5G spectrum innovation and global update
Today’s agenda

- Where are we with 5G today?
- What are some important 5G “Game Changers”?
- How much progress has been made in allocating spectrum for 5G?
- Questions?
5G accelerating globally

- 95+ Operators with 5G commercially deployed
- 305+ Additional operators investing in 5G
- 750M+ 5G smartphones to ship in 2022
- 1B+ 5G connections by 2023 – 2 years faster than 4G
- 3.8B+ 5G smartphones to ship between 2020 and 2024

Empowering the 5G device ecosystem

700+

5G designs launched or in development

Qualcomm Snapdragon is a product of Qualcomm Technologies Inc. and/or its subsidiaries
5G Rollout Outlook

USA
- Now: NSA Sub-6 GHz
  - Sub-6 FDD
  - Standalone
- 2021: Sub-6 carrier aggregation + Sub-6 + mmWave aggregation

Europe
- Now: NSA Sub-6 GHz
  - Sub-6 FDD
- 2020: mmWave
- 2021: Sub-6 carrier aggregation + mmWave

China
- Now: NSA Sub-6 GHz
- 2020: Sub-6 FDD
  - Standalone
- 2021: Sub-6 carrier aggregation + mmWave

India
- 2021: NSA Sub-6 GHz
  - mmWave
  - Standalone

SEA
- Now: NSA Sub-6 GHz
- 2020: mmWave
- 2021: Sub-6 carrier aggregation + Standalone

Japan
- Now: NSA Sub-6 GHz
- 2020: mmWave
- 2021: Standalone + Sub-6 + mmWave aggregation

Korea
- Now: NSA Sub-6 GHz
- 2020: mmWave
- 2021: Sub-6 FDD
  - Sub-6 carrier aggregation
  - Sub-6 + mmWave aggregation

Australia
- Now: NSA Sub-6 GHz
- 2020: Sub-6 FDD
- 2021: mmWave
  - Sub-6 carrier aggregation
  - Standalone

"+" implies the year indicated and beyond.
5G carrier aggregation
for ultimate operator flexibility and performance

- Double sub-6 peak speeds in standalone mode
- Increase capacity
- Expand coverage
- Improve user experience
- Accelerate transition to standalone mode

- Higher capacity, throughput, bandwidth
- mmWave carrier aggregation (e.g., up to 8x100 MHz)
- Sub-6 carrier aggregation
- Low-bands (sub-6): Allows operators to maximize spectrum use for 5G capacity and coverage
- Mid-bands (sub-6)
- Wider coverage
- TDD
- FDD
Our 3rd Gen 5G modem-RF system

World’s first 5nm baseband
First to support 5G carrier aggregation across FDD and TDD
3rd generation mmWave antenna module
NSA, SA, FDD, TDD, CA, DSS support
5G voice-over-NR
Spectrum is critical for 5G success
Using all spectrum types and bands

**Licensed spectrum**
- Exclusive use
- Over 40 bands globally for LTE, remains the industry's top priority

**Shared spectrum**
- New shared spectrum paradigms
- Ex: 3.5 GHz USA, 3.7 GHz Germany

**Unlicensed spectrum**
- Shared use
- Ex: 5 GHz / 6 GHz / 60 GHz global

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High bands above 24GHz (mmWave)

