

December 8<sup>th</sup>, 2020

Fierce Wireless Webinar

@qualcomm\_tech

Qualcomm

# 5G spectrum innovation and global update

The background of the slide is a high-angle, night-time photograph of a city skyline, likely Hong Kong, with numerous skyscrapers illuminated. Overlaid on this image is a complex network of white, glowing arcs and dots, representing a global or city-wide communication network. The arcs connect various points across the city, symbolizing connectivity and data flow.

# 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?



## Our presenter

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**Dean Brenner**

Senior Vice President  
Spectrum Strategy and  
Technology Policy  
Qualcomm Incorporated

Twitter: @deanbrenner

# 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

Sources – 5G commercial networks: operator public announcements. Operators investing in 5G: GSA, Oct 2020. 5G device shipment projections: Qualcomm internal estimates, Nov 2020. 2023 5G connections: avg of ABI (Jun 2020), Ericsson (Jun 2020) and GSMA Intelligence (Oct 2020). Cumulative 5G smartphone shipments - avg of CCS Insight (Sep 2020), CounterPoint Research (Sep 2020), IDC (Aug 2020), Strategy Analytics (Oct 2020).

Qualcomm  
snapdragon



# 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

FRITZ!box  
6850 5G CPE



OPPO  
5G CPE Omni



LG  
V60 ThinQ 5G



5G Always  
Connected PC



OPPO  
Reno 4 Pro 5G



Samsung  
Galaxy S20+



Vivo  
X50 Pro 5G



Nokia  
8.3 5G



Inseego  
5G MiFi M1000  
Mobile Hotspot



Sharp  
AQUOS R5G



Samsung  
Galaxy S6 5G



Sierra Wireless  
EM9190 5G Module



Xiaomi  
Mi 10 Pro 5G



Nokia  
FastMile 5G  
CPE



Sony  
Xperia 1 II



Netgear  
MR5200 5G  
Mobile Router



Black Shark  
3 Pro 5G



Motorola  
Edge Plus 5G



# 5G Rollout Outlook



“+” implies the year indicated and beyond

# 5G carrier aggregation

for ultimate operator flexibility and performance

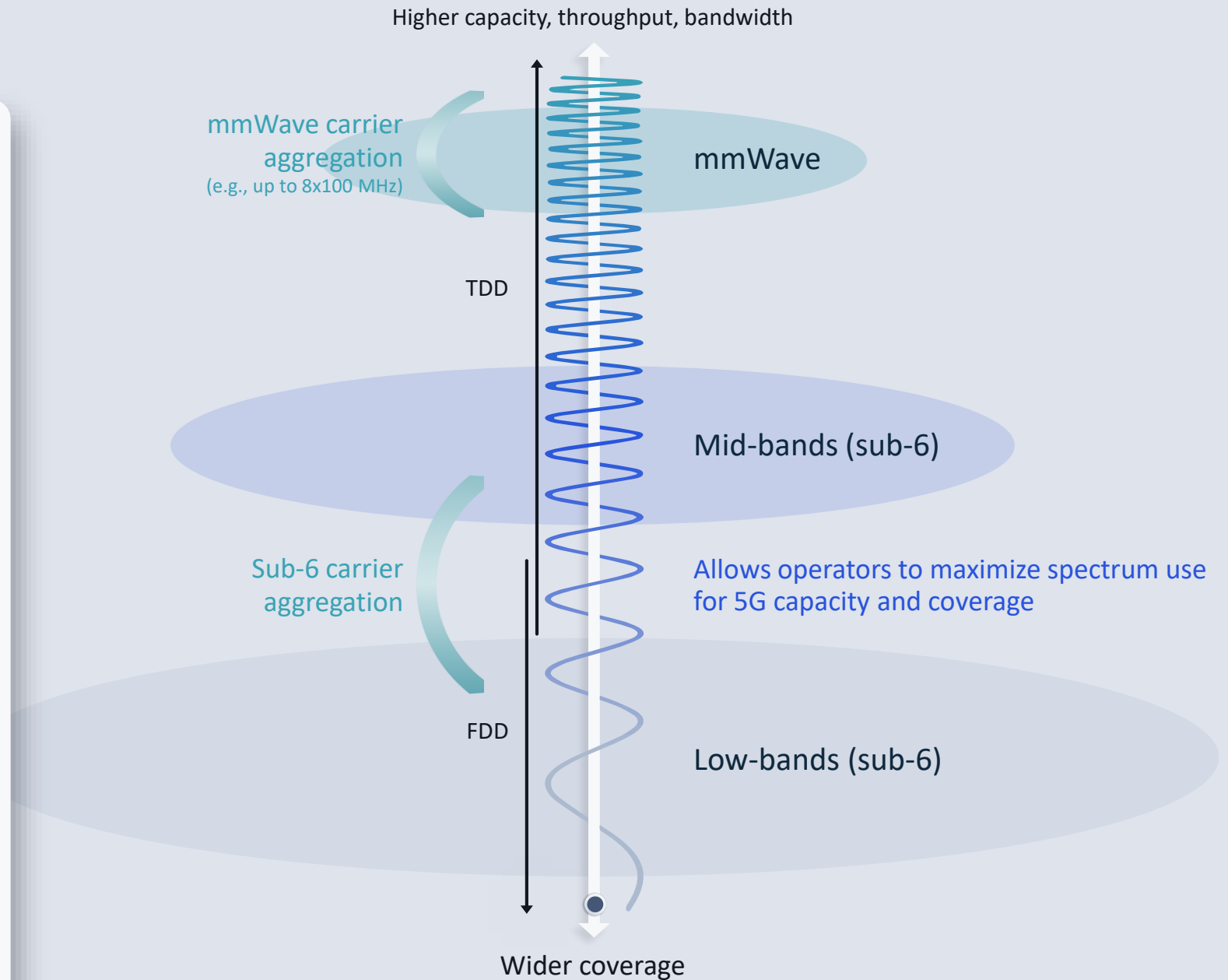
Double sub-6 peak speeds in standalone mode

Increase capacity

Expand coverage

Improve user experience

Accelerate transition to standalone mode



Qualcomm  
snapdragon  
X60 5G modem-RF system



Our  
**3<sup>rd</sup> 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



# 5G

# 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



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

## North America

LTE bands:  
71,29,12,13,14,5/26,2/25,4/66,7,30,41,46,48  
5G NR bands:  
n71,n66,n2,n41,n5,n12,n25,n48,n78,n258,n260,261  
LTE 2CA: 2+4/66,25+41,4+7,7+30  
LTE 3CA: 2+66+30,2+4+7  
LTE 4x4 MIMO bands: 2,4/66,7,25,30  
LTE UL CA:  
EN-DC: 2+n66, 25+n41,5+n12, 41+n41,2+n66+30

