defined as 0.4 bps/Hz = 320 Mbps for 8x100 MHz channel bandwidth
Significant 5G NR mmWave outdoor coverage via co-siting

Simulations based on over-the-air testing and channel measurements
Spectrum aggregation essential to 5G NR deployments

Dual Connectivity across LTE and NR
Fully leveraging LTE investments and coverage, including NSA operation for early 5G NR deployments

CA across spectrum bands
E.g., tight CA between 5G NR mmWave and sub-6 GHz to address mmWave coverage gaps

CA across FDD and TDD bands
Sub-1 GHz and mid/high band aggregation; supplemental uplink for better coverage, supplemental downlink for capacity

CA across spectrum types
E.g., Licensed and unlicensed with 5G NR Licensed Assisted Access (LAA) – approved Rel-15 Study Item

Carrier Aggregation (CA) and Dual Connectivity enable deployments with tightly and loosely coordinated cells

Building on solid LTE CA and Dual Connectivity foundation
Dual connectivity to fully leverage LTE investments

Gigabit LTE provides the coverage foundation for 5G eMBB

Existing deployments

Ubiquitous LTE coverage

640+ Commercial networks
9,500+ Commercial devices
2.3B+ LTE/LTE-A subscriptions

Gigabit LTE, VoLTE

5G augmented deployments

Seamless mobility
Simultaneous dual-connectivity across 5G NR and 4G LTE

Gigabit LTE, VoLTE

5G NR below 10 GHz

5G NR above 10 GHz

5G NR low/mid-band and LTE coverage

5G NR mmWave

Enabling gigabit experiences everywhere

Providing VoLTE leveraging LTE’s ubiquitous coverage

Supplementing 5G NR mid-band and mmWave

5G NR FDD/TDD CA to support mid-band deployments

Low-band FDD can help increase 5G NR TDD UL data rate/range\(^1\)

**5G NR mmWave**
- e.g., TDD 28 GHz

**5G NR mid-band**
- e.g., TDD 3-5 GHz

**Low-band**
- e.g., FDD 700 MHz

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### Non-Standalone (NSA)

Low-band LTE or NR UL can help increase UL data rate/range

- NR DL
- LTE DL
- NR UL
- LTE UL
- e.g. <1 GHz
- LTE Anchor

NR TDD, e.g. 3.5 GHz

### Standalone (SA)

NR low-band can carry NR uplink control and data for edge cell users

- NR DL
- NR UL
- e.g. <1 GHz

NR TDD, e.g. 3.5 GHz

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1 Thanks to less path loss and no DL:UL split - depends on massive MIMO, site density, TDD configuration
Non-Standalone (NSA) stepping stone to new core

- 4G Evolved Packet Core
- 4G Radio Network
- Data + control over 4G LTE link
- Dual connectivity
- Fast-to-launch | VoLTE & CS voice

Standalone (SA) for new core benefits

- New 5G Next Gen Core
- 5G mmWave
- 5G sub-6GHz
- Carrier Aggregation
- Data and control over 5G NR link
- NFV and SDN | VoNR & fallback to VoLTE

5G mmWave and/or sub-6GHz

5G NR Data and control over 5G NR link

Data only over 5G NR link

Dual connectivity

Data + control over 4G LTE link
5G next Gen Core (NGC) also part of 3GPP Rel-15

Increased flexibility through NFV and SDN – essential to 5G NR expansion

- Mobile broadband
- Mission-critical control
- Internet of Things

- Configurable end-to-end connectivity per vertical
- Modular, specialized network functions per service
- Flexible subscription models
- Dynamic control and user planes with more functionality at the edge

NFV: Network Functions Virtualization; SDN: Software Defined Networking

Better cost/energy efficiency | Optimized performance | Flexible biz models and deployments | Dynamic creation of services
Making 5G NR a commercial reality

Qualcomm, leading the world to 5G
In research and development

>$50B*

Our system-level inventions fuel the mobile industry

*Cumulative expenditures to date since 1985. Taking significant risks to start early with an end-to-end design.
Foundation to 5G leadership is technology leadership
Early R&D and technology inventions essential to leading ecosystem forward

- Invention: Invent new technologies and e2e system architecture
- Proof-of-concept: Deliver end-to-end prototypes and impactful demonstrations
- Vision: Identify a problem or need; establish requirements
- Standardization: Drive e2e design with ecosystem and through standards process
- Commercialization: Engage with global network operators to deploy new features with standards-compliant infrastructure and devices
- Trials: Collaborate on OTA field trials that track 3GPP standardization and drive ecosystem towards rapid commercialization
Qualcomm has led the evolution and expansion of LTE
Delivering fundamental systems-level inventions that are essential to 5G

