The Future of 5G

Dr. James H. Thompson
EVP, Engineering & CTO
Qualcomm Technologies, Inc.
5G global rollout

30+ launched in 6 months
Faster than 4G
Driving the 5G expansion

Our technology inventions drove the 5G foundation

- Private networks
- 5G massive IoT
- 5G broadcast
- mmWave evolution, indoor, enterprises
- Sub-6 GHz evolution, new use case
- New device classes like tethered XR
- New device classes like boundless XR
- Fixed wireless access
- Laptops
- Automotive
- Industrial IoT with eURLLC
- 5G NR C-V2X, smart transportation
- Future verticals, services, devices
- Shared / unlicensed spectrum
- Rel.15 eMBB expansion
- Rel.16-17
- Smartphones
On-device AI use-cases today

We can do more with 5G
The intelligent wireless edge

On-device AI
Augmented by edge cloud

New experiences
Privacy/security
New verticals
Immediacy
Processing over 5G
Efficiency
Customized/local value
Reliability
Private/public networks
Personalization
Process data at the source to scale and make sense of a digitized world

Past
Cloud-centric AI
AI training and AI inference in the central cloud

Today
Partially-distributed AI
Power efficient on-device AI inference

Future
Fully-distributed AI
With lifelong on-device learning
Enriched user experiences, new use case, new verticals

Distributed functionality

5G

Longer latency
Big data/aggregated value
Content/storage/AI/processing

5G low latency
Customized/local value
Content/storage/AI/processing

On-premise control for ultra-low latency
On-device intelligence assisted by cloud
Distributed processing, like boundless XR
New services
Cloud computing, storage, instant access
Low-latency gaming
Real-time assisted services like voice UI

Compute, vision, sensing
AI powered use cases
Internal AI optimizations
Enhanced mobile broadband

Massive IoT

Ultra-reliable low-latency

Automated guided vehicle (AGV)

Computer vision

Sensors

Wireless edge analytics

Head mounted display

Handheld terminal

Industrial robot
Road safety
V2V/V2I: Intersection assist, non-line of sight warning

On-device intelligence
Key for cars to act with immediacy

RSU with AI-based camera

Traffic hazard warning
AI-based camera detects hazards and alerts

Pedestrian alert
Traffic light detects crossing and alert cars via I2V

Evolving 5G for smart transportation

C-V2X direct communication

RSU with AI-based camera

Traffic light

V2P

I2V

V2V
Virtual telepresence collaboration

Boundless XR
Photorealistic Graphics
Sleek formfactor

Real-time insights
37
2.3M

Six degrees of freedom
XR

5G

Edge cloud—but not necessarily on-premise
Augmenting on-device processing over 5G
Mobile has made a leap every ~10 years

1980s
Analog voice
AMPS, NMT, TACS

1990s
Digital voice
D-AMPS, GSM, IS-95 (CDMA)

2000s
Wireless Internet
CDMA2000/EV-DO, WCDMA/HSPA+

2010s
Mobile broadband
LTE, LTE Advanced, Gigabit LTE

2020s
Wireless Edge
5G New Radio (NR)
The 5G foundation started long ago

1985: Qualcomm founded to solve system-level problems

1993: Wireless Internet first OTA demo over CDMA

1998: EV-DO as we realized a new design was needed

2002: Integration of low-power compute

2007: Device to device proximity services Foundation to 3G and 4G

2012: Cellular in unlicensed spectrum

2014: Flexible framework, scalable OFDM, spatial design, mobile mmWave

Foundational to 5G
1993: Wireless Internet
First demo over CDMA
While other were adding data to 2G, we realized that

A fundamentally new design was needed for TCP/IP over wireless
1998: EV-DO
Over-the-air demo
The foundation to mobile broadband

- Data optimized channel
- Adaptive modulation/coding
- Opportunistic scheduling
- OFDM for broadcast
- RX diversity
- Carrier aggregation
- OFDM(A) for wider spectrum
- More antennae-MIMO
- Mobile VoIP with QoS
Envisioned devices that would consume all the mobile broadband