## Latin America

LTE bands:  
28,12,5/26,8,1,2,3,4/66,7,38,41,42,46  
5G NR bands: no confirmed plans available  
LTE 2CA: 1+3,1/3+7,2+4,4+7  
LTE 3CA: 1+3+7  
LTE 4x4 MIMO bands: 1,2,3,4,7  
LTE UL CA:  
EN-DC:

## Europe

LTE bands: 28A,20,8,32,1,3,7,38,46  
5G NR bands:  
n78,n28A,n8,n20,n38,n1,n3,n7,n75/76,  
n257,n258  
LTE 2CA:  
8+20,20+28A,1+3,1/3+7,1/3+38,3+32  
LTE 3CA: 1+3+7,3+7+38,3+7+32  
LTE 4x4 MIMO bands: 1,3,7,38  
5G NR UL-MIMO: n78  
EN-DC: 8+20+n28A,1+3+7+n75+n78

## Middle East / Africa

LTE bands: 20,8,1,3,7,38,40,41  
5G NR bands: no confirmed plans available  
LTE 2CA: 1+3,3+38/40  
LTE 3CA: 1+3+38/40  
LTE 4x4 MIMO bands: 1,3,7,38,40  
LTE UL CA:  
EN-DC:

## China (incl. Taiwan and Hong Kong)

LTE bands: 5,8,1,3,7,34,39,40,41,(4,12,20,38 roaming)  
5G NR bands: 41+,79,1,3,78  
LTE 2CA: 39+41,3+41,1+3  
LTE 3CA:  
LTE 4x4 MIMO bands: 1,3,39,41  
5G NR UL-MIMO in SA: n41,n78,n79  
EN-DC: 3+n41,39+n41,3+n79,1/3+n78,5/8+n78

## India

LTE bands: 5,8,1,3,40,41  
5G NR bands: no confirmed plans available  
LTE 2CA: 3+40,1+3,1/3+41  
LTE 3CA: 1+3+41  
LTE 4x4 MIMO bands: 1,3,40,41  
LTE UL CA:  
EN-DC:

## South Korea

LTE bands: 5,8,1,3,7,40,46  
5G NR bands: n78,n257  
LTE 2CA: 1+3,3+7,1/3+40  
LTE 3CA: 1+3+7/40  
LTE 4x4 MIMO bands: 1,3,7,40  
LTE UL CA:  
EN-DC: 3+7+n78

## Japan

LTE bands: 28,26,8,11,19,21,1,3,41,42,46  
5G NR bands: n77,n78,n79,n1,n3,n257  
LTE 2CA: 18+28A,1+3,1+21,3+41/42  
LTE 3CA: 1+3+41,  
LTE 4x4 MIMO bands: 1,3,40,41,42  
5G NR UL-MIMO in NSA: n77,n79  
EN-DC: 3+n77/n79,41+n77/n79,42Rx+n79

## South East Asia / Oceania

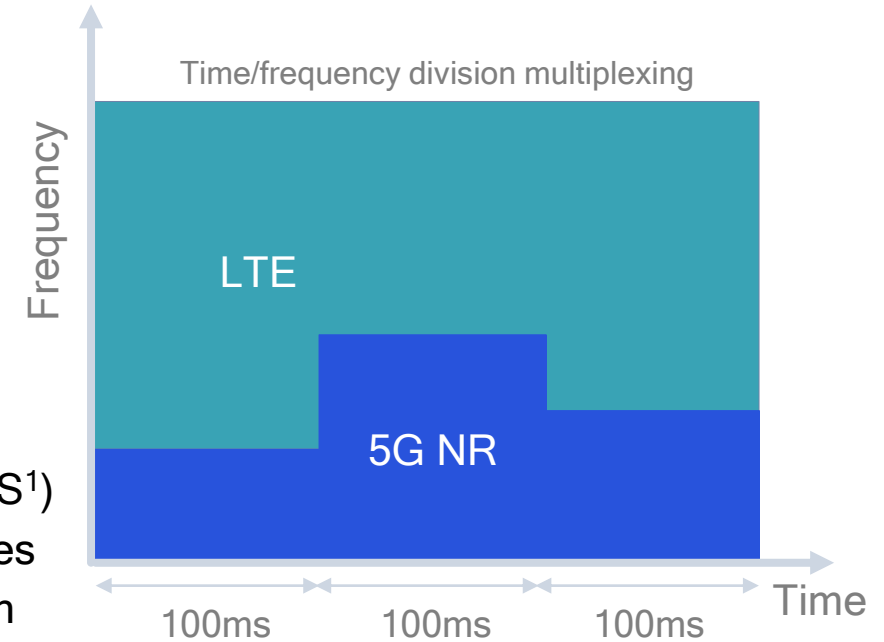
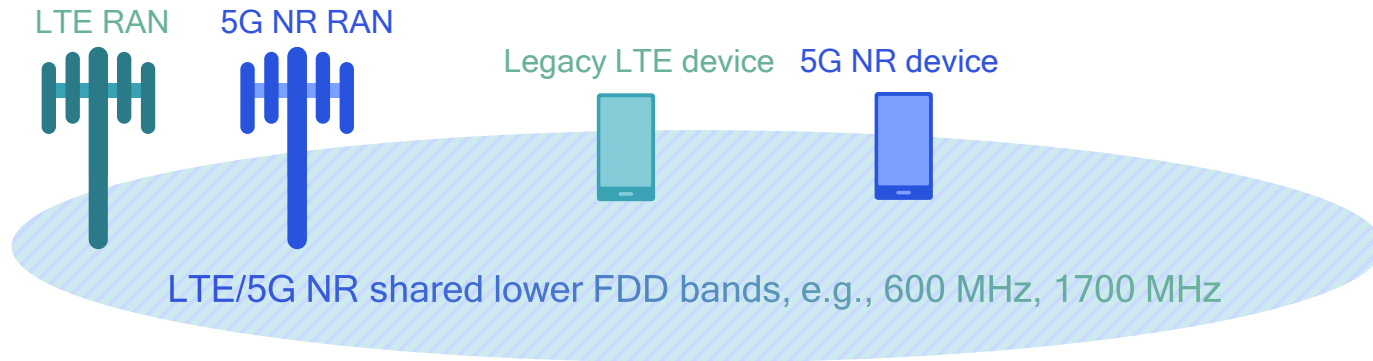
LTE bands: 28,20,5,8,1,3,7,38,40,41  
5G NR bands: n78,n2,n40,n257,n258  
LTE 2CA: 1+3,3+7,3+40,(3+41)  
LTE 3CA: 1+3+7,3+7+40  
LTE 4x4 MIMO bands: 1,3,7,38,40,41  
LTE UL CA:  
EN-DC:

# 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<sup>1</sup>)
- 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

<sup>1</sup> Cell Specific Reference Signal

Supports 5G NR in LTE bands today with “soft refarming”

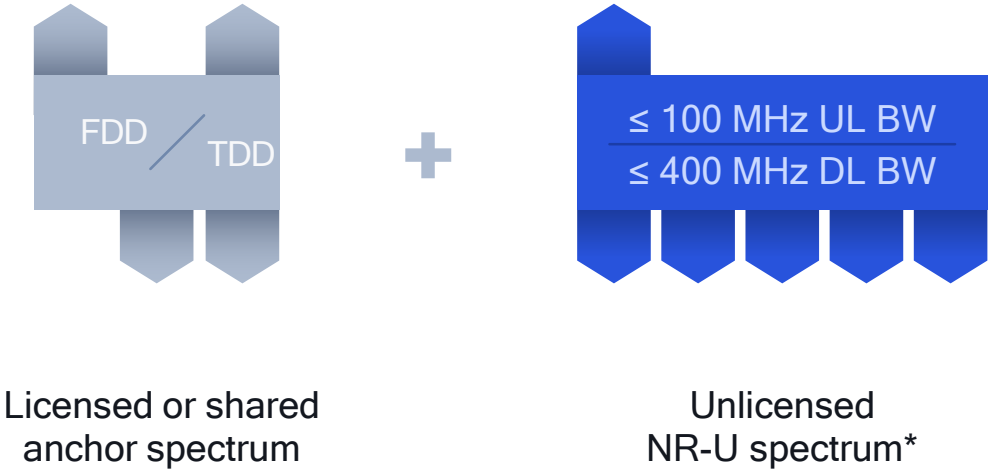
Efficient use of spectrum with low sharing overhead

DSS & carrier aggregation are key enablers for SA migration

# 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\*

\* Still under discussion in Rel-16

Unlock more spectrum globally

New markets and verticals

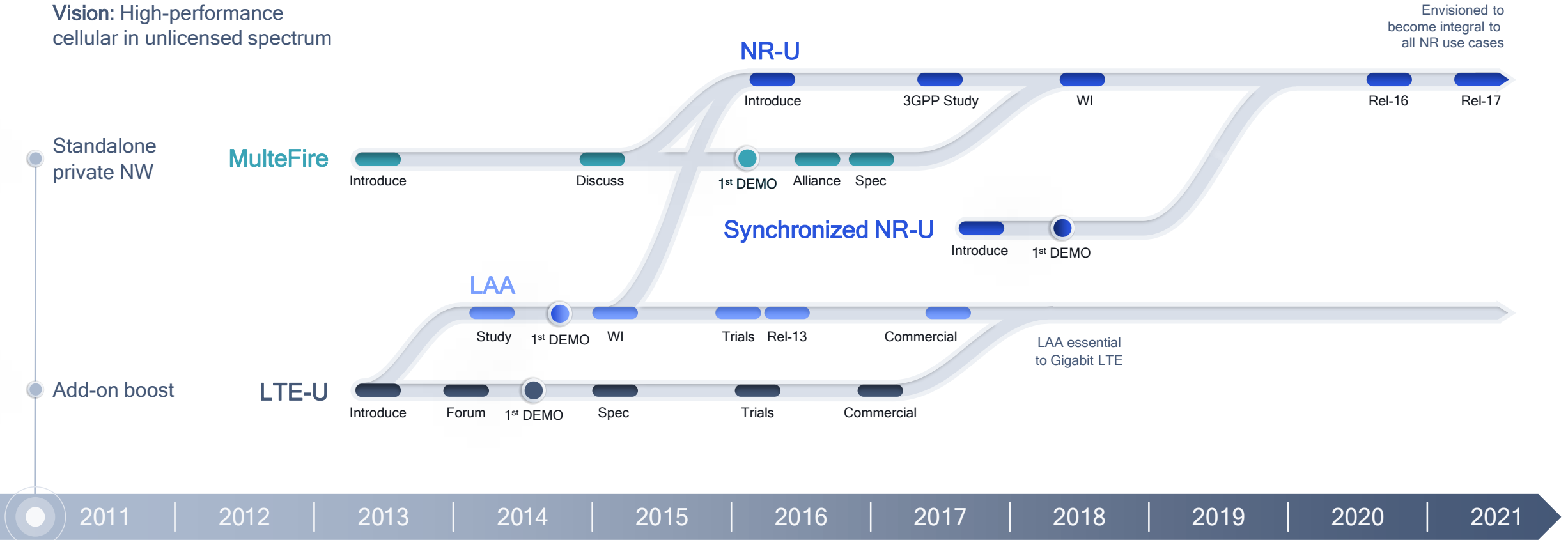
New deployment scenarios

# Almost a decade of leadership in unlicensed spectrum

From LTE-U/LAA to NR-U

Vision: High-performance cellular in unlicensed spectrum

Envisioned to become integral to all NR use cases



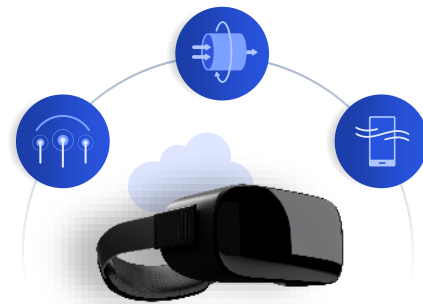
Continuous research, industry first over-the-air LAA, eLAA, MulteFire demos, co-existence with Wi-Fi

# NR-U synchronized sharing brings higher performance

Opportunity for greenfield spectrum

## Asynchronized sharing

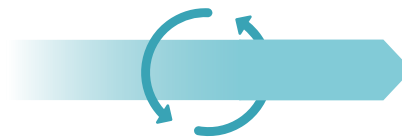
Evolutionary path: Existing coexistence rules in unlicensed spectrum



