The Road to 5G

Brian K. Daly

Director – Core Network & Gov’t/Regulatory Standards
AT&T
Future mobile technology — “5G” — is focused on enabling a seamlessly connected society in the 2020 timeframe and beyond that brings together people along with things, data, applications, transport systems and cities in a smart networked communications environment.

It is expected to enable a fully mobile and connected society and to empower socio-economic transformations in countless ways many of which are unimagined today, including those for productivity, sustainability and well-being.


One of the interesting things that happened in yesterday’s Commission meeting was that my colleagues talked about how we don’t know exactly what 5G will become. We can see a lot of shadows.

- REMARKS OF FCC CHAIRMAN TOM WHEELER AS PREPARED FOR DELIVERY ADVANCED WIRELESS RESEARCH INITIATIVE LAUNCH EVENT JULY 15, 2016
A Look to the Future – 2020 and Beyond, the rise of “Things”
2020 and Beyond - Smart Cities
The Coming “Augmented Age” and the “Age of Things”

- Industrial Age
- Space Age
- Digital Age
- Information Age

Augmented Age / Age of Things
Artificial Intelligence
“Robotification”
“Information of Everything”

Time
Connected “Everything” ➔ Every Changing Cyber Risk Landscape

To adequately protect from security breaches, a multi-layered approach is recommended.

- **Endpoint**
  - **Endpoint Layer:** Helps secure the actual device or endpoint that is connected to the internet. Ex: robot, car, oil rig, etc.

- **Network**
  - **Network Layer:** Helps secure data in transit to and from a device that is connected. AT&T is a leader in providing the highly secure transmission of information to help secure data in transit over a wireless and wireline connection.

- **Data & Applications**
  - **Data/Application Layer:** Provides intrusion detection and prevention, specific security policies and controls to help protect stored data, as well as information-affiliated applications used by the device user.

**Threat Management**
- **Threat Analysis Layer:** Involves the collection and examination of data across all the layers (endpoint, network and data/application), to help identify, isolate, and manage threats.

We have seen a dramatic 458% increase in IoT vulnerability scans against devices.
— AT&T Cybersecurity Insights, Volume 1, October 5, 2015
5G Vocabulary – Technology Enablers

• “Softwarization”
  • Network Function Virtualization
  • Software Defined Network
  • Network Slicing

• Open Source

• Mobile Edge Computing

• Mobility on Demand

• mmWave

• Massive MIMO

• UHRLLC

• Densification

• Cloud

• Big Data
5G Requirements

- Massive Connectivity
- Throughput & Capacity
- Latency

8G

1000x Traffic

1/10

1000

Latency

Throughput & Capacity

4G

V2V

Industrial Automation

Cloud Computing

Augmented Reality

4K Video

>100 Mbps Everywhere

1000

Unlicensed mmWave Access

WiFi

Macro

Sub 6GHz

Pico

Sub 6GHz

Pico

mmWave

mmWave Access

Sensor Network

Smart Grid

Healthcare

IoT

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A Look Back

<table>
<thead>
<tr>
<th>Estimated Standards Timeline</th>
<th>Use Case Opportunities</th>
</tr>
</thead>
</table>
| • 3GPP Phase 1: 2018        | • Enhanced mobile broadband  
|                             |   • Throughput of 5 Gbps + |
| • 3GPP Phase 2: end of 2019| • Massive IoT  
|                             |   • Connection Density |
|                             |   • Long battery life   |
| • Expected widespread industry deployments: Phase 2 and beyond | • High reliability / low latency  
|                                                             |   • Industrial control   |
|                                                             |   • Remote manipulation |
The Standardization of 5G
Path to 5G
(Don’t Forget LTE-Adv.)

Pre-Deployment

**LTE-Advanced Evolution (R13&14)**

- FD-MIMO
- Improved densification management
- Dual connectivity
- Improved latency
- Higher order modulation
- Virtualization

**Narrowband LTE**

- Designed for low-power devices, with 10-year battery life
- Standards this summer; deployment late 2017 / early 2018

5G Industry Expectations

**So much more than speed**

- Multi-gigabit speeds and high capacity
- Connectionless Massive IoT
- Ultra-Low Latency and high reliability
- Sub 6 GHz for wide area coverage with improved spectral efficiency
- Flexible, lean carrier design
- Multi-RAT network using sub 6 GHz, mmWave and unlicensed bands in concert
- Massive MIMO
- Densification with self-backhaul
- SDN/NFV based architecture

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“New experiences like virtual reality, self-driving cars, robotics, smart cities and more are about to test networks like never before,”

“Our approach is simple – deliver a unified experience built with 5G, software-defined networking (SDN), Big Data, security and open source software.”

