Mobile Broadband in mmW Bands

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TCB Workshop
April 13, 2016

Note: The views expressed in this presentation are those of the author and may not necessarily represent the views of the Federal Communications Commission.
Growth in Smart Phones/Tablets


Pope Benedict
2 Billion cell phones
34 million in US

Pope Francis
6.9 Billion cell phones
203 million in US
Mobile data continues to grow at >50% CAGR

Mobile data is relatively a small portion of the overall data traffic
How to offer more with less?

What would be the cost structure of 100GB data plan?

Source: Company reporting, Jackdaw Research analysis
Driver: Continued growth of mobile & other services

More Spectrum
- National Broadband Plan
- Middle Class Tax Relief & Jobs Creation Act of 2012
- Presidential Memos
- NTIA ten year plan
- Consider potential reallocations, but becoming more difficult

Efficient Use of Spectrum:
- Continue to advance technology with higher spectral efficiency
- Often spectral efficiency needs to be balanced with capital efficiency

More Sharing
- PCAST Report
- Department of Defense Spectrum Strategy
- Develop advanced spectrum sharing techniques
Why to consider mmW bands?

Spectrum: Key to Wireless Capacity

- AM Radio
- TV Broadcast
- FM Radio
- Cellular
- Wi-Fi
- 60GHz Spectrum
- 77GHz Vehicle Radar
- Active CMOS IC Research
- Shaded Areas ~ Equivalent Spectrum!

mmWave System Tech.

- Fixed 1 Gbps
- Mobile 100 Mbps

Source: Samsung Presentation from IEEE ICC 2013

- Fixed >50 Gbps
- Mobile 5 Gbps

4G frequencies
New higher frequencies

Wireless Carrier Frequencies Have Not Kept Pace
Moore’s Law in the Past 40 Years

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>2016</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Computer Clock Speed</td>
<td>1 MHz</td>
<td>5 GHz</td>
<td>5,000x</td>
</tr>
<tr>
<td>Personal Computer Memory Size</td>
<td>256 KB</td>
<td>500 GB</td>
<td>4,000,000x</td>
</tr>
<tr>
<td>Cellular Phone Carrier Frequency</td>
<td>850 MHz</td>
<td>2.5 GHz</td>
<td>3x</td>
</tr>
</tbody>
</table>

5G BS Massive MIMO/Array Antennas

NON-PUBLIC. FOR INTERNAL USE ONLY
5G Service Vision

ITU-R Usage Scenarios for 5G

Enhanced Mobile Broadband

Wearables

Energy Management

Massive Machine Type Communications

Ultra-reliable, Low-latency Communications

Future IMT

So what is 5G?

>10 Gbps peak data rates

10,000x more traffic

Ultra-reliability

Very low latency

Ultra-low cost

Multi-year Battery

Mission-critical control and automation

Billions of devices with different needs

GBs transferred in an instant

Heterogeneous use cases – diverse requirements

Nokia

"Unlimited experience"

100 Mbps wherever needed

10,000x more traffic

<1 ms radio latency

Ultra-reliability

M2M ultra low cost

Critical machine communication

Massive machine communication

5G

10-100x more devices

M2M ultra low cost

10 years on battery

"For everything"

"Instant action"

"Ultra-reliability"

DRIVING 5G EVOLUTION

New Use Cases & Business Models

New Tools

New deployment options

Massive MTC

Operational Efficiency

Enhanced Broadband

Mission Critical MTC


Intel products fuel the 5G engine by enabling new applications in a variety of spectrum bands
Enabling Technologies

Adaptive Pencil Beamforming

Full Dimensional MIMO

5G Flat Network Architecture

Source: Samsung 5G Vision White Paper
5G Technology Status

Refer to the FCC 5G Workshop discussion materials
https://www.fcc.gov/news-events/events/2016/03/spectrum-frontiers-workshop
Preliminary Timeline to 5G

IMT-2020 Track
- IMT-2020 is the official ITU term for 5G mobile service
- Specifications of IMT-2020 is scheduled to be finalized by October 2020

3GPP Track
- 3GPP will work with ITU timeline to submit an IMT-2020 proposal
- 3GPP does not intend to explicitly use the term “5G” when the work starts. “5G” will remain as a marketing & industry term that companies will use as they see fit.

Source: Tentative 3GPP Timeline for 5G
Expanding Use of the mmW Spectrum

- FCC Notice of Inquiry (NoI) adopted 10/17/14
- FCC Notice of Proposed Rulemaking (NPRM) adopted 10/22/2015
- NPRM proposes a mix of licensed and unlicensed use in the millimeter wave spectrum, and creates opportunities for sharing among different kinds of users; fixed/mobile; federal/nonfederal; terrestrial/satellite; and carrier networks/private networks
- Recommended by Technological Advisory Council

# US Table of Allocation

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Allocations</th>
<th>FCC Service Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>9KHz – 95GHz</td>
<td>Various Allocations in Primary, Co-Primary, or Secondary</td>
<td>Various service rules for a given allocation</td>
</tr>
<tr>
<td>95GHz - 275GHz(^1)</td>
<td>Various allocations (large amount of allocation for passive services)</td>
<td>No Service Rules</td>
</tr>
<tr>
<td>275GHz - 1000GHz(^1)</td>
<td>No Allocation</td>
<td>No Service Rules</td>
</tr>
</tbody>
</table>

\(^1\) Experimental Licensing Process supports various activities in these bands
Spectrum Frontiers NPRM – Key Components

- Bands of Interests – Licensed and Unlicensed
  - 27.5-28.35; 38.6-40; 37-38.6; 64-71
  - 24.25-24.45; 25.05-25.25; 29.1-29.25; 31-31.3; 31.8-33; 42-42.5; 71-76; 81-86+

- Licensing, Operating and Regulatory Rules/Issues
  - Part 30: Upper Microwave Flexible Use Service (UMFUS)
  - Geographic Area Licensing, Area Size, Band Plan, License Term
  - Performance Requirement; Spectrum Holding

- Satellite Sharing
  - 275.-28.35; 37.5-40

- Federal Sharing
  - 39.5-40; 37-38.6; Passive Service <37GHz

- Technical Rules
  - Duplexing; TX Power, Emission Limit; IX Protection and Coordination; Equipment Authorization; Part 15 Rules for 64-71
Proposed Technical Rules

- **Flexible Duplexing**
  - TDD and FDD support is proposed

- **TX Power**
  - Max EIRP of 62dBm/100MHz is proposed for BS
  - Max EIRP of 43dBm is proposed for MS
  - Sought comments on the bandwidth factor for mmW band technologies

- **OOBE**
  - Radiated measurement is assumed due to lack of RF port
  - 43+10logP is proposed and sought comments on the measurement bandwidth, offset and other parameters as applicable from PCS/AWS rules

- **Field Strength at Market Borders**
  - Sought comments on the applicability of 47dBuV/m per Part 27 rules

- **Measurement Techniques**
  - Sought comments on measurement challenges of mmW bands, particularly on the radiated measurement techniques
Questions?