The Promise of 5G mmWave – How Do We Make It Mobile?

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Today’s Presenters

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Agenda

• Background to mmWave in 5G – Heavy Reading
• Mobilizing MmWave – Qualcomm
• A Unified 5G New Radio (NR) – Qualcomm
• Q&A Session
IMT-2020 Performance Targets

Relative to IMT Advanced (4G)

Relative to Major Use Case Categories

Source: ITU Recommendation ITU-R M.2083-0, September 2015
MmWave Bands (>24 GHz)

- **Massive MIMO possible at shorter $\lambda$**
- **Large amount of spectrum above 24 GHz**
- **Wider channels (up to 1GHz)**
  - 3G — 5 MHz (+CA)
  - 4G — 20 MHz (+CA)
  - 5G — 500 MHz / 1 GHz
- **WRC-19 to harmonize internationally**
Enabling Mobile MmWave

Better Understanding of MmWave
• Academic research & corporate R&D driving a rethink of mmWave applications
• Previously limited to point-to-point short-range & fixed wireless access

Miniaturization
• Highly complex antenna processing functions embedded in silicon
• Can be integrated into battery-powered handheld devices

Radical Advances in Baseband & RF Processing
• Computation capability embedded in silicon to enable the beam-forming and beam-tracking
• Ability to integrate large number of antenna elements & RF chains into cost effective phased array RFICs

A Halley’s Comet Moment
• A once in a lifetime event for RF researchers & engineers
• Opportunity to ‘open-up’ a vast swath of spectrum for mobile
## Operator MmWave Field Tests & Trials

### AT&T (U.S.)
- Trials at 15 GHz & 28 GHz
- Test beds at multiple U.S. locations
- Initial focus on fixed access

### DOCOMO (Japan)
- Trials at multiple frequencies
- Indoor, outdoor & mobile
  - Results published in DOCOMO Technical Journal

### Verizon (U.S.)
- 28 GHz trials with vendors
- Initial focus on fixed-wireless access
- Potential commercial service in 2017 for fixed residential access

### National Initiative (Korea)
- Consortium of universities, vendors & operators
- Developing mmWave test bed
- Plan to showcase network at 2018 Winter Olympics

**Trials to Inform 3GPP Standards Development**
Making mmWave a reality for 5G enhanced mobile broadband

With adaptive beamforming and beam tracking
The large bandwidth opportunity for mmWave
The next frontier of mobile broadband for extreme throughput and capacity

- Multi-Gbps data rates
  - With large bandwidths (100s of MHz)
- Much more capacity
  - With dense spatial reuse
- Flexible deployments
  - Integrated access/backhaul

5G proposed

6GHz 24GHz 100GHz

4G

5G mmWave
(e.g. 24.25-27.5 GHz, 27.5-29.5 GHz)
Realizing the mmWave opportunity for mobile broadband

The challenges in mobilizing mmWave

- Robustness due to high path loss and susceptibility to blockage
- Device cost/power and RF challenges at mmWave frequencies

5G

Smart beamforming and beam tracking
Increase coverage and minimize interference

Tight interworking with sub 6 GHz
Increase robustness, faster system acquisition

Optimized mmWave design for mobile
To meet cost, power and thermal constraints
Mobilizing mmWave requires a new system design
Direction antennas with adaptable beamforming and beam tracking

Massive MIMO with 3D beamforming

NLOS operation

Tight integration with LTE or 5G sub-6 GHz

Seamless Mobility

Intelligent beam search and tracking algorithms

Tight integration with sub-6 GHz

Coordinated scheduling for interference management
Directional beamforming improves mmWave coverage and reduces interference

~150m line-of-sight (LOS) and non-line-of-sight (NLOS) coverage possible in dense urban outdoor deployment

28GHz: Outdoor-to-Outdoor Path Loss & Coverage

* Manhattan 3D map, Results from ray-tracing
Qualcomm Research 5G mmWave prototype system

TDD synchronous system operating in the 28 GHz band

**mmWave User Equipment (UE)**

- Four selectable sub-arrays, each a phased array with 4 controllable RF channels

**mmWave Base Station (eNB)**

- 128 antenna elements\(^1\) with 16 controllable RF channels; design to support multiple UEs

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1 Qualcomm Research is a division of Qualcomm Technologies, Inc.

\(^1\) Commercial base stations could have more antenna elements depending on their size, coverage area, etc.
5G mmWave prototype system GUI
Showcasing adaptive beamforming and beam tracking techniques

UE intelligently selects the best sub-array on which to receive and transmit.

Selected sub-array uses beam-tracking and beam-steering to track the associated beam from eNB.