Mid bands 1GHz to 7GHz

Low bands below 1GHz
Significant RF complexity with 5G

10,000+ early 5G band combinations

<table>
<thead>
<tr>
<th>Region</th>
<th>LTE bands:</th>
<th>5G NR bands:</th>
<th>LTE CA:</th>
<th>LTE UL CA:</th>
<th>EN-DC:</th>
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<tbody>
<tr>
<td><strong>North America</strong></td>
<td>71,29,12,13,14,5/26,2/25,4/66,7,30,41,46,48</td>
<td>n71,n66,n2,n41,n5,n12,n25,n48,n78,n258,n260,251</td>
<td>2+4/66,25+41,4+7,7+30</td>
<td>2+66+30,2+4+7</td>
<td>8+20+n28A,1+3+7+n75+n78</td>
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<td><strong>Europe</strong></td>
<td>28A,20,8,32,1,3,7,38,46</td>
<td>n78,n28A,n8,n20,n38,n1,n3,n7,n75/76, n257,n258</td>
<td>1+3+7,3+7+38,3+7+32</td>
<td>3+7+38,7+30,25+41,1+3</td>
<td>3+n41,39+n41,3+n79/78,1+3+n78,5/8+n78</td>
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<tr>
<td><strong>Middle East / Africa</strong></td>
<td>28,12,5/26,8,1,2,3,4/66,7,38,41,42,46</td>
<td>n78,n12,3/41,3/7,3/40,7+38,41,3+7,3+40</td>
<td>1+3+7,3+7+40,3+41</td>
<td>1+3,3+7,2+4,4+7</td>
<td>3+7+n78</td>
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<td>28,12,5/26,8,1,2,3,4/66,7,38,41,42,46</td>
<td>n78,n12,3/41,3/7,3/40,7+38,41,3+7,3+40</td>
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<td>3+7+n78</td>
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<td><strong>China (incl. Taiwan and Hong Kong)</strong></td>
<td>5,8,1,3,7,34,39,40,41,(4,12,20,38 roaming)</td>
<td>41+,79,1,3,78</td>
<td>39+41,3+41,1+3</td>
<td>3+n41,39+n41,3+n79/78,1+3+n78,5/8+n78</td>
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<td><strong>South Korea</strong></td>
<td>5,8,1,3,7,40,46</td>
<td>n78,n257</td>
<td>1+3+7,1/3+40</td>
<td>1+3+7/40</td>
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<td><strong>Japan</strong></td>
<td>28,26,8,11,19,21,1,3,41,42,46</td>
<td>n77,n78,n91,n3,n257</td>
<td>18+28A,1+3+1+21,3+41/42</td>
<td>1+3+41</td>
<td>1+3+41</td>
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<td><strong>South East Asia / Oceana</strong></td>
<td>28,20,5,8,1,3,7,38,40,41</td>
<td>n78,n2,n40,n257,n258</td>
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5G Game Changers
Dynamic Spectrum Sharing (DSS) in 3GPP Release 15

For supporting 5G NR in lower FDD bands for NSA and SA deployments

- LTE controlled sharing – 5G NR to avoid resources used by LTE (e.g., LTE CRS)¹
- No impact to legacy LTE devices – DSS support only required for 5G NR devices
- System efficiency depends on LTE/5G NR traffic volume and device penetration

Supports 5G NR in LTE bands today with “soft refarming”
Efficient use of spectrum with low sharing overhead
DSS & carrier aggregation are key enablers for SA migration

¹ Cell Specific Reference Signal
Rel-16 introduces NR in unlicensed spectrum

**Anchored NR-U**
Unlicensed spectrum is combined with other licensed or shared spectrum as anchor

- Licensed or shared anchor spectrum
- Unlicensed NR-U spectrum*

**Standalone NR-U**
Only unlicensed spectrum is used

- Unlicensed NR-U spectrum*
- ≤ 100 MHz UL BW
- ≤ 400 MHz DL BW

* Still under discussion in Rel-16

Unlock more spectrum globally
New markets and verticals
New deployment scenarios
Almost a decade of leadership in unlicensed spectrum

From LTE-U/LAA to NR-U

Vision: High-performance cellular in unlicensed spectrum

Continuous research, industry first over-the-air LAA, eLAA, MulteFire demos, co-existence with Wi-Fi
NR-U synchronized sharing brings higher performance

Opportunity for greenfield spectrum

Asynchronized sharing
Evolutionary path: Existing coexistence rules in unlicensed spectrum

Synchronized sharing
Revolutionary path: Time synchronized sharing in unlicensed and shared spectrum

Anchored NR-U

Standalone NR-U

Time synchronization
Provides great potential to share spectrum more efficiently

5G CoMP, predictable sharing, and spatial sharing
Deeper 5G coverage with small cells

5G network densification with spectrum reuse

Powered by Qualcomm® FSM™ small cell platforms

Capable of being developed to utilize mmWave and sub 6 GHz

Supporting uniform 5G speeds and experiences, indoors and outdoors
Qualcomm® 5G RAN Platforms for small cells

Cutting edge technology for flexible, virtualized, scalable, and interoperable cellular network infrastructure

Selected by global infrastructure innovators
Qualcomm®
QTM527 mmWave antenna modules

Extends Qualcomm® Snapdragon™
X55 5G Modem-RF System to deliver a comprehensive solution for flexible, cost-effective, high performance 5G mmWave customer-premises equipment (CPE) designs

Extended Range
Suitable for compact smartphone industrial designs with four mmWave modules

Fully-integrated mmWave RF
Fully-integrated mmWave RF including transceiver, PMIC, RF front-end components, and a phased antenna array

Global Band Support
Support for up to 800 MHz of bandwidth in n257, n258, n260, and n261 5G NR mmWave bands

Improved consumer experience
Deliver 5G’s multi-gigabit speeds and ultra-low latency to a wider customer base within a large coverage footprint

1. 3GPP band definition are n257 (26.5-29.5 GHz), n258 (24.25-27.5 GHz), n260 (37-40 GHz), n261 (27.5-28.35 GHz)
30+ Global OEMs

Qualcomm Snapdragon X55 5G modem-RF system
Rural America: Extended-Range mmWave delivers significant coverage improvement
Field trial collaboration with U.S Cellular operator and Ericsson
Addressing the homework gap in the U.S.