Compute + mobile was born, now realizing the full potential of 5G with the intelligent wireless edge
2013: MWC
Device-to-Device communication

LTE-Direct proximity services over-the-air demos

Took longer than anticipated, but led to many new use cases

C-V2X for basic safety
D2D for public safety, relays
5G NR C-V2X adv. use-cases

Integrated access and backhaul
5G: framework with D2D/side-link
Offload, IoT relays, mesh, V2P
2013: MWC

Cellular in unlicensed spectrum

LTE-U coexistence with Wi-Fi over-the-air demo

Commercialized in LTE and integral to 5G design

- LTE-LAA
- NR-U LAA
- NR-U standalone

Synchronized NR-U
Spectrum sharing paradigms
2014

Industry aligns

But we envisioned a unified solution
A unified design for efficient implementation with fundamental inventions

Supporting the 5G vision and future expansion
2016: MWC
First non-line-of-sight mobility OTA mmWave demo

Overcome an ‘impossible’ challenge to mobilize mmWave

Robust mobility Non-line-of-sight
Coverage with co-siting RFIC, thermal, size
2017: MWC
World’s first NR-based connection using the flexible framework and new spatial design

Foundation to efficient MIMO, 5G expansion, new verticals

Reciprocity based massive MIMO
Unlicensed spectrum

eURLLC with CoMP
New spatial sharing paradigms
Making 5G NR a reality

www.qualcomm.com/5G-timeline
Sets the vision. Proves the path. First to arrive.

Early visions foundational to 5G

A unified future-proof platform

Delivering on the 5G vision

Standard comes after vision and research

First non-line of sight mmWave mobility demo MWC 2016

World’s first 5G NR based connection MWC 2017

World’s first IoDT mmWave and sub-6 GHz end 2017

World’s first products launched in 2019

Early end-to-end system prototypes

Industry-first demos and proof-of-concepts

Industry-first Interop testing and field trials

Industry-first launches

Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.
An innovation platform for today’s and future services

Early visions foundational to 5G

A unified future-proof platform

Delivering on the 5G vision

Diverse services

Diverse spectrum

Diverse deployments
Delivering on the 5G vision

Dr. John Smee
VP, Engineering and 5G R&D lead
Qualcomm Technologies, Inc.
First to demo

End-to-end prototyping, early interoperability with partners, accelerate commercialization

70+ milestones on the path making 5G NR a reality in 2019 found at https://www.qualcomm.com/5g-timeline
### Demonstrating the future of 5G today

<table>
<thead>
<tr>
<th>Sub-7 GHz testbed</th>
<th>E2E system: antenna range</th>
<th>Outdoor mmWave</th>
<th>Indoor mmWave</th>
<th>5G NR C-V2X</th>
<th>5G standardization</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmWave testbed</td>
<td>5G Industrial IoT</td>
<td>Synchronized NR-U</td>
<td>Wide-area augmented reality</td>
<td>System RF front-end</td>
<td>2019</td>
</tr>
<tr>
<td>Industrial IoT and spectrum testbed</td>
<td>mmWave testbed</td>
<td>Automotive testbed</td>
<td>mmWave testbed</td>
<td>mmWave testbed</td>
<td>mmWave testbed</td>
</tr>
</tbody>
</table>

Early end-to-end prototyping, drive evolution, drive and reflect standards, accelerate commercialization
Driving the 5G roadmap and ecosystem expansion

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
Continued evolution to deliver on the 5G vision

Rel-15
Established 5G NR technology foundation

Rel-16
Expanding to new use cases and industries

Rel-17: Likely candidates
Continued expansion and enhancements

1. Enhancing Rel-14 LTE eMTV to meet 5G requirements; 2. eMTC/NB-IoT in-band 5G NR and connected to 5G core; 3. MIMO, power consumption, mobility, MR DC/CA, interference management and more; 4. Non-terrestrial networks, non-public networks (private networks), NR SON/MDT and more; 5. further improvements to capacity, coverage, mobility, power consumption, spectral efficiency; 6. mixed-mode multicast, small data transmission, multi-SIM, satellite, multimedia
Expanding 5G with the flexible framework

