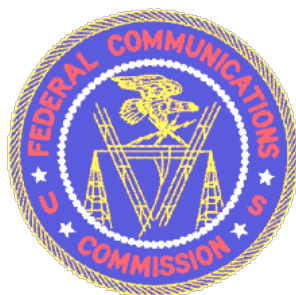


Mobile Broadband in mmW Bands



Michael Ha, Deputy Chief
Policy and Rules Division
Office of Engineering and Technology

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

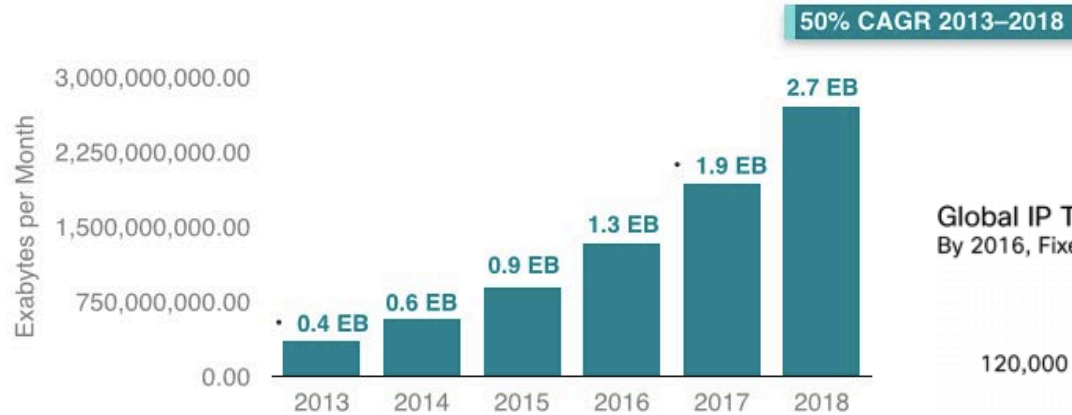
<http://www.nydailynews.com/news/world/check-contrasting-pics-st-peter-square-article-1.1288700>

Mobile Data Growth



US Mobile Data Traffic Growth / Top-Line

US Mobile Data Traffic will Increase Nearly 8-Fold from 2013—2018



Source: Cisco VNI Global Mobile Data Traffic Forecast, 2013–2018

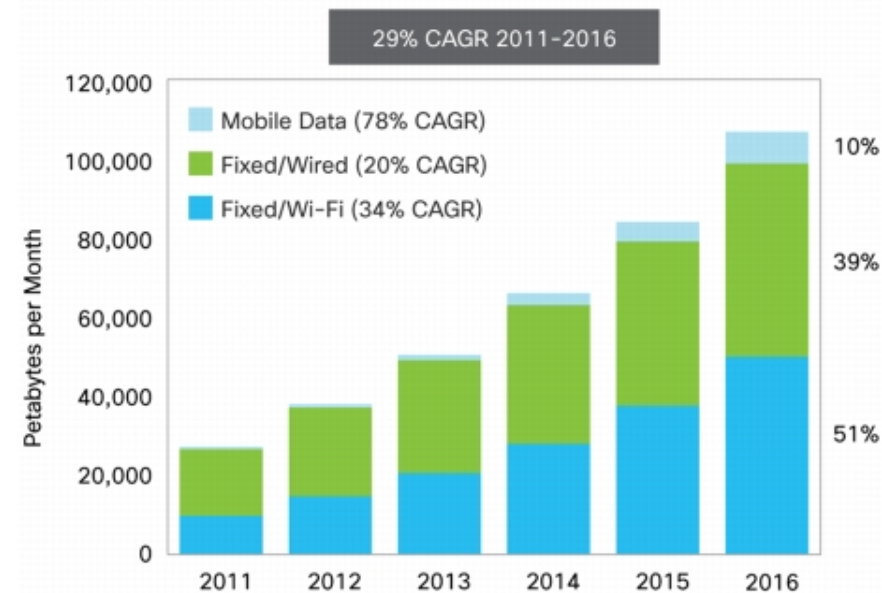
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Mobile data continues to grow at >50% CAGR