Providing connectivity and devices for remote learning students

The CARES Act
Enacted in March 2020 provides the first-ever federal funding for hardware, software, and connectivity – $13.5B through the U.S. Department of Education

The HEROES Act
Passed by the House of Representatives in May 2020 and provides $2B for the FCC’s E-Rate program for connectivity and devices

A Senate counterpart bill further increased the amount to $4B, and subsequent versions of the legislation have included as much as $12B – negotiations continue, and we continue to work with policymakers on the legislation

States and local school districts have started to purchase laptops, hotspots, and connectivity for their students

**Louisiana**
June 29th, 2020

Computers, internet access key targets of federal aid under governor’s control


**Alabama**
July 31st, 2020

Governor Ivey Allocates $100 Million for Alabama Broadband Connectivity for Students


**Arkansas**
August 5th, 2020

Arkansas CARES Act committee recommends extra $100 million to expand rural broadband


**Pennsylvania**
September 10th, 2020

Gov. Wolf putting CARES Act funding into high-speed internet for schools to support remote learning


**Oregon**
August 30th, 2020

Polk County set to expand internet service to rural areas using CARES Act funds


And more…
Our cutting-edge technologies and mobile solutions are closing the homework gap created by remote learning.

Mobile operators are supporting remote learning in the U.S.

**AT&T**
Distance Learning and Family Connection Fund commits $10M to support remote learning due to COVID-19 school closures

**T-Mobile**
$10.7B committed to provide free hotspots, limited free or discounted data, and laptops/tablets at cost for K-12 students through a grant program offered to schools
More information at https://www.t-mobile.com/business/education/empowered2

**Verizon**
National Verizon Distance Learning Program provides distance learning for over 36M students across 38 states and the District of Columbia
Federal, state, and local funding for connectivity and devices


- State & local initiatives all over the US – for more details, please visit: www.hunt-institute.org/covid-19-resources/geer-fund-utilization
C-V2X

Rel 14/15 C-V2X established basic safety
Rel 16 5G V2X saw continued evolution for advanced safety use cases

- **V2V** Vehicle-to-vehicle, e.g., collision avoidance safety systems
- **V2P** Vehicle-to-pedestrian, e.g., safety alerts to pedestrians, bicyclists
- **V2I** Vehicle-to-infrastructure, e.g., roadside traffic signal timing/priority
- **V2N** Vehicle-to-network, e.g., real-time traffic/routing, cloud services

- Release 14/15 C-V2X standards completed
- 5G: Broad industry support with 5GAA
- Global trials started in 2017; first commercial deployment expected in 2020
- Qualcomm® 9150 C-V2X chipset announced in September 2017
- Integration of C-V2X into the Qualcomm® Snapdragon™ Automotive 4G and 5G Platforms announced in February 2019

Qualcomm 9150 C-V2X and Qualcomm Snapdragon Automotive 4G/5G Platforms are products of Qualcomm Technologies, Inc. and/or its subsidiaries.
Strong C-V2X momentum globally