Early vision

A unified future-proof platform

Delivering on the 5G vision and expansion

A flexible framework with forward compatibility
Efficiently multiplex today’s and unforeseen services on same frequency

Flexible slot-based framework
Scalable OFDM-based air interface
Expanding 5G with the flexible slot-based framework

- Dynamic spectrum sharing (Rel-15+)
- Broadcast/enTV (Rel-16+)
- Cellular V2X–network side shown (Rel-16+)
- Wide-area mission-critical (Rel-15/16+)
- Massive IoT (Rel-16+)

- Enhanced mobile broadband (Rel-15+)
- Sidelink (Rel-17+), e.g., for offload
- Unknown service not yet defined
- Integrated access and backhaul (Rel-16+) for mmWave only (not shown)
- 5G NR eMBB
- Broadcast/enTV (Rel-16+)
- Cellular V2X–network side shown (Rel-16+)
- Wide-area mission-critical (Rel-15/16+)
- Massive IoT (Rel-16+)

- LTE
- 5G NR eMBB
- Broadcast
- Sidelink
- C-V2X
- Blank subcarriers

- NR-Light
- eMTC
- NB-IoT

- System bandwidth

- Scalable numerology

- Expanding 5G with the flexible slot-based framework
Vision: Low-complexity IoT/M2M mobile connectivity

A small form-factor Low Duty Cycle (LDC) asset tracker concept from 2005

Reducing data rate, system complexity, power consumption

Longer sleep periodicity, half duplex, no/limited voice support

1. End-to-end system design based on CDMA20001x for low data rate, delay-tolerant applications; 2. Relays can be either network (Uu) or sidelink (PC5) based; 3. NB-IoT to support higher-order modulation such as 64-QAM and carrier aggregation; 2. Unlicensed spectrum is supported in Rel-17+
A system approach for efficient implementation

Can't approach fundamental components like waveform on single use case basis

Need a system approach to address all use cases and efficient implementation—common framework

Numerous OFDM-based waveforms considered for 5G

- **Multi-carrier OFDM waveforms**: OFDM variants with windowing/imaging enhancements for better frequency localization
- **CP-OFDM with windowing**
  - Customized windowing can be a block of contiguous OFDM subcarriers
  - Time domain windowing to soften edges of symbols—used in 4G LTE downlink today
  - **UFMC**
- **FBMC / OFDM**: Customized subcarrier pulse shaping achieved through oversampling

**IFFT/FFT**

- All waveforms based on OFDM Synthesis

- **Single-carrier OFDM waveforms**
  - Single-carrier OFDM variants that use IFFT spreading to reduce power variations in uplink

- **SC-OFDM with windowing**
  - IFFT spreading with cyclic prefix (CP) insertion—used in 4G LTE uplink today

**Zero-tail SC-OFDM**

- IFFT spreading with windowing to avoid post-insertion of fixed CP for higher spectral efficiency

Optimized 5G waveforms and multiple access

With heavy reliance on the OFDM family

- **5G Downlink**
  - A single waveform for flexible service multiplexing
  - **CP-OFDM**
  - **OFDMA**
- **5G Uplink**
  - Optimized waveforms for different use cases
  - **CP-OFDM**
  - **OFDMA**

- Low energy single-carrier
- RSMA

- For energy efficient small data bursts
- For low latency, grant-less small data bursts

Download Qualcomm Research whitepaper for detailed analysis:
www.qualcomm.com/5g-whitepapers

Slides from 2015 Qualcomm industry analyst day
Expanding mmWave spectrum with the common framework

- **Potential 5G band under study**
  - Supported mmWave bands in Rel-15
  - Prioritized expansion of mmWave in Rel-17
  - Further mmWave expansion targeting Rel-17 and beyond
  - Prioritizing the expansion to 71 GHz, then to 114.25 GHz
  - Common expanded framework
  - Common framework

**Expansion of low/mid band spectrum**

- **Sub-7 GHz** (e.g., 3.5 GHz)
- **Millimeter wave** (e.g., 28, 39 GHz)
- **410 MHz to 6 GHz and mmWave 24.25GHz 52.6 GHz**