John Donovan
Chief Strategy Officer and Group President
AT&T Technology and Operations
Next Steps

• Trials and Testing
• Standardization
• Key Architecture Components:
  • NFV / SDN
  • Big Data / Analytics
• Architecture Considerations:
  • X-RAN
  • Transport
• Core Network Development
Thank You
Dr. Eshwar Pittampalli, Director – Wireless Technology

The Next Generation of Wireless: 5G Leadership in the U.S.
# Wireless Evolution

<table>
<thead>
<tr>
<th>Road Type</th>
<th>CHANNEL Size</th>
<th>APPLICATIONS</th>
<th>FREQUENCY BAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>1G: Dirt road</td>
<td>30 KHz</td>
<td>Voice</td>
<td>800 MHz</td>
</tr>
<tr>
<td>2G: Paved one lane road</td>
<td>200 KHz</td>
<td>+ Text, Email, Limited Internet</td>
<td>800/1900 MHz</td>
</tr>
<tr>
<td>3G: Two lane road</td>
<td>1.25 MHz</td>
<td>+ Internet, low quality video</td>
<td>800/1700/1900 MHz 2.1 GHz</td>
</tr>
<tr>
<td>4G: Four lane highway</td>
<td>20 MHz</td>
<td>+ Social media, streaming video</td>
<td>700/800/1700/1900 MHz 2.1/2.3/2.5 GHz</td>
</tr>
<tr>
<td>5G: Ten lane superhighway</td>
<td>200 MHz</td>
<td>+ HD video, VR, AR, High-speed data</td>
<td>High Band</td>
</tr>
</tbody>
</table>
5G: The Next Generation of Wireless

- **5G will:**
  - Have speeds at least 10x faster than 4G;
  - Support 100x more devices; and
  - Be 5x more responsive.

- **These next-generation wireless networks could add $2.7 trillion to the U.S. economy by 2030.**

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**3G**
384 Kbps [2000]

**4G**
100 Mbps [2010]

**5G**
>1 Gbps [2020+]

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**Consumer Benefits of 5G**
By the Numbers

- 10x Faster
- 100x More Devices
- 5x More Responsive

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1 inch

4.6 feet
5G spectrum & infrastructure

High Band Spectrum
- Complete Spectrum Frontiers proceeding quickly
- Adopt flexible service rules
- Licensing framework that provides certainty and encourages investment

Low/Mid Band
- Low band – enable broad coverage
- Mid band – capacity and small cells

Infrastructure
- Small cell placement
- Pole attachments
Unleashing 5G

• CTIA supports the Commission’s efforts to allocate additional spectrum for mobile broadband services.

• The Commission’s examination of bands above 24 GHz should be part of a holistic examination of high-, mid-, and low-band spectrum for mobile use.
  • High-band spectrum is complementary to spectrum below 3 GHz.
  • Low- and mid-band spectrum have better propagation characteristics and, for the foreseeable future, will be more advantageous for macro network coverage and capacity.

• Streamlined pole and siting policies are also necessary to support spectrum deployments.
  • Higher frequencies mean more infrastructure – carriers will need to deploy thousands of small cells to take advantage of the new spectrum to provide users with service.
High Band Spectrum is Vital to America’s 5G Future
July 14, 2016: The rules adopted (by FCC) today creates a new Upper Microwave Flexible Use Service in the 28GHz (27.5-28.35 GHz), 37 GHz (37-38.6 GHz), and 39 GHz (38.6-40 GHz) bands, and new unlicensed band at 64-71 GHz.