Mobile data is relatively a small portion of the overall data traffic

Global IP Traffic by Local Access Technology

By 2016, Fixed/Wi-Fi Traffic Surpasses Fixed/Wired Traffic

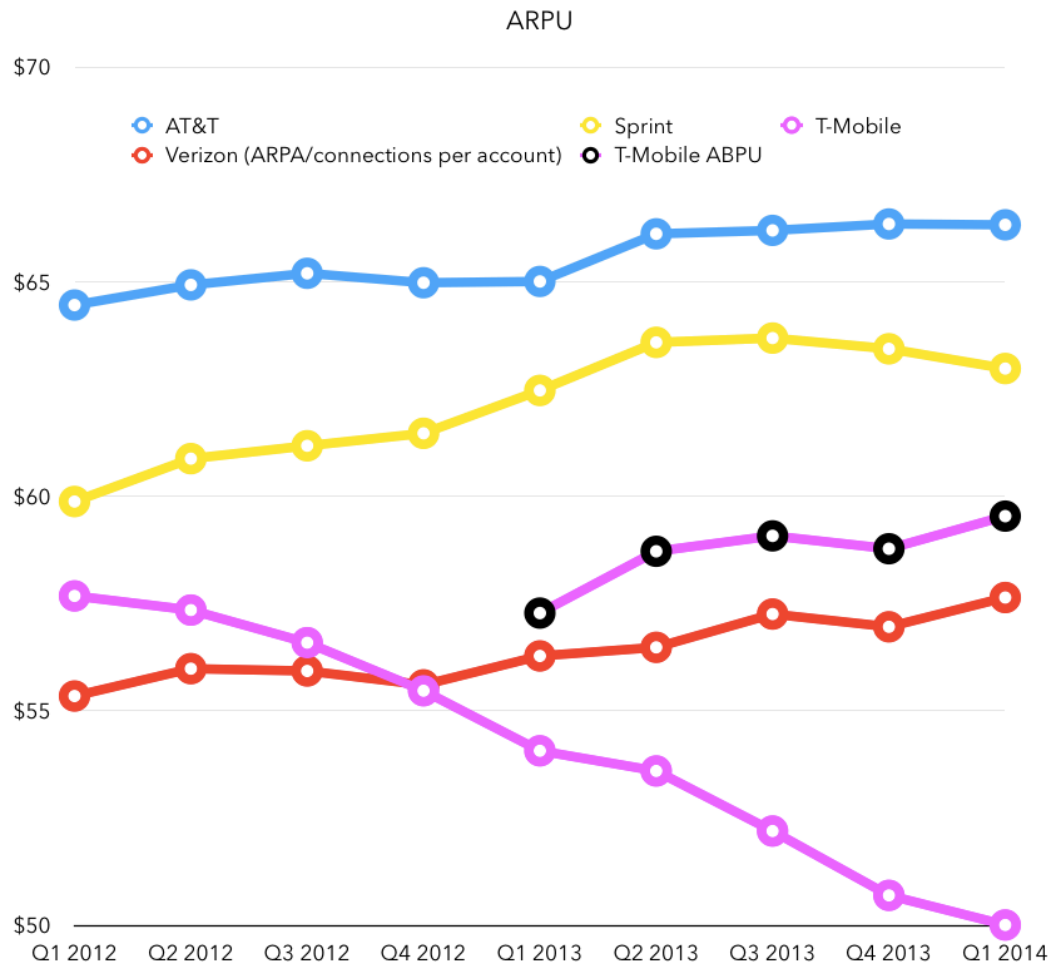


Source: Cisco VNI Global Forecast, 2011–2016

Wireless Industry Challenge



How to offer more with less?



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

Source: Company reporting, Jackdaw Research analysis

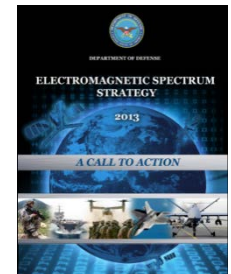
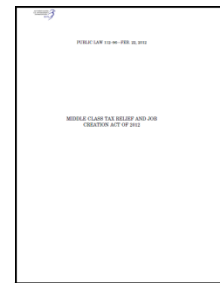
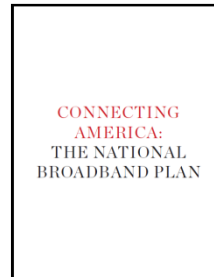
Spectrum Strategy