**Potential 5G band for future study**

1 Rel-15 supported 450 MHz to 6 GHz and mmWave 24.25GHz 52.6 GHz. To support global unlicensed 60 GHz bands, SCS scaling from 24.25-52.6 GHz band with same characteristics (e.g., waveforms)
Vision and persistence brought unlicensed spectrum to 5G

- Continuous research, industry first over-the-air LAA, eLAA, MulteFire demos, interoperability with Wi-Fi

- Vision: High-performance cellular in unlicensed spectrum
  - Standalone in unlicensed spectrum
  - Add-on boost with licensed anchor

- NR-U
  - Synchronized NR-U
  - 1st Demo

- LAA
  - 1st Demo

- MulteFire
  - 1st Demo

- LTE-U
  - 1st Demo

- Envisioned to become integral to all NR use cases

Timeline:
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
- 2017
- 2018
- 2019
- 2020
- 2021
A spectrum sharing vision exploiting the spatial domain

Flexible framework with efficient spatial design
Flexibility, lower latency, reciprocity based massive MIMO feedback/pilot/measurements

NR eMBB with massive MIMO
Single operator in dedicated spectrum

NR based LAA
Uncoordinated sharing with anchor

NR based Standalone
Uncoordinated spectrum sharing

Vision: Coordinated sharing to enable new paradigms

Continuous research

5G
CoMP
New verticals like Industrial IoT with URLLC

Predictable sharing
Synchronized sharing in unlicensed spectrum NR-U

Spatial sharing
Also for entities to efficiently share spectrum at boundaries
Exploiting the spatial domain with CoMP for new verticals

Capacity from spatial multiplexing
Multiple transmissions at the same time to multiple locations without interfering

Capacity vs. reliability tradeoff
Small cells with few antennas create many distributed antennas for spatial domain

Reliability from spatial diversity
CoMP\(^1\) is key to ultra reliability for eURLLC by overcoming radio shadowing

1. Coordinated Multi Point in the form of Joint Transmission (JT) with same data via multiple base stations with beamforming. Coherent JT enables nulling; requires channel knowledge and antenna calibration
EV-DO is the foundation to mobile broadband

1993 vision: Wireless Internet

Continuous research and innovations, early prototyping, industry first demos and trials

1. Assign all resources to a user, fast hybrid ARQ and power control
2. Higher order modulation for users with good signal quality
3. Multi-user diversity to prioritize users with better radio signal—fairness

Data optimized channel with Turbo Codes¹
Adaptive modulation/coding²
Opportunistic scheduling³

OFDM in EV-DO (broadcast)
Multiple antennas for RX diversity
Carrier aggregation (rev B/HSPA+)
Mobile VoIP with QoS

Unlicensed spectrum
OFDMA for wider spectrum
More antennae-MIMO
FDD/TDD/DC/SDL aggregation

Mobile mmWave
Unified, flexible framework
Scalable OFDM numerology
Reciprocity-based massive MIMO
Multi-Edge LDPC and CRC-Aided Polar codes

Our inventions drove the 5G foundation

All-IP EV-DO
 Demo
 Launch

Foundation to HSPA

Foundation to LTE

Foundation to 5G NR eMBB

Continue to enhance the eMBB foundation

R15 lessons learned
Optimizations and new features to R16 and R17+

Foundational
Coverage, capacity, latency, power saving, mobility

Deployment
New spectrum, topologies, integrated backhaul...

