How do we plan for 5G NR network deployments coming in 2019?

Manish Tripathi
Vice President, ESG
Qualcomm Technologies, Inc.
Agenda

1. Making 5G NR a commercial reality
   Networks and devices in 2019

2. Deploying 5G NR for outdoor networks
   Sub-6 GHz and mmWave

3. Supporting new mobile experiences with mmWave
   Venues and enterprises

4. Questions?
A unifying connectivity fabric for future innovations

Like electricity, you will just expect it everywhere
Global ecosystem is accelerating 5G NR deployments
A comparison with the global 4G transition

1 By TeliaSonera in Sweden and Norway; 2 September 2010 by MetroPCS in two markets, December 2010 by Verizon in 38 markets; 3 Vodafone Germany in 2 markets; 4 Samsung Galaxy Indulge; 5 EE in 5 cities
Making 5G NR mmWave 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 & QTM052 RFFE
- Commercial 5G NR mmWave networks and products

Qualcomm Snapdragon and QTM052 are products of Qualcomm Technologies, Inc. and/or its subsidiaries.
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
Multi-Gigabit over mmWave on working Snapdragon X50 silicon

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

Providing Qualcomm Reference Design to accelerate commercial devices

October, 2017

February, 2018

2H 2018

Sept 2018

Oct 2018

1H 2019

World’s first 5G NR modems

- 5G NR standards compliant
- Sub-6 + mmWave
- Premium-tier smartphones in 2019
QTM052 5G mmWave antenna module

Rapid miniaturization of mmWave modules to bring 5G smartphones to the World in 2019

Qualcomm 5G NR reference design (partially assembled state)
Deploying 5G NR for outdoor networks
Defining 5G NR coverage by co-siting with existing LTE

- LTE provides ubiquitous coverage and essential services like VoLTE
- Gigabit LTE is here now and delivers a virtually seamless 5G mobile experience
- LTE IoT, private LTE, C-V2X are expanding to new industries today
Non-Standalone (NSA) stepping stone to new core

Fast-to-launch | VoLTE & CS voice

Standalone (SA) for new core benefits

NFV and SDN | VoNR & fallback to VoLTE
5G NR massive MIMO enables the use of higher mid-band
E.g., Co-siting 3.5 GHz with existing lower-band LTE infrastructure

- Exploit 3D beamforming with up to 256 antenna elements
- Enhanced reference signals\(^1\) improve massive MIMO operations
- Mitigate UL coverage with 5G NR massive MIMO + HPUE\(^4\)
- 5G NR co-located with existing LTE macro sites

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

- Optimized design for TDD reciprocity procedures utilizing UL SRS\(^2\)
- Enhanced CSI-RS\(^3\) design and reporting mechanism
- Advanced, high-spatial resolution codebook supporting up to 256 antennas
- New features, such as CoMP\(^5\)

Deployment of active antenna systems for 3.5 GHz

Active antenna system performance depends on:

- # of supported sync. & reference signals
- Users distribution
- Infrastructure implementation

Key considerations include:

- # of elements: more elements enable better beamforming but tradeoff with cost/weight
- Square-shape: supporting horizontal & vertical traffic distribution
- Inter-beam overlap impacts MU-MIMO

Recommendations:

Massive MIMO with 128x2 elements with configuration of 8(h) x 16(v) x 2(x-pol.) for urban, dense urban deployments

### Massively MIMO delivers significant capacity gains

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Beamforming and MU-MIMO gains</th>
</tr>
</thead>
<tbody>
<tr>
<td>4T4R(SU-MIMO)</td>
<td>1x</td>
</tr>
<tr>
<td>8T8R</td>
<td>4.0x</td>
</tr>
<tr>
<td>16T16R</td>
<td>5.1x</td>
</tr>
<tr>
<td>32T32R</td>
<td>6.4x</td>
</tr>
<tr>
<td>64T64R</td>
<td>7.9x</td>
</tr>
</tbody>
</table>