- ❑ 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:

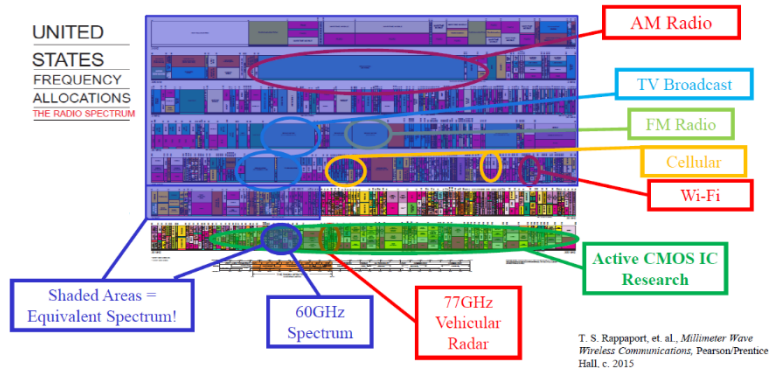
- ❑ Continue to advance technology with higher spectral efficiency
- ❑ Often spectral efficiency needs to be balanced with capital efficiency

- ❑ More Sharing

- ❑ PCAST Report
- ❑ Department of Defense Spectrum Strategy
- ❑ Develop advanced spectrum sharing techniques

Why to consider mmW bands?

Spectrum: Key to Wireless Capacity

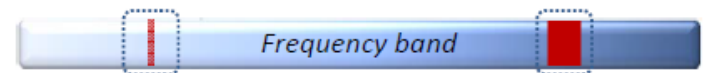


mmWave System Tech.

Source: Samsung Presentation from IEEE ICC 2013

Fixed 1 Gbps
Mobile 100 Mbps

• Fixed >50 Gbps
• Mobile 5 Gbps

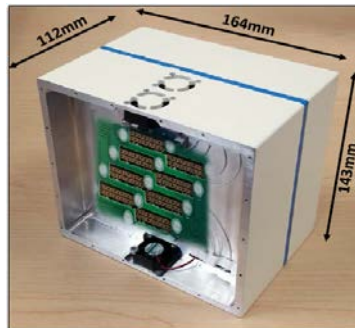
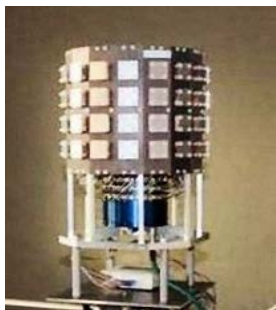


4G frequencies

New higher frequencies

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

	1976	2016	Increase
Personal Computer Clock Speed	1 MHz	5 GHz	5,000x
Personal Computer Memory Size	256 KB	500 GB	4,000,000x
Cellular Phone Carrier Frequency	850 MHz	2.5 GHz	3x