- **Sep. 2016**: SGAA founded. Qualcomm Incorporated was the founding member.
- **Feb. 2017**: Towards 5G trial in France announced.
- **Sep. 2017**: 3GPP C-V2X trial in Germany announced.
- **Mar. 2017**: First 5G C-V2X spec finalized.
- **Oct. 2017**: Rel-14 C-V2X chipset introduced.
- **Nov. 2017**: 5GAA founded.
- **Jan. 2018**: Towards 5G C-V2X testbed announced.
- **Mar. 2018**: 5G C-V2X in D.C.
- **May 2018**: First multi-OEM demo in D.C.
- **Jun. 2018**: First 5G C-V2X chipset introduced.
- **Oct. 2018**: First C-V2X chipset introduced.
- **Nov. 2018**: Multi-OEM performance evaluation of C-V2X completed.
- **Dec. 2018**: First multi-OEM demo in D.C.
- **Feb. 2019**: C-V2X integrated with Qualcomm Snapdragon Automotive 4G/5G platforms.
- **Mar. 2019**: 5GAA SAIC project complete.
- **May 2019**: C-V2X ecosystem demos.
- **Jun. 2019**: First multi-OEM demo in D.C.
- **Jul. 2019**: 5GAA live demos show C-V2X as a market reality.
- **Sep. 2019**: China ICV 2025 Vision published.
- **Oct. 2019**: FCC 5.9 GHz NPRM comments received.
- **Nov. 2019**: CAMP congestion control scenario testing by OEM consortium.
- **Dec. 2019**: C-V2X deployed in Virginia with VaDoT.
- **Jan. 2020**: ETSI European specifications and standards for C-V2X completed.
- **Feb. 2020**: C-V2X devices passed.
- **May 2020**: China ICV 2025 Vision published.
- **Jun. 2020**: FCC 5.9 GHz NPRM comments received.
C-V2X is ready for prime time

FCC assigned upper 30 MHz of 5.9 GHz to C-V2X and adopted streamlined process for C-V2X to get on the air as soon as possible.
Driving C-V2X global presence

Gaining traction across numerous regions and industry sectors

From standards completion to independent field testing to initial deployments

Collaborating with partners and customers

- Tier 1s and OEMs
- Third-party software providers
- Test equipment, module, component, and antenna suppliers
- Road infrastructure providers
- Mobile network operators
- Design services
- Service providers

5GAA Automotive Association

- 8 of the top 9 global automakers
- Top automotive Tier 1 suppliers
- 9 of the top 10 global telecommunications companies
- Top 3 global smartphone manufacturers
- Top global semiconductor companies
- Top 5 global wireless infrastructure companies
- Top global test and measurement companies and certification entities
- Global representation from Europe, China, US, Japan, Korea, and elsewhere

1 Crash Avoidance Metrics Partnership LLC and this project includes the listed OEMs and Qualcomm  2 Ministry of Industry and Information Technology
Global Spectrum Status
<table>
<thead>
<tr>
<th>Region</th>
<th>Band</th>
<th>Frequency Range</th>
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<tbody>
<tr>
<td>600MHz (2x35MHz)</td>
<td>900MHz</td>
<td>2.5/2.6GHz (B41/n41)</td>
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<td>600MHz (2x35MHz)</td>
<td>24.25-24.5GHz</td>
<td>37-37.6GHz</td>
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<td>600MHz (2x35MHz)</td>
<td>24.75-25.25GHz</td>
<td>37.6-40GHz</td>
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<td>3.55GHz</td>
<td>37-37.6GHz</td>
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<td>3.7GHz</td>
<td>37.6-40GHz</td>
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<td>3.8GHz</td>
<td>47.2-48.2GHz</td>
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<tr>
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<td>3.9GHz</td>
<td>57-64GHz</td>
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<td>4.0GHz</td>
<td>64-71GHz</td>
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<tr>
<td>700MHz (2x30 MHz)</td>
<td>26.5-27.5GHz</td>
<td>&gt;95GHz</td>
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</tbody>
</table>

Global snapshot of allocated/targeted 5G spectrum
5G is being designed for diverse spectrum types/bands
Standardized in 5G NR Release 16 – First global cellular standard with both license-assisted and standalone use of unlicensed spectrum

Unlicensed Spectrum Bands in 3GPP

- <1 GHz
  - Low-bands (sub-1)

- 1-7 GHz
  - Mid-bands (sub-7)

- 24+ GHz
  - High-bands (mmWave)