Note: Chart shows benefits of beamforming gains by adding more analog RF ports, not array gains (antenna used is an array of 128x2 elements for all scenarios).
Collaborating with global operators to predict coverage
For 5G NR sub-6 GHz and mmWave

Defining geographic maps and site locations
Selecting dense urban areas of global cities that experience high mobile traffic

Establishing link budget and RF propagation model
Developing link budget for a target cell edge spectral efficiency

Predicting 5G NR coverage
Using a commercial planning tool to model 5G NR coverage and performance
5G NR coverage prediction methodology
Use of link budget & RF planning tool
Downlink Coverage %

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%

Significant 5G NR 3.5 GHz outdoor & indoor coverage

Co-siting 5G NR with existing outdoor LTE cell sites – opportunity to density indoors
Model tuning needed to accurately predict coverage / SINR
Allows accurate beamforming and MU-MIMO estimations at 3.5 GHz

Default model without tuning
Mean error: -1.15 dB
Error sigma: 5.73 dB

Tuned model for 3.5 GHz
Mean error: 0 dB
Error sigma: 3.34 dB
Impact of deploying sparse 5G NR in the 3.5 GHz band
Non-co-located LTE/NR may cause near-far effect requiring additional optimization

Analyzing a dense urban cluster with optimization of site azimuths as site density is reduced

Out-to-out coverage is minorly impacted with reduction in sites
Out-to-in coverage is more impacted – opportunity to densify indoors
5G NR mmWave will support new and enhanced mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- Massive capacity for unlimited data
- Lower cost per bit
A system approach to the mobile mmWave challenge

1. Cutting-edge R&D
   Overcoming numerous challenges to make mmWave viable for mobile use cases

2. Prototyping while driving standards
   Validating mobile 5G NR mmWave technologies, feedback loop to standards

3. Advanced network and system simulations
   Accurately predicting mmWave coverage, capacity, performance using real network models

4. Broad interoperability testing and trials
   Fully leveraging prototype systems and our leading global network experience

5. Leading modem and RFFE solutions
   Announced the Qualcomm® Snapdragon™ X50 5G modem family & QTM052 antenna module
Measuring 5G NR mmWave propagation characteristics
At Qualcomm San Diego campus

For line-of-sight (LOS), measured pathloss closely follow propagation model

For non-line-of-sight (NLOS\(^1\)), measured pathloss shows variations → requiring accurate 3D maps

1. NLOS measurements are at locations experiencing varying obstructions (foliage, body) and reflection losses.
Accurately predicting 5G NR mmWave coverage

Utilizing geographically accurate 3D models
2m x 2m resolution with accurate and up-to-date information on buildings/foliage

Co-siting with 4G LTE sites in service today
Macro/small cell sites are used, including exact antenna height/orientation

Establishing baseline with potential to improve
No additional sites used in simulations (e.g., outdoor Wi-Fi) that can further improve coverage

Example: San Francisco
Significant 5G NR mmWave outdoor coverage via co-siting

Simulations based on over-the-air testing and channel measurements
VoLTE remains to be the 5G voice solution for many years

Example VoLTE adoption timeline in the US

- VoLTE requirements
- Test specifications
- Lab/interoperability testing
- Field trials
- LTE network optimizations
- Device certification
- Friendly user trials
- Initial launches
- Network-wide launches
- Commercial network optimization
- Continue improvements to address increased demand

1 – 1.5 years from specifications to field trials

6 – 9 months to user trials

3 to 6 months to network wide launch

>1 year to address commercial market challenges

1 Including device, RAN, and IMS; 2 Improving accessibility, retainability, voice quality;

Voice over 5G NR is expected to follow similar standardization to commercialization timeline as VoLTE
Supporting new mobile experiences with mmWave
Extending 5G NR mmWave to indoors for new and enhanced experiences
Complementing Wi-Fi deployments

- Bringing multi-Gigabit, low-latency, and virtually unlimited capacity
- Supporting devices beyond smartphones – tablets, always-connected laptops, XR
- Leveraging existing infrastructure – Wi-Fi or cellular – by co-siting small cells

Venues
Conventions, event halls, concerts, stadiums, etc.