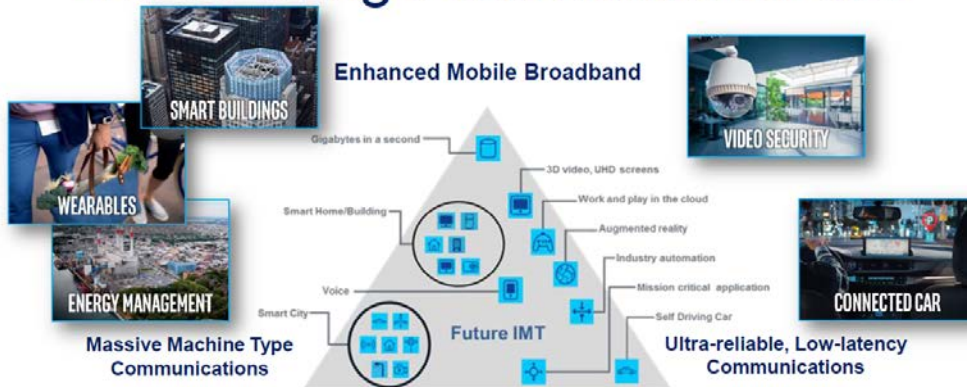


5G BS Massive MIMO/Array Antennas

5G Service Vision



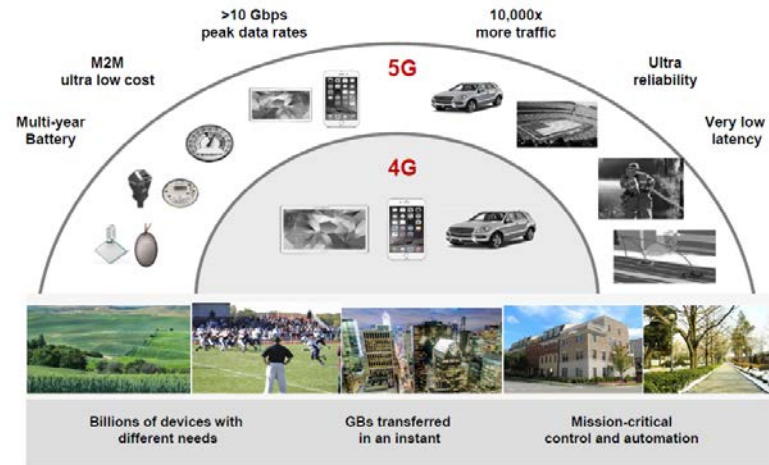
ITU-R Usage Scenarios for 5G



Source: Recommendation ITU-R M.2083 "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond"

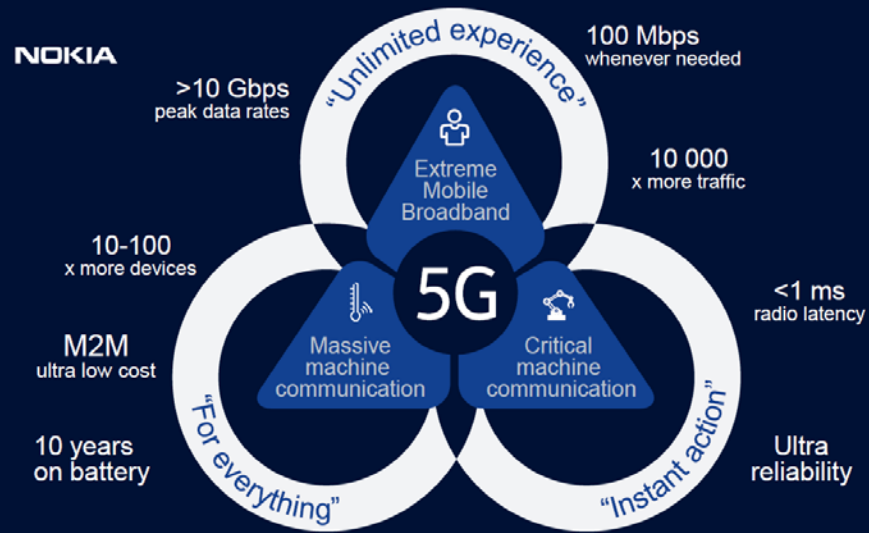
Intel products fuel the 5G engine by enabling new applications in a variety of spectrum bands

So what is 5G?