Demonstrates robust mobile broadband communications even under NLOS RF channel conditions and UE mobility.
Demonstrating LOS and NLOS coverage
In diverse locations and with device mobility

NLOS coverage through reflection
Indoor mobility and eNB handover
Outdoor mobility
Performing extensive channel measurements & simulations

Across mmWave frequencies
From 22 GHz to 67 GHz, including comparisons with 2.9 GHz

Across deployment scenarios
Outdoor - both high and low density; Indoor - e.g. venue, residential; Outdoor-to-Indoor

Across different materials
Different foliage/trees, various construction materials, humans, etc.

Driving system design/algorithm & 3GPP contributions
Outdoor mmWave propagation measurements

Channel response from omni-directional antennas
(Example measurement)

Key mmWave observations made

- Additional reflections at mmWave band provide alternative paths when LOS is blocked
- Alternative paths in mmWave can have very large receive signal
- Small objects affect mmWave propagation more than 2.9 GHz\(^1\) (e.g. tree branches)
- mmWave NLOS path loss exponents across frequencies not dramatically different than 2.9 GHz\(^2\)

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1 Due to easier diffraction around the objects at lower frequencies; 2 Non-line-of-sight path loss normalized to 1m antenna distance--actual path loss = [reference loss at 1m for a given frequency] + [normalized Propagation Loss]
Spherical Scan measurements

**Indoor Office**
- Diversity in elevation
- Numerous resolvable paths in elevation
- Significant path diversity in azimuth → Ability to withstand blockage events

**Outdoor**
- Diffraction
  - Foliage obstructed diffracted path → Energy spread across wide azimuth
  - Reflections from tall buildings result in wide elevation spread

**Diversity in Azimuth**
- Foliage obstructed diffracted path → Energy spread across wide azimuth
- Reflections from tall buildings result in wide elevation spread
Measuring effect of hand blocking and the role of diversity

Both corner antennas are operating

No Hand

With Hand

Hand Blockage
Making mmWave a reality for mobile

Qualcomm is driving 5G mmWave

60 GHz chipset commercial today for mobile devices

Developing robust 5G mmWave for extreme mobile broadband

Qualcomm® VIVE™ 802.11ad technology with a 32-antenna array element

Qualcomm Research 28 GHz end-to-end prototype system demonstrates beam forming and scanning to address NLOS scenarios, improve indoor/outdoor range, and provide robust mobility
Flexible deployments with 5G mmWave

Integrated access and backhaul simplifies deployment of small cells

mmWave backhaul

mmWave access

Fully flexible resource allocation between access and backhaul
5G mmWave is part of a unified, more capable 5G New Radio (NR)

Unified design across all spectrum types/bands
Our 5G vision: a unifying connectivity fabric

### 5G

#### Enhanced mobile broadband
- Multi-Gbps data rates
- Extreme capacity
- Uniformity
- Deep awareness

#### Mission-critical services
- Ultra-low latency
- High reliability
- High availability
- Strong security

#### Massive Internet of Things
- Low cost
- Ultra-low energy
- Deep coverage
- High density

- **Mobile devices**
- **Networking**
- **Automotive**
- **Robotics**
- **Health**
- **Wearables**
- **Smart cities**
- **Smart homes**
5G NR: A unified air interface for the next decade+
OFDM adapted to an extreme variation of requirements

- Optimized OFDM-based waveforms
  With scalable numerology and TTI, plus optimized multiple access for different use cases

- A common, flexible framework
  To efficiently multiplex services and features—designed for forward compatibility

- Advanced wireless technologies
  Such as massive MIMO, robust mmWave and a flexible self-contained TDD design
A unified 5G design for all spectrum types/bands
Addressing a wide range of use cases and deployment scenarios

**Licensed Spectrum**
- Cleared spectrum
- EXCLUSIVE USE

**Shared Licensed Spectrum**
- Complementary licensing
- SHARED EXCLUSIVE USE

**Unlicensed Spectrum**
- Multiple technologies
- SHARED USE

Below 1 GHz: longer range for massive Internet of Things

1 GHz to 6 GHz: wider bandwidths for enhanced mobile broadband and mission critical

Above 6 GHz, e.g. mmWave: extreme bandwidths, shorter range for extreme mobile broadband

From wide area macro to local hotspot deployments
- Also support diverse network topologies (e.g. D2D, mesh)
Qualcomm, leading the world to 5G
Driving 5G from standardization to commercialization

Qualcomm 5G activities

- Designing 5G, e.g. OFDM-based unified air interface
- Contributing to 3GPP, e.g. massive MIMO simulations, new LDPC code designs
- Delivering advanced prototypes, e.g. 5G mmWave demo at MWC’16
- Participating in impactful trials and pre-5G activities with major operators

3GPP 5G standardization

- R15 5G work items
- R16 5G work items
- R17+ 5G evolution
- 5G commercial launches

Note: Estimated commercial dates
Thank you

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Q&A