Enterprises
Offices, shop floors, meeting rooms, auditoriums, etc.
5G NR mmWave for dense venue deployments

- Multi-Gigabit speeds with virtually unlimited capacity
- Personalized experiences exclusively at the venue
- New monetization opportunities during and after the event
- Easy and secure access over carrier networks

- Following your favorite player on the field
- New levels of social sharing
- Personalized on-demand instant replays
- Watching the event from virtually any seat
- Wireless screens virtually everywhere
- Rich media and interactive entertainment
5G NR mmWave is suitable for venue deployments
For example: using the 28 GHz band

- Better antenna directivity
- Higher spectral efficiency
- Superior beamforming

- No in-building penetration losses
- Rain & foliage attenuation is not a factor
- Signal decay likely not significant for short ranges

Excellent capacity solution

Typical mmWave coverage challenges not of major concern

* Comparing to typical LTE deployments
• Leveraging existing LTE infrastructure that includes LAA small cells for Gigabit LTE

• Initial deployments can deliver significantly higher capacity even with fewer sectors (i.e., mmWave at a subset of LTE sites)

• Enabling new mobile experiences powered by multi-Gbps throughput and ultra-low latency

1 Cell edge defined as 0.4 bps/Hz
2 Comparing Gigabit LTE using 50 MHz spectrum with an initial 5G-NR mmWave deployment using 800 MHz spectrum and 7:1 DL-UL configuration and 10% 5G-NR capable device penetration

100x Improvement in throughput
233 Mbps Median burst rate
10x Increase in capacity
95% Outdoor coverage

Deploying 5G NR mmWave for dense outdoor venues

Predicting 5G NR mmWave coverage for Music Concert Venue based on actual venue layout and network model
Enterprise networks: 5G NR mmWave + Wi-Fi
Always connected laptops and tablets

Next level of untethering—the mobile office of future

Instant cloud applications, instant cloud storage access

Extreme capacity for heavy use areas—conference room

Connect to projectors/screens with immersive content

Complemented with outdoor connectivity

Beyond laptops: Augmented and virtual reality (XR)

Multi-Gigabit speeds with virtually unlimited capacity

Reuse licensed spectrum— in-/outside mmWave isolation

Private 5G NR indoor network with cellular grade security

1) Requires network connectivity; 2) Expected coverage in typical office environments, actual coverage and performance depends on propagation and deployment.
5G NR mmWave boosts performance in Enterprise networks

- Downlink/uplink coverage comparable to Wi-Fi with 1:1 or partial co-site
- Realize multi-Gigabit burst rate with wider bandwidths (e.g., 800 MHz)
- Complement indoor Wi-Fi deployments

Complete coverage at 28 GHz\(^1\) at Qualcomm headquarters
- ~98% Downlink coverage with 1:1 co-siting
- ~99% Uplink coverage with 1:1 co-siting
- 5 Gbps downlink median burst rate\(^3\)

Coverage simulation based on MAPL (maximum allowable path loss) analysis with ray tracer propagation model and measured material and propagation loss; minimum 0.4/0.1 bps/Hz for downlink/uplink data and control; 2 Maximum Allowable Path Loss; DL: 115 dB, UL: 117 dB; 3 Using 800 MHz DL bandwidth and 100 MHz uplink bandwidth with 7:1 DL/UL TDD
Questions?
Connect with Us

www.qualcomm.com/wireless

www.qualcomm.com/news/ong

@qualcomm_tech

http://www.youtube.com/playlist?list=PL8AD95E4F585237C1&feature=plcp

http://www.slideshare.net/qualcommwirelessevolution