Leading in 5G requires

4G LTE Leadership

- OFDMA, SC-FDMA
- Carrier aggregation (FDD, TDD, FDD+TDD)
- CoMP
- LTE IoT (eMTC, NB-IoT)
- Advanced MIMO technologies, e.g. UL MIMO
- Broadcast (eMBMS, enTV)
- Handover procedure
- VoLTE
- Fast link adaptation
- LTE in Unlicensed (LAA/eLAA)
- HetNets with Small Cells and Interference Management
- Security
- LTE Direct and C-V2X

Positioning

Hybrid ARQ

MulteFire
World’s first announced 2 Gbps LTE modem

World’s first announced 7nm chip

World’s first announced 14nm RF chip

World’s first announced 7x carrier aggregation

Strengthening the Gigabit LTE foundation of 5G NR multi-mode networks
Best-in-class 5G NR mobile prototype systems
Sub-6 GHz and mmWave

- 5G NR Baseband
  - Flexibly designed to track and drive 3GPP standardization in Rel-15+

- 5G NR UE
  - RFFE in mobile form-factors to mimic real-world performance

- 5G NR gNodeB
  - Enable early system-level testing and demonstrations

- World’s first announced 5G NR prototype – June 2016
- World’s first 5G NR data connection – February 2017
- World’s first interoperable 5G NR system – November 2017
World’s first 5G NR milestones led by Qualcomm

November 2017
World’s first interoperable 5G NR sub-6 GHz data connection

December 2017
World’s first interoperable 5G NR mmWave data connection

February 2018
Successful multi-band 5G NR interoperability testing

MWC 2018
Interoperable 5G NR sub-6 GHz & mmWave connections with 5 vendors

June 2018
5G NR interoperability testing preparing for the Chinese mass market

2H-2018
Rel-15 5G NR trials based on Snapdragon X50 modem chipset and QTM052 antenna modules

Driving the 5G ecosystem towards 2019 launches in collaboration with 18+ global mobile network operators and 20+ device manufacturers
Commercializing mmWave in a smartphone form factor

mmWave (60 GHz) viability in handset form factor
11ad in Asus Zenfone 4 Pro

Qualcomm® 5G NR mmWave prototype

Qualcomm® 5G NR mobile test device

5G NR mmWave Qualcomm® Reference Design

Qualcomm Reference Design is a program of Qualcomm Technologies, Inc. and/or its subsidiaries.
X50
5G Modem family

World’s first announced 5G NR multimode modems

- 5G NR standards compliant
- Sub-6 + mmWave
- Premium-tier smartphones in 2019
**5G Modem family**

- **5G NR standards compliant**
- **Sub-6 + mmWave**
- **Premium-tier smartphones in 2019**

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**Multi-Gigabit over mmWave on working Snapdragon X50 silicon**

- 1.24 Gbps
- 4.51 Gbps

**5G NR Interoperability and field trials using form factor mobile test device**

- First 5G NR mmWave over-the-air data call, with Ericsson
- First 5G NR Sub 6 GHz over-the-air data call, with Ericsson

**Providing Qualcomm Reference Design to accelerate commercial devices**

- 73.8 mm
- 9.5 mm

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**World’s first 5G NR modems**

- 5G NR standards compliant
- Sub-6 + mmWave
- Premium-tier smartphones in 2019

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**Qualcomm Snapdragon**

- Snapdragon X50 5G modem

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Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.
Global operators and OEMs using Snapdragon X50 5G NR modem family for mobile 5G NR trials and devices
QTM052 5G mmWave antenna module

Rapid miniaturization of mmWave modules to bring 5G smartphones to the World in 2019
5G NR is expanding to new use cases and verticals

- Mobile broadband evolution
- Mobile mmWave evolution
- 5G NR C-V2X
- Industrial IoT with URLLC
- 3GPP Rel-16
- Unlicensed/shared spectrum
- Massive IoT
- Broadcast
5G NR

5G is the foundation to what’s next. We are the foundation to 5G.

Learn more at www.qualcomm.com/5G

Making 5G NR a commercial reality for 2019 eMBB deployments

Driving the expansion of 5G NR ecosystem and opportunity
Thank you!

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