Anchored NR-U



Standalone NR-U

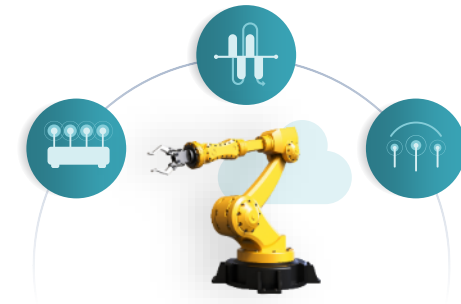


### Time synchronization

Provides great potential to share spectrum more efficiently

## Synchronized sharing

Revolutionary path: Time synchronized sharing in unlicensed and shared spectrum



5G CoMP, predictable sharing, and spatial sharing

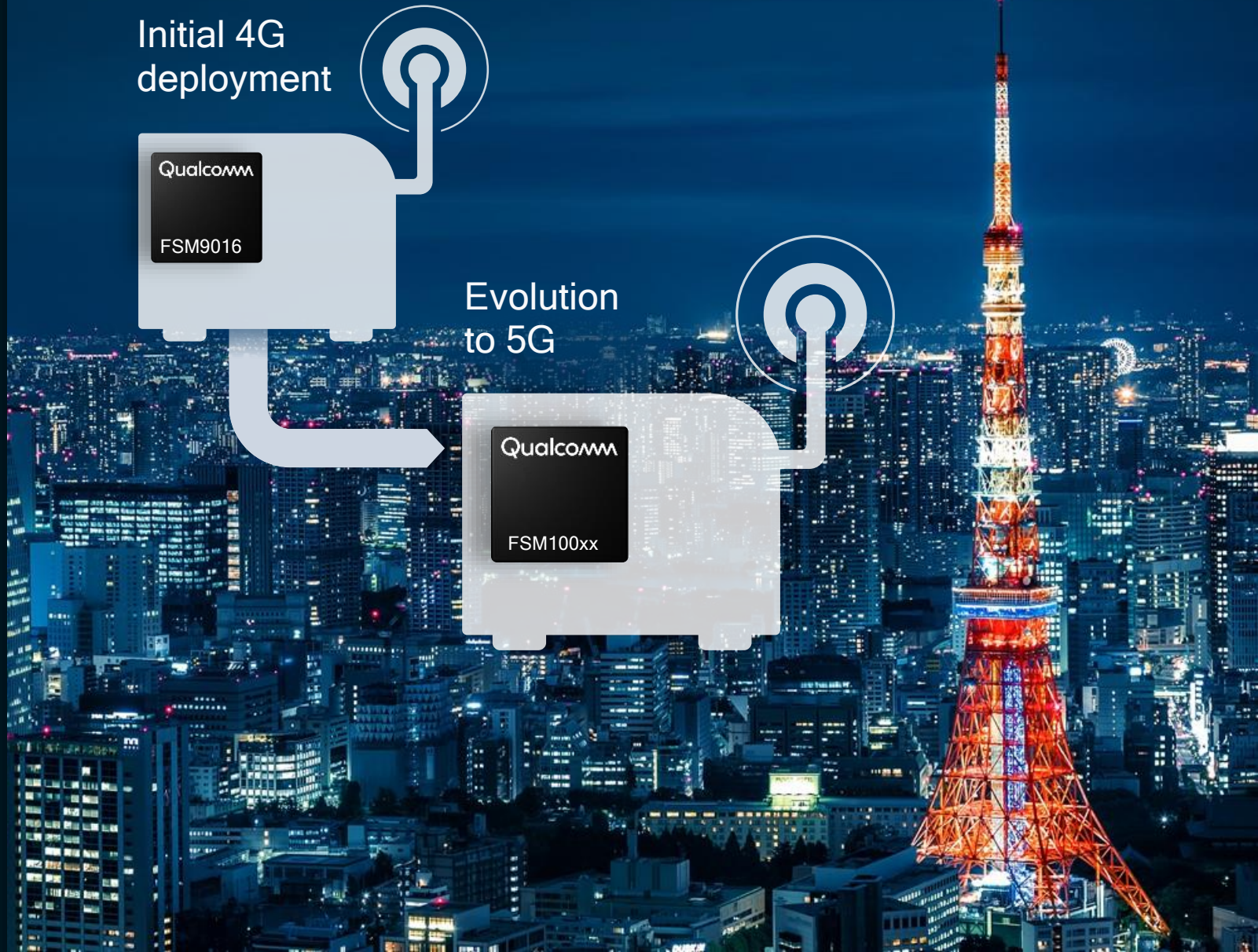
# Deeper 5G coverage with small cells

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

# Qualcomm® 5G RAN Platforms for small cells

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

Qualcomm 5G RAN Platforms is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.