New services
Latency, reliability, positioning, use cases like XR

- Enhanced DL/UL MIMO and multiple transmission points
- Integrated access/backhaul for easier mmWave deployments
- Unlicensed spectrum including standalone and license assisted
- Enhanced low/mid-band and mmWave CA and async DC
- Further improved MIMO for e.g., higher mobility
- Enhanced IAB with full duplex and spatial multiplexing
- Further power saving for idle and small data
- Supporting even higher bands, up to 114.25 GHz
- Further enhanced mobility for mixed topologies
- Others such as, >4 Rx, 1024-QAM, multi-SIM

Rel-15
Rel-16
Rel-17: Likely candidates
5G enabled capabilities not possible when 4G was defined

Efficient TDD spatial design
Flexibility, lower latency, reciprocity based massive MIMO, new feedback/pilot/measurements

Scalable numerology
Low, to mid to high mmWave bands, deployment types

Hardware enablers
Such as faster baseband processing

Mobile mmWave
Overcoming an ‘impossible challenge’

Continuous research, technology breakthroughs, new architectures, distribution of processing/AI/content,…

Technology leap for new capabilities and reduced cost
5G is the innovation platform for the next decade

- A unified future-proof platform
- Delivering on the 5G vision
- New deployments, new spectrum, new use cases, new verticals,…
- Some future requirements only possible on a new platform

Market needs: enhanced/emerging/unknown services to 5G

- Technology breakthroughs, hardware progress, new architectures, distribution of processing/AI/content,…
- Research: for 5G enhancements and for next gen. leap

Historically 10 years between generations

Next technology leap for new capabilities and reduced cost

Rel-15 Initially eMBB
Rel-16 Expansion to new industries
Rel-17
Rel-18
Rel-19
Rel-20
Rel-21 and beyond
Continued evolution
Expansion of 5G

Dr. Durga Malladi
SVP & GM, 4G/5G
Qualcomm Technologies, Inc.
Driving the 5G expansion

**Future proof platform**
- Rel-15 commercialization

**Delivering on the 5G vision**
- Rel-16 commercialization
- Rel-17 evolution

**2019 eMBB**
- Global smartphone launches
- Fixed wireless access

**2020 eMBB expansion**
- Beyond smartphone (PC, FWA, ...)
- New markets/regions
- Nationwide coverage & SA migration

**Longer term expansion**
- Industrial IoT, enterprise, automotive networks
- Private networks
- Unlicensed spectrum

---

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
30+ launched in 6 months—faster than 4G

2019 is the year of 5G. 2020 is the year of expansion
5G smartphones

- Lenovo Z6 Pro 5G
- LG V50 ThinQ 5G
- Motorola moto z4/z3 + 5G moto mod
- Nubia Mini 5G
- OnePlus 7 Pro 5G
- OPPO Reno 5G
- Samsung Galaxy S10 5G
- Samsung Galaxy Fold
- Samsung Galaxy Note10+ 5G
- Samsung A90 5G
- Vivo iQOO 5G Edition
- Vivo NEX 3 5G
- Xiaomi Mi MIX 5G
- ZTE Axon 10 Pro 5G
- ZTE 

5G modules

- Askey
- Inseego
- HTC
- Netcomm
- Netgear
- Nokia
- WNC
- ZTE
- Compal
- Fibocom
- Longsung
- Quectel
- Sierra
- Wireless
- SIMcom
- Telit

150+ 5G devices launched or in development
Comprehensive 5G modem-RF solutions

### Qualcomm Snapdragon

**X50 5G modem-RF system**

- **1st gen**
  - Sub-6 and mmWave
  - NSA, TDD, Multi-SIM
  - Qualcomm® 5G PowerSave
  - Qualcomm® Smart Transmit
  - Qualcomm® Signal Boost

**First wave of devices**

- Early 2019

**X55 5G modem-RF system**

- **2nd gen**
  - Added features
    - Integrated 5G to 2G
    - Standalone (SA), FDD
    - Dynamic Spectrum Sharing
    - Qualcomm® Wideband Envelope Tracking
    - Platforms for PC, fixed wireless access, automotive, and more

**Second wave**

- Late 2019

### Snapdragon 8, 7, 6 Series Mobile Platforms

**1st half 2020**

- Broader, faster adoption

System-level integration delivers best-in-class power-efficiency and performance

Qualcomm 5G PowerSave, Smart Transmit, Signal Boost and Wideband Envelope Tracking are products of Qualcomm Technologies, Inc. and/or its subsidiaries.
System-level integration delivers best performance

Qualcomm QTM525 is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.
Optimization through co-design of hardware and software
Optimization through co-design of hardware and software