- Available now
- Under study/ review

China

- 5.2 - 5.8 GHz
- 5.7 - 6.5 GHz

France

- 5.2 - 5.7 GHz
- 5.8 - 6.5 GHz

Italy

- 5.9 - 7.1 GHz

South Korea

- 5.2 - 5.8 GHz
- 5.7 - 6.5 GHz

Japan

- 5.2 - 5.8 GHz
- 5.7 - 7.1 GHz

Canada

- 5.8 - 6.5 GHz

European Union

- 5.9 - 6.4 GHz

United Kingdom

- 5.9 - 6.4 GHz

Germany

- 5.2 - 5.9 GHz
- 5.7 - 6.5 GHz

China

- 5.2 - 5.8 GHz
- 5.7 - 6.5 GHz

South Korea

- 5.2 - 5.8 GHz
- 5.7 - 6.5 GHz

Japan

- 5.2 - 5.8 GHz
- 5.7 - 7.1 GHz

Canada

- 5.8 - 6.5 GHz

European Union

- 5.9 - 6.4 GHz

United Kingdom

- 5.9 - 6.4 GHz

Germany

- 5.2 - 5.9 GHz
- 5.7 - 6.5 GHz

India

- 5.2 - 5.8 GHz
- 5.7 - 6.5 GHz

Australia

- 5.9 - 6.4 GHz

United States

- 24+ GHz
The FCC is driving key spectrum initiatives to enable 5G

Across low-band, mid-band, and high-band including mmWave

**Low-band**
Broadcast incentive auction completed in March 2017

- Successfully auctioned a portion of the 600 MHz band that generated $19.8B in proceeds after assignment phase
- Includes 70 MHz (2 x 35 MHz) of licensed spectrum and 14 MHz for unlicensed use
- FCC allocated 2 x 3 MHz in 900 MHz for broadband, principally for utilities
- Spectrum availability timing aligns with 5G

**Mid-band**
CBRS\(^1\), 3.4-3.5 GHz, 3.7-3.98 GHz, 4.94-4.99 GHz

- Opened 150 MHz in 3.5 GHz band with 3-tier sharing with incumbents, PAL\(^2\), GAA\(^3\)
- In Sep 2019, FCC approved initial GAA deployments and in Sep. 2020, FCC completed PAL auction
- In Mar 2020, FCC allocated 3.7-4.0 GHz. Auction scheduled for Dec. 2020
- NTIA and FCC are studying repurposing of 3.1-3.45 GHz for commercial use

**High-band**
FCC has completed 3 mmWave auctions, including most recently the largest auction in history

- In 2016, FCC allocated 10.85 GHz in multiple mmWave bands\(^4\), 70% of newly opened spectrum is shared or unlicensed
- In Nov 2017, FCC adopted second order allocating 24.25-24.45, 24.75-25.25 GHz, and 47.2-48.2 GHz
- In Jun 2018, FCC proposed making 25.25-27.5 and 42-42.5 GHz for flexible wireless use
- FCC has held auctions in 28 & 24 GHz bands
- In Mar 2020, FCC has completed the auction for upper 37, 39, & 47 GHz bands
- FCC is considering rules for 70/80/90 GHz, and FCC has opened spectrum above 95 GHz

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1 Citizen Broadband Radio Services; 2 Priority Access Licenses to be auctioned; 3 General Authorized Access; 4 FCC ruling FCC 16-89 on 7/14/2016 allocated 3.25 GHz of licensed spectrum and 7.6 GHz of shared/unlicensed spectrum.
Low-band: 600 MHz LTE initially deployed in areas already clear of TV stations and is now being used for 5G

Meeting 5G timeline
Completed auction in March 2017; process of clearing the spectrum & repacking TV stations to end in 39 months. Process is on track.

Greater capacity and wider coverage
Low-band spectrum is optimized for long-range macro deployments - optimal for connecting the wide-area IoT and more

Broad industry support
Qualcomm Technologies Inc. is working closely with operators & OEMs to enable early launches, incorporating our industry-leading modem, transceiver, and RFFE
FCC to start C-Band auction (3700-3980 MHz – 280 MHz) in December 2020, 100 MHz to be clear by December 2021 and 180 MHz to be clear by December 2023
6 GHz brings new unlicensed bandwidth for Wi-Fi and 5G

Standardized for 5G NR-U in the United States

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Bandwidth</th>
<th>Wi-Fi 6E</th>
<th>5G</th>
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<td>83.5 MHz</td>
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</tr>
<tr>
<td>6</td>
<td>350 MHz</td>
<td>250 MHz</td>
<td></td>
</tr>
</tbody>
</table>

A massive amount of new unlicensed spectrum is now available in the U.S. for Wi-Fi 6E and 5G

AFC= Automated frequency control, DFS= Dynamic Frequency Selection, LPI= Low power indoor
Technologies that will power the future of connectivity

Multi-gigabit Throughput
Ultra Low Latency
Massive Capacity
High-band: FCC rapidly bringing mmWave spectrum to market

FCC opened total of 10.85 GHz as part of the Spectrum Frontiers Ruling
- Licensed: 27.5-28.35 GHz (2x425 MHz); 37.6-38.6 GHz (5x200 MHz); 38.6-40 GHz (7x200 MHz)
- Shared/unlicensed: 37-37.6 GHz (3x200 MHz); 64-71 GHz that expands the existing 60 GHz band