Selected by global infrastructure innovators

*Airspan*

ALTIOSTAR

Bicells

Innowireless

FOXCONN

NOKIA

Corning

Radisys

Rakuten

SAMSUNG

SERCOM

T&W

verizon✓



# 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



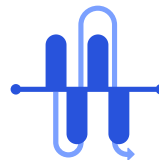
## Extended Range

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<sup>1</sup>



## 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



Gemtek



T&W



FIBOCOM

MEIG 美格

arcadyan



LINKSYS



SAGEMCOM



SHARP



Telit

FIH



SERCOM



ZTE



NOKIA



inseego



oppo

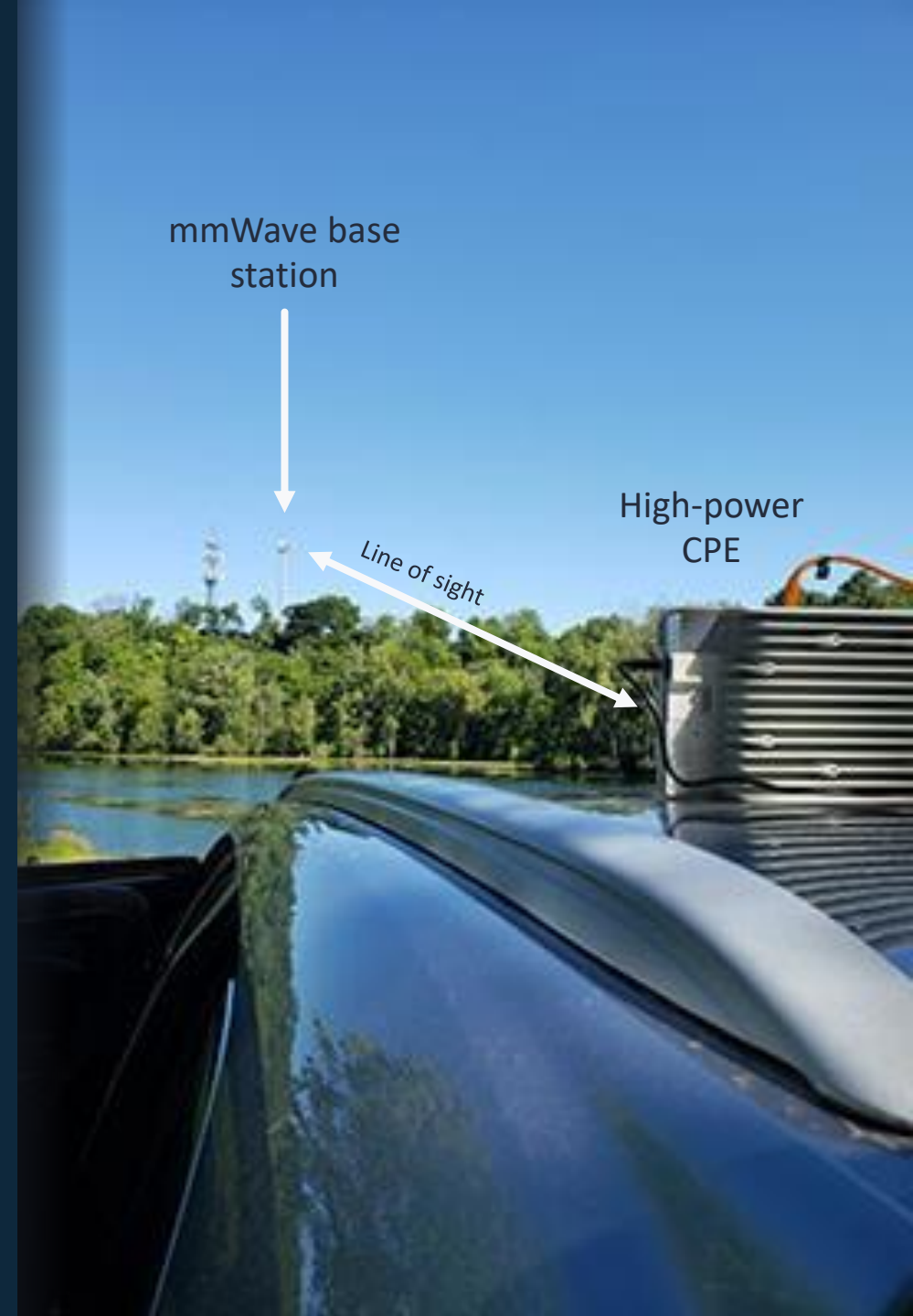
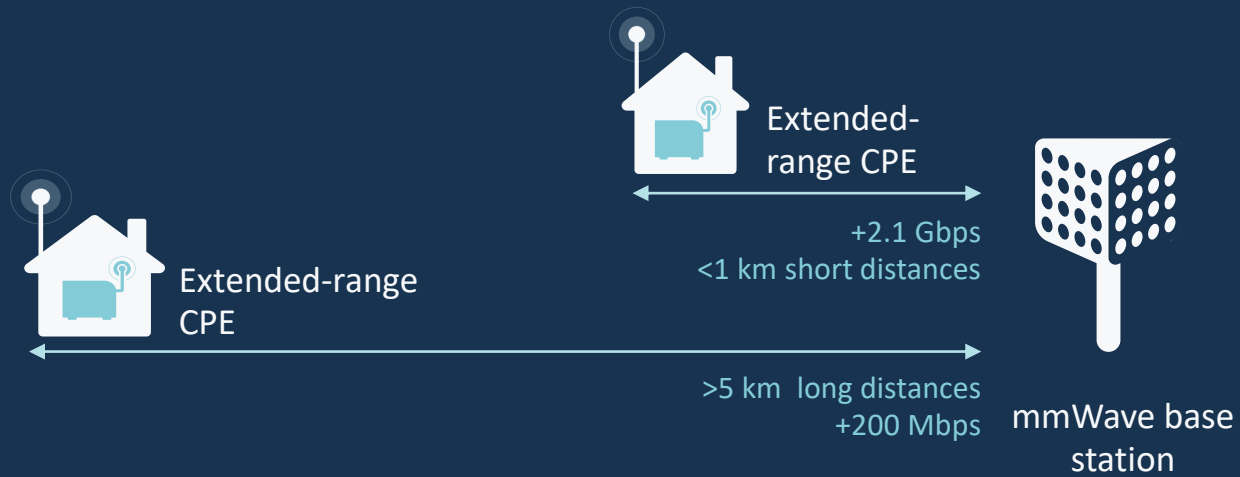


SUNSEA



# 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

## Louisiana

June 29<sup>th</sup>, 2020

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

The Advocate  
[https://www.theadvocate.com/baton\\_rouge/news/politics/legislature/article\\_16dfbbe4-ba18-11ea-8d5c-e3c15513511d.html](https://www.theadvocate.com/baton_rouge/news/politics/legislature/article_16dfbbe4-ba18-11ea-8d5c-e3c15513511d.html)

## Arkansas

August 5<sup>th</sup>, 2020

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

ABC7 - KATV  
<https://katv.com/news/local/cares-act-committee-recommends-additional-100-million-to-expand-arkansas-internet-access>

## Pennsylvania

September 10<sup>th</sup>, 2020

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

Penn Live  
<https://www.pennlive.com/life/2020/09/gov-wolf-putting-cares-act-funding-into-high-speed-internet-for-schools-to-support-remote-learning.html>

## Alabama

July 31<sup>st</sup>, 2020

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

The office of Alabama Governor – Press Release  
<https://governor.alabama.gov/newsroom/2020/07/governor-ivey-allocates-100-million-for-alabama-broadband-connectivity-for-students/>

And more...

## Oregon

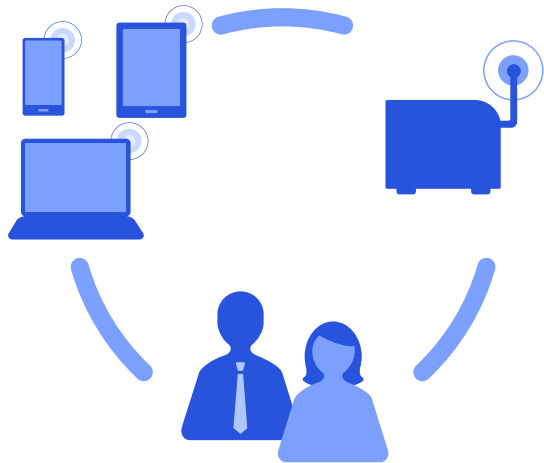
August 30<sup>th</sup>, 2020

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

The Salem Statesman Journal  
<https://www.statesmanjournal.com/story/news/2020/08/30/polk-county-expand-internet-rural-areas-using-cares-act-funds/5646941002/>

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

# 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

More information at [https://about.att.com/story/2020/distance\\_learning\\_family\\_connections.html](https://about.att.com/story/2020/distance_learning_family_connections.html)

## 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

More information at <https://enterprise.verizon.com/solutions/public-sector/education/distance-learning/>

Qualcomm

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

# Federal, state, and local funding for connectivity and devices

- CARES Act – enacted into law by US Congress on March 27<sup>th</sup>, 2020. Appropriated \$13.5 Billion for K-12 education & permitted uses included connectivity & devices.
- HEROES Act – passed U.S. House on May 15<sup>th</sup> & October 1<sup>st</sup>, 2020. Includes \$12 billion in dedicated, emergency funding for K-12 schools to buy 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](http://www.hunt-institute.org/covid-19-resources/geer-fund-utilization)