Qualcomm® mmWave modules

Qualcomm® mmWave Smart Transmit
Support for all radios 5G-2G, Wi-Fi

X55 Multimode 5G modem

Qualcomm® 5G PowerSave

Qualcomm® Wideband envelope tracking

Multimode RF Transceiver

RF Front End

Sub-6 GHz (5G, LTE)

Qualcomm® Signal Boost antenna tuning

Modem

RF Transceiver

RF Front-end
Our solution delivers best-in-class performance

**Fastest speeds**
5G downloads up to 7 Gbps
4G downloads up to 2.5 Gbps

**Sleek form factors**
Tightly coupled modem-to-antenna 5G to 2G multimode solution

**Quick availability**
Turnkey solution including modules allows for quick, cost-optimized commercialization at global scale

**Longer battery life**
Including Qualcomm® 5G PowerSave and wideband envelope tracking

**Better 5G coverage**
Including Qualcomm® Signal Boost and Smart Transmit

**Enhanced 5G roaming**
Any key major band and region along with multi-SIM

Our solution delivers best-in-class performance
We overcome the ‘impossible’ mobile mmWave challenge

Limited coverage and too costly
Limited to just a few hundred feet, thus requiring many small cells

Significant coverage with co-siting
Analog beamforming w/ narrow beam to overcome path loss. Leverage lower bands for full coverage

Works only line-of-sight (LOS)
Blockage from hand, body, walls, foliage, rain severely limits signal propagation

Line-of-sight and non-line-of-sight
Pioneered advanced beamforming, beam tracking leveraging path diversity and reflections

Only viable for fixed use
Only commercially proven for wireless backhauls and satellites

Robust mobility
Robustness with adaptive beam steering and switching to overcome blockage from hand, head, body, foliage

Immature RFIC technology
Power hungry due to wider bandwidth with thermal challenges in small formfactor

Commercialized smartphone
Launched modem, RF, and antenna products to meet formfactor, thermal constraints and regulatory compliance
Expanding our eMBB solution beyond the smartphone

- Expand 5G coverage and performance
- Expand fixed wireless access, integrated with Wi-Fi
- Expand device classes to always connected PC/Laptop
- Expand experiences, like XR tethered to smartphones
- Expand 5G eMBB modules to more verticals
- Expand reach with our small cell solution
- Expand eMBB to vehicles - initially with Rel-14 C-V2X
- Expand mobile gaming including cloud gaming
Accelerating the expansion of 5G network with small cells

Powered by Qualcomm® FSM™ small cell platforms

Capable of being developed to utilize mmWave and sub-6 GHz

Supporting uniform 5G speeds and experiences, indoors and outdoors

Expected to begin sampling in 2020
Fueling fixed wireless broadband

Customer premise equipment (CPE) powered by Snapdragon X55 5G Modem-RF System for flexible, cost-effective deployments
First integrated extended range mmWave solution

mmWave QTM527 modules expand Snapdragon X55 5G Modem-RF System for fixed wireless access

- More antennas—up to 64 dual polarization elements
- For power class 1 devices
- Global mmWave bands

1 3GPP band definition are n257 (26.5-29.5 GHz), n258 (24.25-27.5 GHz), n260 (37-40 GHz), n261 (27.5-28.35 GHz)
Accelerated 5G to 2019 with non-standalone mode

- Lower band LTE
- Higher band 5G
- EPC
- LTE
- UE
- 5G NR
- Dual connectivity
- NSA UE
- NSA
- UE
- Accelerated 5G to 2019 with non-standalone mode
- Higher band 5G
- Lower band LTE
Expand coverage with lower bands

Expand 5G coverage
- Dynamic Spectrum Sharing (DSS)
- 5G FDD in low bands

Higher band 5G NR

Lower band LTE + 5G NR

Higher band 5G NR

Lower 5G/4G FDD band
Direct migration to standalone core network with DSS

Option 2 to introduce 5G core services like QoS, security, slicing.
Increase 5G performance with carrier aggregation

Aggregated performance

Extends high band usable coverage to downlink limit\(^1\)

5G core network

Standalone option 2

Higher band 5G NR

Lower band LTE + 5G NR

5G NR

High/mid 5G band

5G NR

5G UE

Extended coverage with DSS and FDD low bands
Indoor enterprises
Offices, meeting rooms, auditoriums

Indoor/outdoor venues
Conventions, concerts, stadiums

Transportation hubs
Airports, train terminals, subway stations

Expanding mmWave indoors, public/private networks
Multi-Gigabit speeds with virtually unlimited capacity

Beyond smartphones, laptops, tablets, extended reality, ...