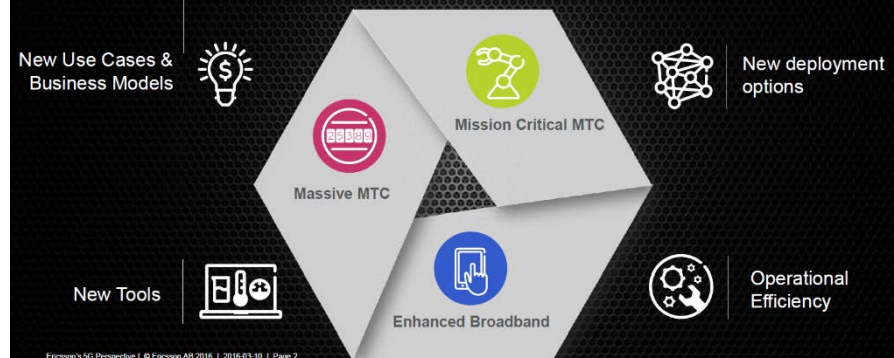


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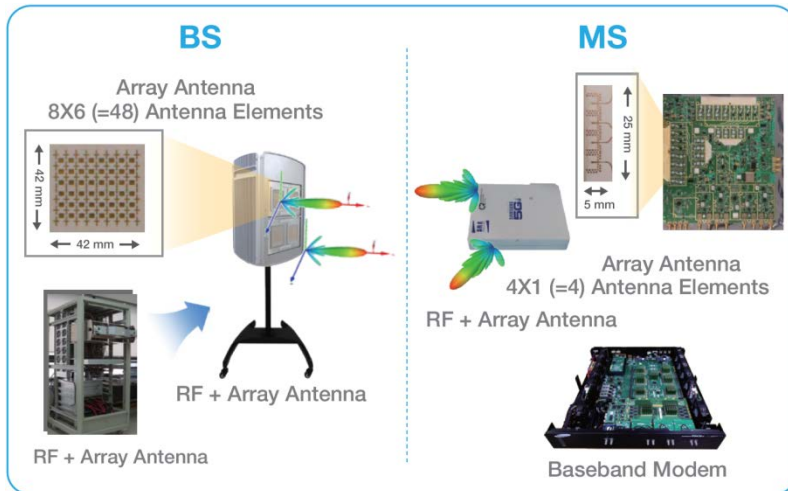
Heterogeneous use cases – diverse requirements