FCC proposed making mmWave spectrum for flexible deployment
- 25.25-27.5 GHz and 42-42.5 GHz

FCC announced second order allocating additional mmWave spectrum
- 24.25-24.45 GHz, 24.75-25.25 GHz, and 47.2-48.2 GHz

FCC announced first wave of mmWave auctions
- November 2018: 24 GHz and 28 GHz
- 2H2019: 37 GHz, 39 GHz, and 47 GHz

FCC announced procedures for the largest mmWave auction
- Auction started on Dec. 10th, 2019
- Included 37.6-38.6 GHz and 47.2-48.2 GHz across the US and some licenses for 38.6-40 GHz

FCC completed the largest mmWave auction
- Successfully completed actions of 37 GHz, 39 GHz, and 47 GHz

Timeline:
- July 2016: FCC opened total of 10.85 GHz as part of the Spectrum Frontiers Ruling
- June 2018: FCC proposed making mmWave spectrum for flexible deployment
- July 2019: FCC announced second order allocating additional mmWave spectrum
- July 2018: FCC announced first wave of mmWave auctions
- March 2020: FCC completed the largest mmWave auction
European Commission driving a Gigabit Society

Deploying 5G across Europe by 2020 with pre-commercial trials starting in 2018

- Early trials in 2017, pre-commercial trials from 2018
- Full commercial 5G services (one major city per country) in 2020
- All urban areas and major terrestrial transport paths with 5G coverage by 2025

Pioneer spectrum bands for 5G (low: 700 MHz, mid: 3.4-3.8 GHz, high: 24.25-27.5 GHz)
- EC Mandate to CEPT focusing on 3.5 GHz and 26 GHz pioneering bands – completed in 2018
- Additional EC Mandate to CEPT on extended L band (1427 - 1518 MHz) – completed in 2018
- CEPT harmonization of the 26 GHz band ahead of WRC-19 – completed in June 2018
- EC working on binding decision for EU Member States – completed in Q1 2019
- 5G commercial services to use both 3.4-3.8 GHz and 26 GHz in Europe – targeting 2020

Full set of 5G spectrum bands and implementation measures
- EC mandate to CEPT on the development of harmonized technical conditions suitable for 5G in the 900 MHz, 1.8 GHz, 2.6 GHz, and the paired terrestrial 2 GHz frequency bands – completed in 1H 2019
- RSPG\(^2\) working on how to defragment 3.4-3.8 GHz band and on the impact of the future use of 5G in areas other than MBB\(^3\)

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5G spectrum auctions in Europe – 700 MHz band

**Awarded or ongoing auction**
- Band awarded in 12 European countries: Austria, Germany, Hungary, Switzerland, France, Finland, Italy, Luxembourg, Sweden, Netherlands, Norway and Denmark

**Expected to be awarded in 2020**
- Additional 9 countries expected to award spectrum in 2020: Belgium, Bulgaria, Czechia, Estonia, Greece, Latvia, Lithuania, Slovakia and Turkey
- Latvia and Lithuania might have some spectrum restrictions until 2022

**Expected to be awarded in 2021**
- Additional 9 countries to award spectrum in 2021: Ireland, Poland, Spain, Slovenia, Croatia, Montenegro, Romania, Serbia, Ukraine
5G spectrum auctions in Europe – 3.4 to 3.8 GHz band

- **Awarded or ongoing auction**
  - Spectrum awarded in 17 European countries: Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Luxembourg, Norway, Slovakia, Switzerland, Spain, Romania and UK

- **Expected to be awarded in 2020**
  - Additional 6 countries expected to award spectrum in 2020: Bulgaria, Denmark, Greece, Lithuania, Portugal, Sweden

- **Expected to be awarded in 2021**
  - Additional 6 countries expected to award spectrum in 2021: Poland, Montenegro, Croatia, Slovenia, Serbia, Ukraine
5G spectrum auctions in Europe – 26 GHz band

- **Auctioned or to be awarded on market demand**
  - Italy, Finland and Russia have awarded 26 GHz
  - UK has made available based on market demand and indoor only, 24.5 - 26.5 GHz – the whole 26 GHz band expected in 2021

- **Expected to be awarded in 2020**
  - Germany, Greece and Denmark are expected to award the band in 2020

- **Expected to be awarded in 2021**
  - Slovenia, Sweden, Croatia, Montenegro, Poland expected to award the band in 2021
5G spectrum status in China, South Korea, and Japan