Leveraging existing Wi-Fi or cellular by co-siting
Enterprise networks
For 5G PCs, enterprise XR and more

The untethered mobile office of the future

Complemented with outdoor 5G connectivity

Create with real-time collaboration

Instant access to cloud compute and storage

Immersive virtual telepresence with wireless flexibility

Beyond laptops: Augmented and virtual reality (XR)

Multi-Gigabit mmWave speeds with virtually unlimited capacity, collocated with Wi-Fi

Reuse operators mmWave spectrum, in/out isolation, new business models opportunity

Private indoor network with cellular grade security, managed by enterprise or 3rd party
Emerging dedicated private networks for targeted needs
Multiple spectrum options
For private 5G networks

Licensed spectrum by mobile operators
Operators can allocate spectrum in a specific area

Dedicated regional spectrum
Regional spectrum such as 3.7GHz in Germany for IIoT

Unlicensed spectrum with async sharing
NR-U with asynchronous sharing work for many applications

Unlicensed spectrum with synch sharing
Synchronized sharing can provide reliability and eURLLC for IIoT
Industrial IoT

Big data analytics

Sensitive traffic/data stays on site
Enables ultra-low latency

Edge cloud analytics

Local network

On-device

5G

Massive IoT

5G

eURLLC

5G

eMBB

Security

Sensors

Gateway

15.4 W-HART

Wi-Fi

BLE

Wired

Machines

On-device intelligence

Access

Low-power processing

Sensor fusion

Computer vision

Sensor fusion

Computer vision

Low-power processing

Massive IoT

Computer vision

On-device intelligence

Low-power processing

Computer vision

On-device intelligence

Low-power processing
Enhanced network communication
Faster access to cloud for in-vehicle experiences, car OEM services and telematics

New direct communication
V2V, V2I, and V2P communications for latency-sensitive use-cases, e.g. collision avoidance

Massive Internet of Things
Deeper coverage to connect road infrastructure (e.g. sensors and traffic cameras)

Evolution to 5G NR supports smart transportation use cases

Connected car services
In-vehicle experiences
Road safety
Transportation efficiency
Connected road sensors
Smarter transportation infrastructure

- Communications
  - Direct via C-V2X
  - Network via 4G/5G
- Radar
- Multiple cameras
- Localization
- AI-based RSU
  - Compute for perception and sensor fusion
- Telematics
- I2V road world model
- Multiple cameras
- AI-based RSU
- Compute for perception and sensor fusion
Delivering on the 5G vision
Where virtually everyone and everything is intelligently connected
Thank you

Follow us on:  

For more information, visit us at:  
www.qualcomm.com & www.qualcomm.com/blog

Nothing in these materials is an offer to sell any of the components or devices referenced herein.

©2018-2019 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.

Qualcomm and Snapdragon are trademarks of Qualcomm Incorporated, registered in the United States and other countries. Other products and brand names may be trademarks or registered trademarks of their respective owners.

References in this presentation to “Qualcomm” may mean Qualcomm Incorporated, Qualcomm Technologies, Inc., and/or other subsidiaries or business units within the Qualcomm corporate structure, as applicable. Qualcomm Incorporated includes Qualcomm’s licensing business, QTL, and the vast majority of its patent portfolio. Qualcomm Technologies, Inc., a wholly-owned subsidiary of Qualcomm Incorporated, operates, along with its subsidiaries, substantially all of Qualcomm’s engineering, research and development functions, and substantially all of its product and services businesses, including its semiconductor business, QCT.