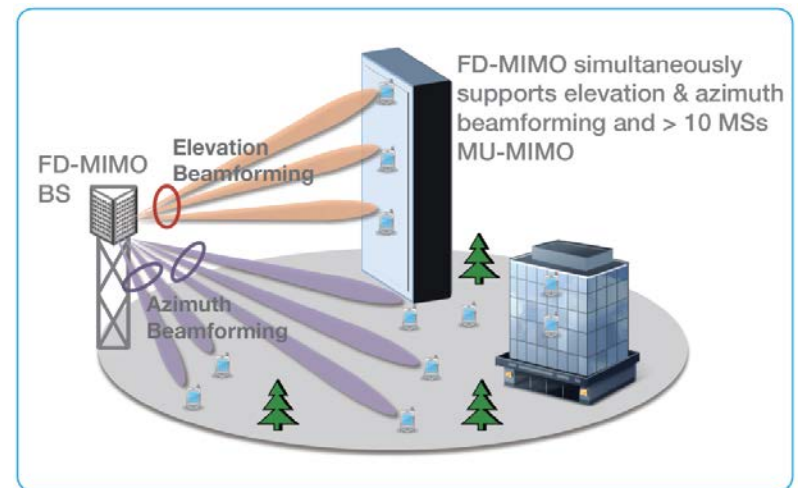
DRIVING 5G EVOLUTION



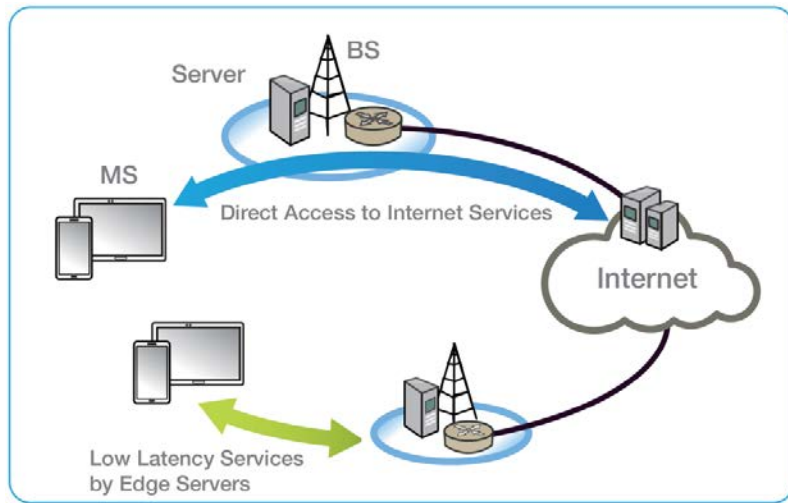
Enabling Technologies



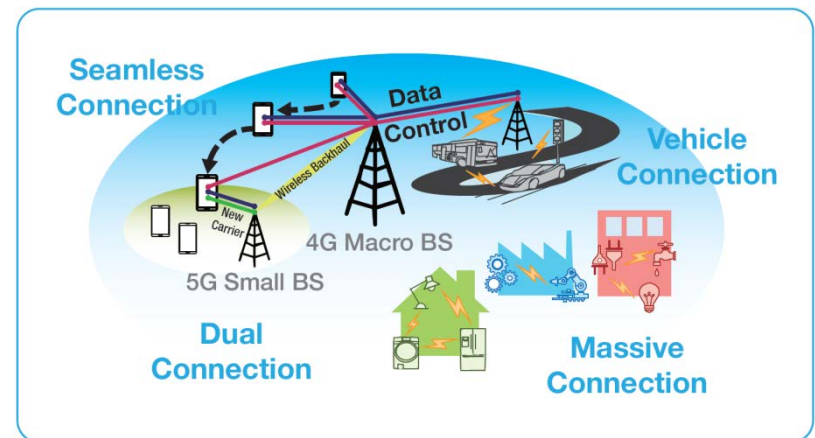
Adaptive Pencil Beamforming



Full Dimensional MIMO



5G Flat Network Architecture



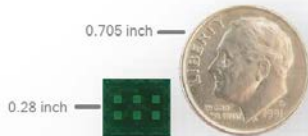
5G Deployment Scenario

Source: Samsung 5G Vision White Paper

5G Technology Status

Making mmWave a reality for mobile Qualcomm is driving 5G mmWave

60 GHz chipset commercial today for mobile devices



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

Qualcomm VIVE is a product of Qualcomm Atheros, Inc.; Qualcomm Research is a division of Qualcomm Technologies, Inc.

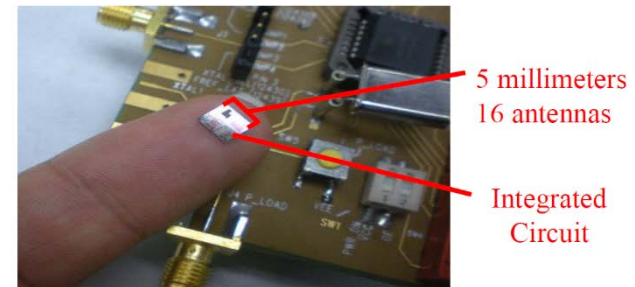
Developing robust 5G mmWave for extreme mobile broadband



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

5

mmWave Wavelength Visualization – 60 GHz

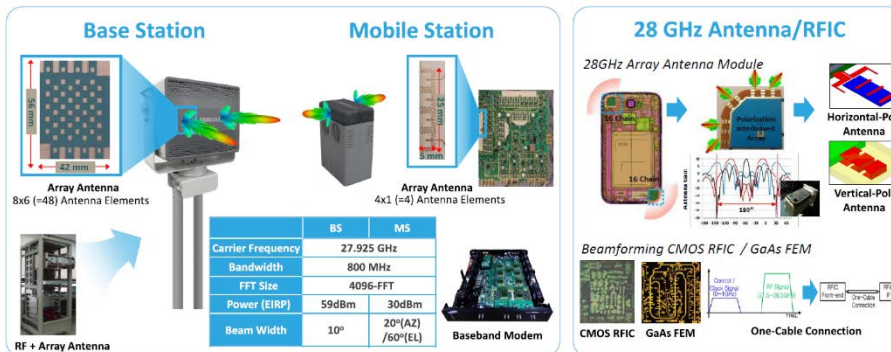


Source: F. Gutierrez, S. Agarwal, K. Purnish, and T.S. Rappaport, "On-Chip Integrated Antenna Structures in CMOS for 60 GHz WPAN Systems," IEEE Journal on Selected Areas in Communications, vol. 27, no. 8, October 2009, pp. 1367–1377.

mmWave Testbed / Chipset Development

SAMSUNG

World's 1st mmWave Testbed and Antenna/RFIC for Devices



Verizon 5G Technology Forum Partners



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Refer to the FCC 5G Workshop discussion materials