China

• MIIT officially allocated 700MHz (703-733/758-788MHz), 3.3-3.6 GHz & 4.8-5.0 GHz as 5G bands; in addition, 2.6 GHz (Band n41) has been allowed for both 4G & 5G deployments
• Chinese government approved 5G technology R&D trial frequencies usage in 24.75-27.5 GHz & 37-42.5 GHz mmWave ranges in Jul’17
• Chinese government supported global IMT identification in 5925-7125MHz, 24.75-27.5GHz, 40.5-43.5GHz and 66-71GHz frequency ranges in WRC19

South Korea

• MSIT has successfully completed 5G spectrum auction in June 2018 for both sub-7 and mmWave, including 3.42-3.7 GHz and 26.5-28.9 GHz
• The world first commercial 5G smartphone for sub-7 was launched in Apr’19. mmWave was commercially launched for smart factory in Jul’20
• Achieved over 7.9 million 5G subscribers as of Jul’20
• MSIT plans to allocate additional 5G spectrum in 2022-2023

Japan

• In Apr’19, MIC assigned new 5G spectrum, 3.6-4.2 GHz, 4.4-4.9 GHz and 27-29.5 GHz, to four operators
• All existing 4G spectrum bands, 700 MHz, 850 MHz, 900 MHz, 1.5 GHz, 1.8 GHz, 2.1 GHz (FDD), 2.5 GHz and 3.5 GHz (TDD) are available for 5G NR deployment
• Technical rules for private network bands in 2575-2595 GHz (NSA anchor) and 28.2-28.3 GHz have also been regulated. Additional private network bands in 1.9 GHz (NSA anchor), 4.6-4.9 GHz and 28.3-29.1 GHz will be regulated in Q4’20
• Technical rules for additional licensed spectrum (4.9-5 GHz, 26.6-27 GHz, 39.5-43.5 GHz) will be studied by 2021
• As per WRC-19 outcome, 7025-7125 MHz study will also be conducted
## 5G spectrum status in Oceania, South East Asia, and India

**Australia**
- 3.4-3.7 GHz allocated and 5G has been commercially deployed
- 3.7 - 4.2 GHz under consultation for 5G, FS, FSS deployment
- 26 GHz: spectrum allocation for 5G scheduled for March 2021
- 26/28 GHz: apparatus licenses for local 5G + FWA to start 1Q21

**New Zealand**
- 3.5 GHz: 3400-3590 MHz and 3590 - 3800 MHz access until 2022, longer term access to be provided prior to 2022
- mmWave 26/28 GHz under consideration

**Hong Kong**
- 3.3, 3.5, 4.8 GHz: 5G Spectrum allocated
- 26/28 GHz: 3 operators awarded 400 MHz each, with 400 MHz reserved for local licensing
- 5G commercially deployed from April 2020
- Additional 4.9 GHz spectrum under consultation

**Taiwan**
- 3.3, 3.5 GHz: 5G spectrum allocated
- 27.9 - 29.5 GHz: 5G spectrum allocated (27.0 - 27.9 GHz held for future allocation)
- 5G commercially deployed from July 2020
- 4.9 GHz spectrum planned for localized networks

**Singapore**
- 3.5 GHz: 5G spectrum allocated for 2 networks
- 800 MHz of mmWave allocated to 4 operators
- 5G deployed

**Vietnam**
- Government has announced timeframe for planned commercialization in 2020
- 3.8 GHz and 4.8 GHz bands are under consultation
- 26/28 GHz in ongoing consultation process
- 5G trials underway by all 3 mobile network operators

**Thailand**
- 2.5 GHz TDD spectrum allocated for 2 networks
- 26 GHz spectrum allocated to 4 operators
- 28 GHz spectrum being considered
- 5G commercially deployed

**Indonesia**
- All operators conducted 5G trials in 28 GHz
- Government plans to conduct trial in 3.5 GHz
- Government announced that it will consult on 5G policy and sub 6 GHz, 26 GHz and finalize policy in 2020.