5G

# 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

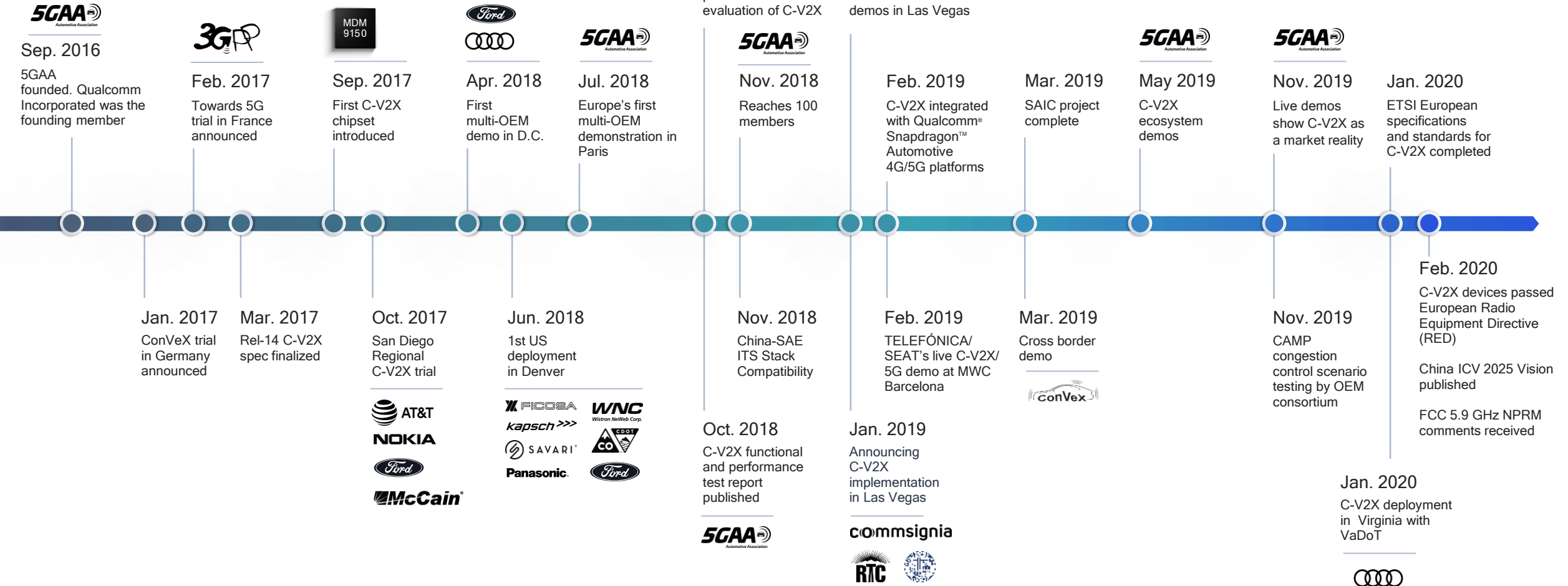
**V2I**  
Vehicle-to-infrastructure  
e.g., roadside traffic signal timing/priority

**V2P**  
Vehicle-to-pedestrian  
e.g., safety alerts to pedestrians, bicyclists

**V2N**  
Vehicle-to-network  
e.g., real-time traffic/routing, cloud services

-  Release 14/15 C-V2X standards completed
-  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

# Strong C-V2X momentum globally





# C-V2X is ready for prime time

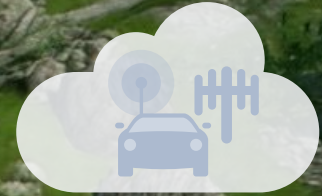
FCC assigned upper 30 MHz of 5.9 GHz to C-V2X and adopted streamlined process for C-V2X to get on the air as soon as possible