<https://www.fcc.gov/news-events/events/2016/03/spectrum-frontiers-workshop>

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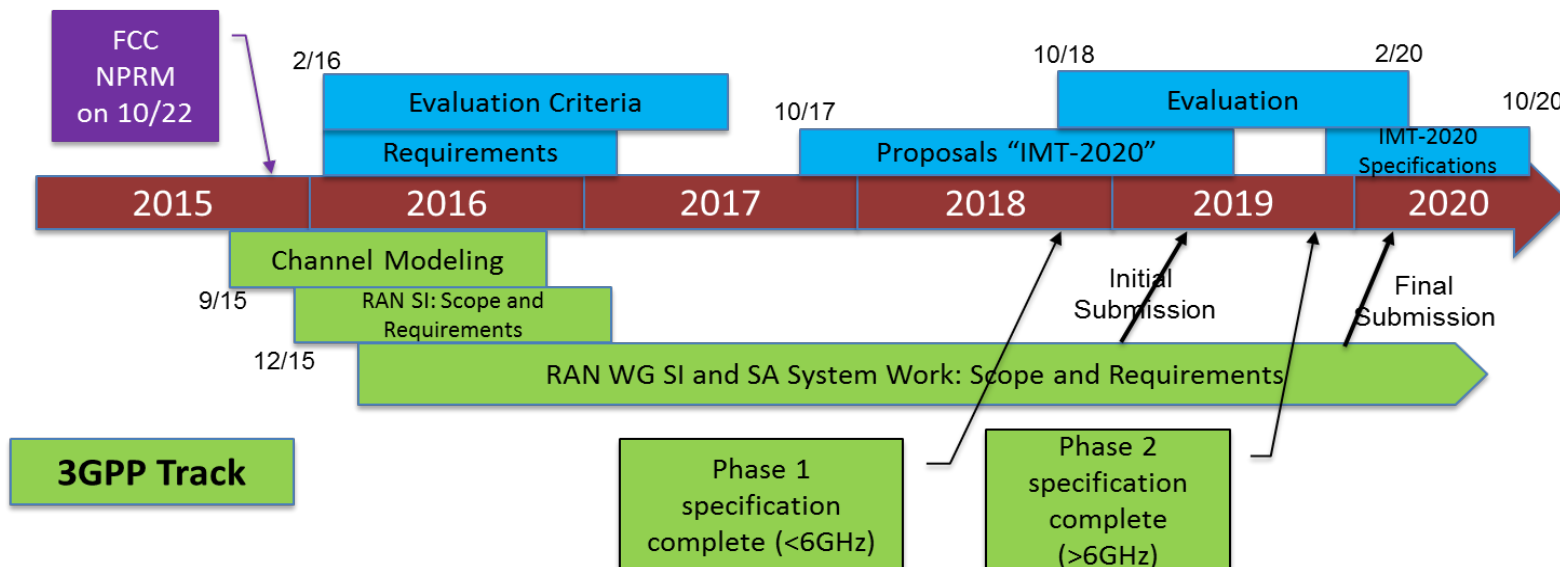
Preliminary Timeline to 5G



IMT-2020 Track

Source: Tentative 3GPP Timeline for 5G

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



- 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.

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

Federal Communications Commission		FCC 15-138
Before the Federal Communications Commission Washington, D.C. 20554		
In the Matter of)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services)	GN Docket No. 14-177
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands)	IB Docket No. 15-256
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band)	RM-11664
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services)	WT Docket No. 10-112
Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0- 38.0 GHz and 40.0-40.5 GHz for Government Operations)	IB Docket No. 97-95
NOTICE OF PROPOSED RULEMAKING		
Adopted: October 22, 2015		Released: October 23, 2015
Comment Date: January 26, 2016		
Reply Comment Date: February 23, 2016		
By the Commission: Chairman Wheeler and Commissioners Clyburn and Rosenworcel approving and issuing separate statements; Commissioners Pai and O'Rielly approving in part and dissenting in part and issuing separate statements.		
TABLE OF CONTENTS		
Heading		Paragraph #
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II. EXECUTIVE SUMMARY		4
III. BAA		5

http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db1023/FCC-15-138A1.pdf

US Table of Allocation



Frequency Range	Allocations	FCC Service Rules
9KHz – 95GHz	Various Allocations in Primary, Co-Primary, or Secondary	Various service rules for a given allocation
95GHz - 275GHz ¹	Various allocations (large amount of allocation for passive services)	No Service Rules
275GHz - 1000GHz ¹	No Allocation	No Service Rules

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
 - ❑ 27.5-28.35; 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
- ☐ OOB E
 - ☐ Radiated measurement is assumed due to lack of RF port
 - ☐ $43+10\log P$ 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?