**Philippines**
- 3.5 GHz band assigned
- 5G deployed commercially in Manila
- mmWave spectrum under consideration by Government

**Malaysia**
- Government plan to allocate 3.5 GHz and 26/28 GHz spectrum in 3Q20 deferred to 1H21
- Operators have conducted 5G trials

**India**
- High Level Forum submitted 5G recommendation in Aug’18
- 617-698 MHz in planning; 698-803 MHz auction in Q4’20
- 3.3-3.6 GHz and 24.25-27.5 GHz auction expected in Q3’21
- 24.25-27.5 GHz, 27.5-29.5 GHz preferred mmWave bands – two years free for trials; also looking at 37-43.5 GHz
Brazil has auction of 3.3-3.7 GHz & 26 GHz planned for Q1 2021
Mexico is evaluating 3.3-3.3 GHz, 3.6-3.8 GHz, 26 GHz for 5G
Uruguay has very small 5G fixed/mobile deployments
Peru will carry out public consultation of 3.5 GHz and 26 GHz bands by end of 2020, and auction is expected to start in first semester of 2021

Chile started the auction process, expecting licenses should be granted to operators by mid-2021 (3.3-3.4 GHz, 3.6-3.65 GHz, 25.9-27.5 GHz)
Dominican Republic is targeting to be the 2nd country in LATAM to auction 5G spectrum, which is planned for Jan. 2021
Colombia is still under consultation process. Spectrum allocation is being planned in 2021 for 700 MHz, 1.9 GHz, 2.5 GHz, and 3.5 GHz band

3.5 GHz

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26/28 GHz

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</tbody>
</table>

* Nationwide or regional licenses for MNO’s public networks
** Spectrum set aside for individual licensing on a local basis for 5G private networks
1 Set aside for individual licensing on a local basis for 5G private networks in the 3.7-3.8 GHz range under consultation
2 Spectrum re-farming desired
3 In Mexico, 3.3-3.35 GHz is assigned to the government (SCT). 3.3-3.4 GHz can be used for both mobile and fixed applications. 3.4-3.425 is identified for FWA and to be auctioned in 2H21. 3.45-3.6 GHz range is assigned for FWA only
4 Brazil reserved the frequency range 27500-27900 MHz for private networks
Global snapshot of spectrum optimized for industrial IoT / vertical / private network use – local licensing or sharing

**USA**
- 3.5 GHz CBRS, exclusive & shared licenses, deployments in 2H19
- 37 - 37.6 GHz shared spectrum/local licenses, under evaluation

**Germany**
- 3.7 - 3.8 GHz
- 24.25 - 27.5 GHz, local licenses, expected Q4 2020
- Local licenses. Assignment complete; available 2H 2019

**U.K.**
- 3.8 - 4.2 GHz
- 24.25 - 26.5 GHz, local licenses, applications open since end of 2019
- Local licenses (50 meters square); regulator database; decision formalized; applications invited from end 2019

**Sweden**
- 3.72 - 3.8 GHz, in consultations

**Finland**
- Sub-licensing of 3.4 - 3.8 GHz
- Local permission via operator lease; assignment complete

**Netherlands**
- 3.5 GHz for local industrial use; 3.7 - 3.8 GHz (in consultations); 2.3 - 2.4 GHz (licensed shared access online booking system)
- 3.5 GHz for local industrial use; however users may need to move to 3.7 - 3.8 GHz, if allocated; 2.3 GHz approved for PMSE

**France**
- 2.6 GHz, regulator database & approval. Up to 40 MHz approved for Professional Mobile Radio

**Czech Republic**
- 3.4 - 3.44 GHz for private networks

**Brazil**
- 3.7 - 3.8 GHz, under consideration
- 27.5 - 27.9 GHz, allocation completed

**Chile**
- 3.75 - 3.8 GHz, allocation completed at end of 2019

**Australia**
- 24.25 - 27.5 GHz and 27.5 - 29.5 GHz for local licensing in 1Q21
- 3.7 - 4.2 GHz under consultation for local licensing

**New Zealand**
- Licenses in 2575 - 2620 MHz may be assigned for localized use

**Malaysia**
- 26.5 - 28.1 GHz will be assigned for the deployment of local/private networks

**Singapore**
- Each operator has acquired 800 MHz of 26/28 GHz spectrum to deploy local networks

**Japan**
- 24.25 - 28.35 (400 MHz) available for local licenses

**Czech Republic**
- Phase 1: 2,575 - 2,595 MHz (NSA anchor) and 28.2 - 28.3 GHz; local licenses, legislated in December 2019
- Phase 2: 1888.5 - 1916.6 MHz (NSA anchor), 4.6 - 4.9 GHz (4.6 - 4.8 GHz indoor only, 4.8 - 4.9 GHz outdoor possible) & 28.3 - 29.1 GHz (150 MHz outdoor use; total 250 MHz range 28.2 - 28.45 MHz); local license. Legislation in 4Q20. Uplink heavy TDD config. using semi-sync is allowed in sub-6 & 28 GHz
Questions?