V2V safety message on dashboard

ITS spectrum

Cellular spectrum



V2N advanced warning on navigation system



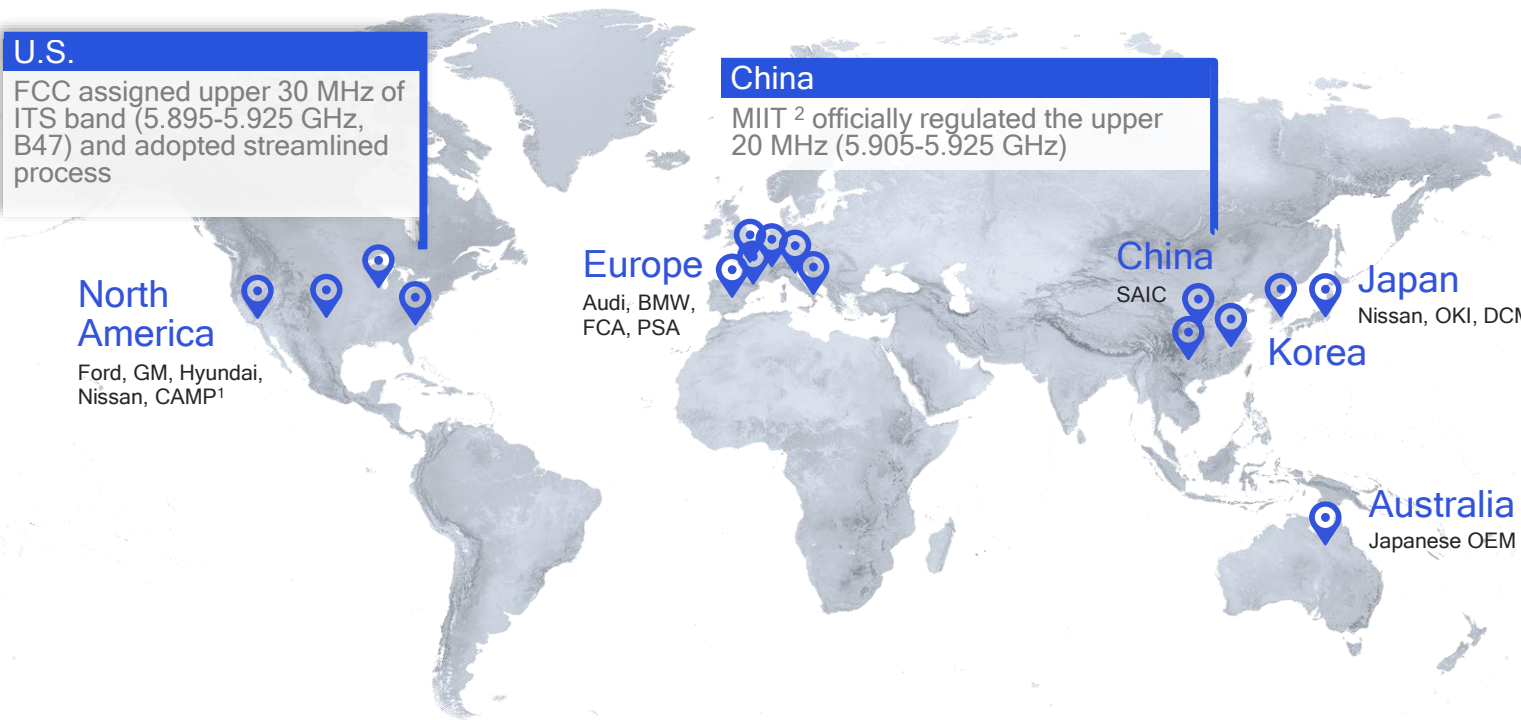
# Driving C-V2X global presence

## 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

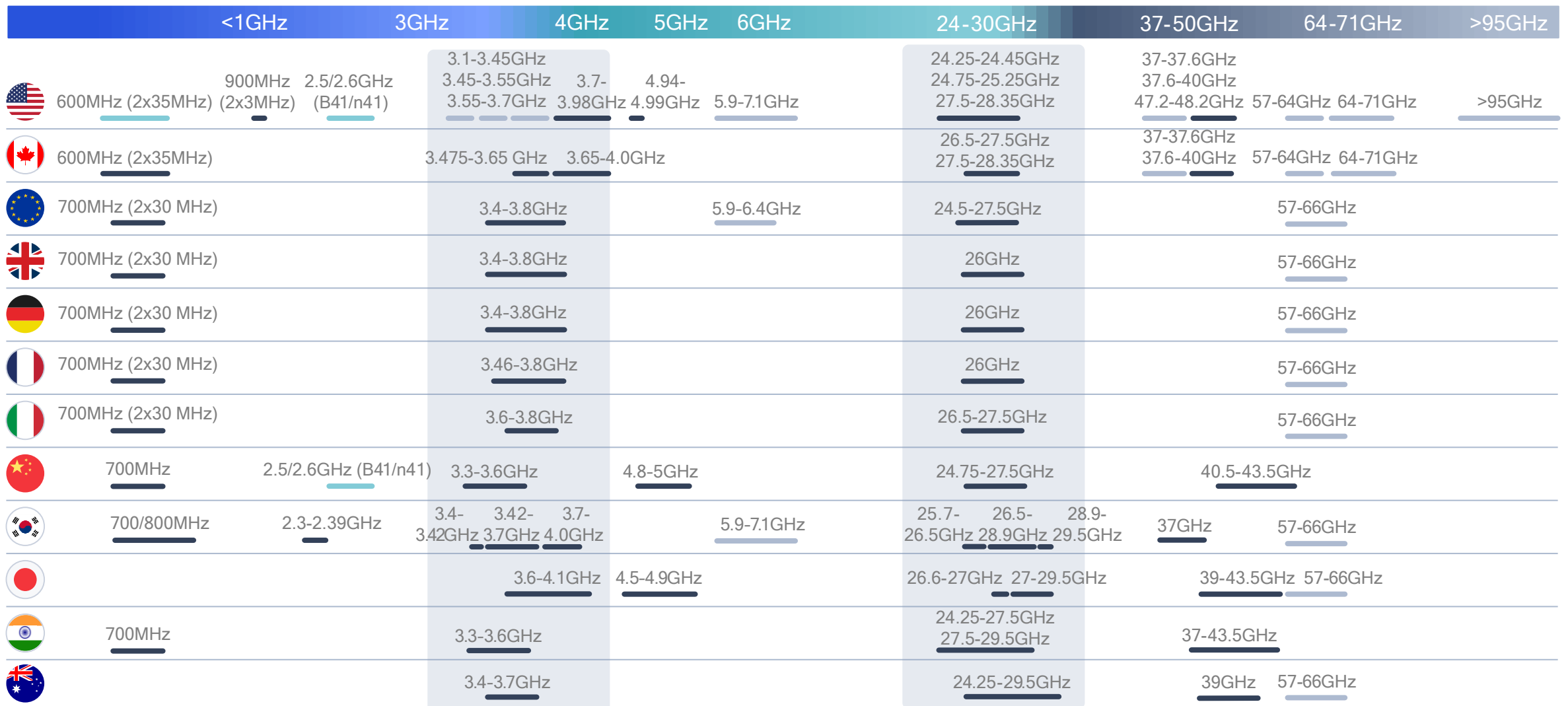


Gaining traction across numerous regions and industry sectors

From standards completion to independent field testing to initial deployments

# Global Spectrum Status

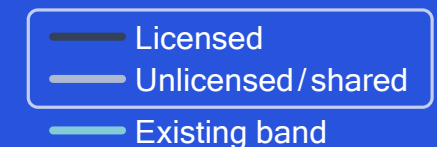




# Global snapshot of allocated/targeted 5G spectrum

5G is being designed for diverse spectrum types/bands

New 5G band



# NR-U

Standardized in 5G NR Release 16 – First global cellular standard with both license-assisted and standalone use of unlicensed spectrum

<1 GHz  
Low-bands (sub-1)

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

24+ GHz  
High-bands (mmWave)



## Unlicensed Spectrum Bands in 3GPP

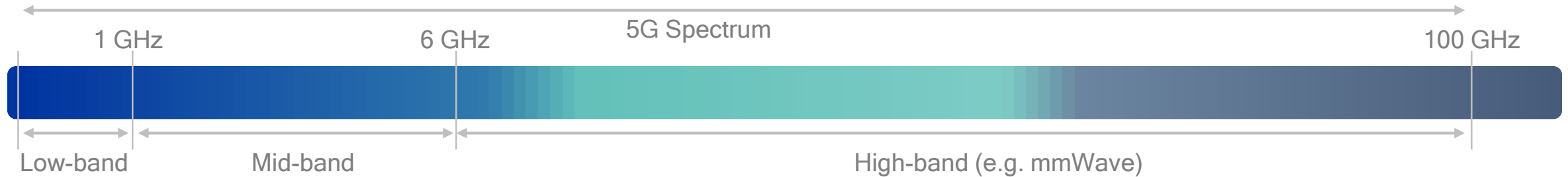
— Available now  
— Under study / review