- 425/425 MHz
- 200 MHz
- 200 MHz
5G benefits

U.S. wireless industry benefits
- >$400B in annual economic impact
- >1.3 million jobs
- U.S. jobs – R&D, industry knowledge, universities

Markets
- Consumers
  - CTIA 5G white paper: [http://tinyurl.com/jh6gemy](http://tinyurl.com/jh6gemy)
  - Speed – Ultra HD video, VR
  - Latency – robotics, MTC
  - IoT – wearables, tags, smart home
- Verticals
  - Industrial IoT, Connected cars, Energy, Transportation, Smart Cities, M-Health and Telemedicine
Leading the World to 5G

John W. Kuzin
Vice President & Regulatory Counsel
QUALCOMM Inc.
July 25, 2016
Transforming our world through intelligent connected platforms

Qualcomm’s vision

Last 30 years
Interconnecting people

Next 30 years
Interconnecting their worlds

Leveraging unparalleled systems leadership in connectivity and compute
Our 5G vision: a unifying connectivity fabric

**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

Unified design for all spectrum types and bands from below 1GHz to mmWave
Evolving LTE to be a critical part of the 5G Platform

We are pioneering 5G technologies today

Advanced MIMO
256QAM
Carrier aggregation

Shared spectrum (LAA, LSA)
Gigabit-class LTE
Narrowband IoT
Device-to-device

eLAA
Massive MIMO
Low Latency
Enhanced broadcast
C-V2X

5G NR
Rel-15 and beyond
5G NR

5G

Rel-10/11/12
LTE Advanced

Rel-13 and beyond
LTE Advanced Pro

Note: Estimated commercial dates. Not all features commercialized at the same time
Multi-mode/multi-connectivity essential to 5G success

5G/4G/3G/Wi-Fi
Multi-mode device

Simultaneous connectivity across 5G, 4G and Wi-Fi

5G NR

5G above 6 GHz

4G below 6 GHz

5G below 6 GHz

Wi-Fi

4G LTE
5G NR

A unified, more capable air interface

Diverse deployments

Diverse spectrum

Diverse services and devices
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)
5G Enhanced mobile broadband

Extreme throughput
Ultra-low latency
Uniform experience

- Mobilizing mmWave
- Wider bandwidths
- Massive MIMO
- Shared spectrum
5G Mission critical services

High reliability
Ultra-low latency
High availability

- Low-latency TDD/FDD
- Network slicing
- Mission-critical transmissions
- Multi-connectivity
5G Massive IoT

Power efficient
Low complexity
Long range

- Multi-hop mesh
- Efficient uplink
- Narrow bandwidth
- Efficient signaling
LTE roadmap the foundation for cellular IoT growth
Scaling LTE to connect the Internet of Things

Scaling down in complexity and power

LTE Cat-1
Up to 10 Mbps

eMTC (Cat-M1)
Up to 1 Mbps

NB-IoT (Cat-NB1)
10s of kbps to 100s of kbps

Energy management
Wearables
Connected healthcare
Object tracking
City infrastructure
Utility metering
Smart buildings
Environment monitoring

Object tracking
Energy management
Wearables
Connected healthcare

Environment monitoring
Smart buildings
Utility metering
City infrastructure
Object tracking
Connected healthcare
Wearables
Energy management
Natively incorporate advanced wireless technologies

Many technology enablers to meet 5G requirements and services

- Hyper dense deployments with full self-configuration
- Coordinated spatial techniques
- Best use of all spectrum types
- mmWave
- Integrated access and backhaul
- Advanced receivers
- Massive MIMO
- Advanced
- Multi-hop and D2D communications
- Energy efficient, low cost IoT communications
- V2X
- Low latency and ultra-reliable communication
- Beam forming
- Multicast
Introducing the Qualcomm Research 5G NR sub-6 GHz prototype system and trial platform

- Operating in sub-6 GHz spectrum bands
  Allows for flexible deployments with ubiquitous network coverage and a wide range of use cases

- Achieving multi-Gbps at low latency
  Showcases innovative Qualcomm 5G designs to efficiently achieve multi-gigabit per second data rates and low latency

- Driving standardization on 5G NR
  OFDM-based designs implemented on the prototype system are being utilized to drive 3GPP standardization

- Will enable impactful 5G NR trials
  Designed to flexibly track 3GPP standardization and be utilized as a trial platform for impactful and timely 5G NR trials

Qualcomm Research is a division of Qualcomm Technologies, Inc.
Making mmWave a reality for extreme mobile broadband

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
Leading the world to 5G™

Wireless technology, chipset and IoT platform leadership

End-to-end system approach from standardization to commercialization

A leader in global network experience and scale
Thank you

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