Frequency Band	Availability	Region	Frequency Band	Availability
5.2-5.8 GHz	Available now	United States	57-71GHz	Under study / review
5.2-5.8 GHz	Available now	Canada	57-71GHz	Under study / review
5.2-5.9 GHz	Under study / review	European Union	57-71GHz	Under study / review
5.2-5.9 GHz	Available now	United Kingdom	57-71GHz	Under study / review
5.2-5.7 GHz	Available now	Germany	57-71GHz	Under study / review
5.2-5.7 GHz	Available now	France	57-71GHz	Under study / review
5.2-5.7 GHz	Available now	Italy	57-71GHz	Under study / review
5.2-5.3; 5.7-5.8 GHz	Under study / review	China	59-64GHz	Under study / review
5.2-5.8 GHz	Available now	South Korea	57-64GHz	Under study / review
5.2-5.7 GHz	Available now	Japan	57-66GHz	Under study / review
5.2-5.5; 5.7-5.9 GHz	Under study / review	India		
5.2-5.8 GHz	Available now	Australia	57-66GHz	Under study / review
5.9-7.1GHz	Available now			
5.9-6.4GHz	Under study / review			



# 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<sup>1</sup>, 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<sup>2</sup>, GAA<sup>3</sup>
- 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
- In Sep 2020, FCC adopted NPRM for 3.45-3.55 GHz and for 4.94-4.99 GHz. Auction of 3.45-3.55 GHz targeted for Dec 2021
- NTIA and FCC are studying repurposing of 3.1-3.45 GHz for commercial use

## High-band

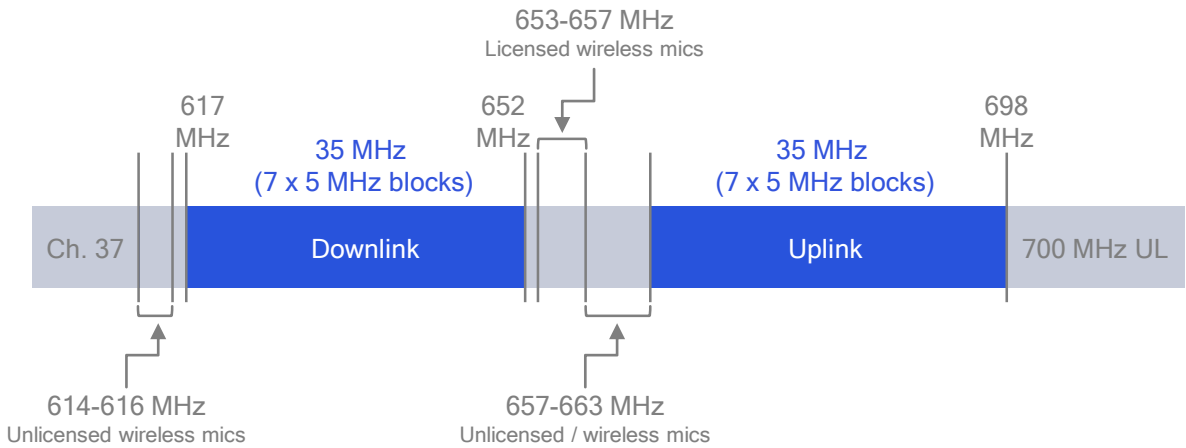
FCC has completed 3 mmWave auctions, including most recently the largest auction in history

- In 2016, FCC allocated 10.85 GHz in multiple mmWave bands<sup>4</sup>, 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

<sup>1</sup> Citizen Broadband Radio Services; <sup>2</sup> Priority Access Licenses to be auctioned; <sup>3</sup> General Authorized Access; <sup>4</sup> 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



600 MHz Spectrum

## 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

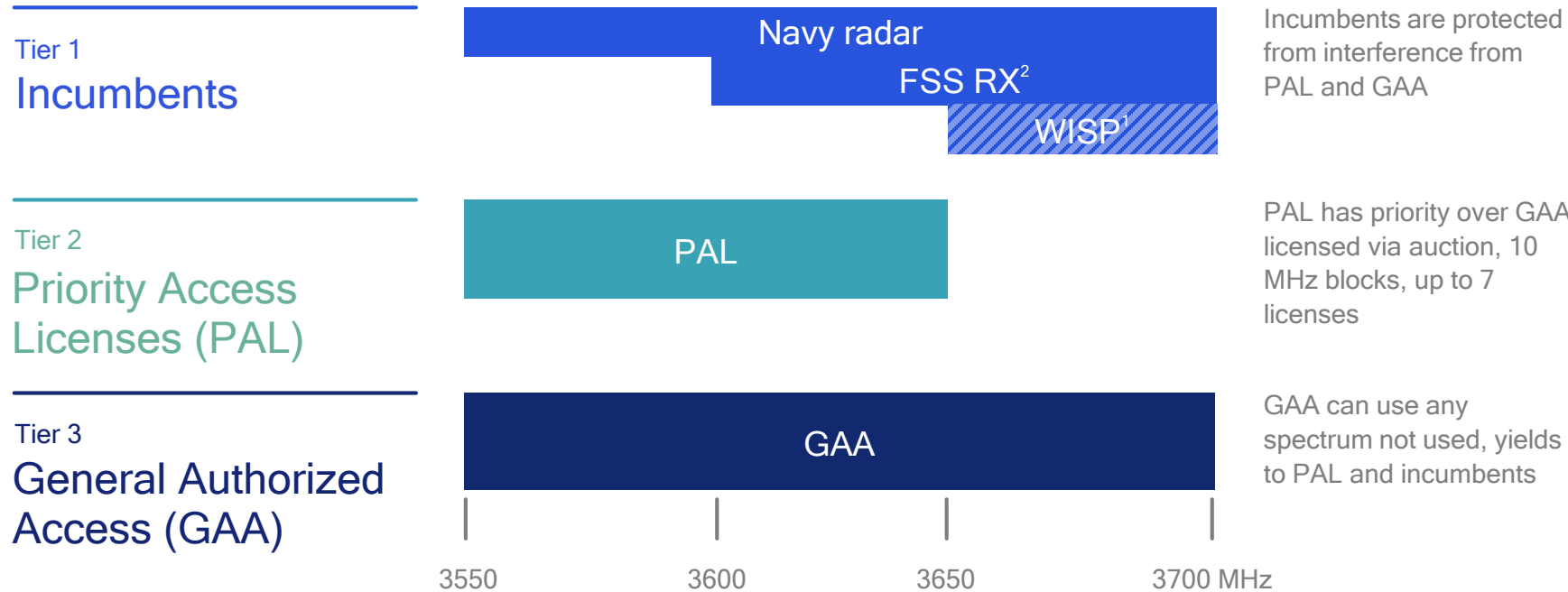
Low-band spectrum is optimized for long-range macro deployments - optimal for connecting the wide-area IoT and more

## Broad industry support

Qualcomm Technologies Inc. is working closely with operators & OEMs to enable early launches, incorporating our industry-leading modem, transceiver, and RFFE



# Mid-band: CBRS in use and FCC about to begin C-Band auction



FCC optimized rules in October 2018, allowed initial GAA deployments in September 2019, and PAL auction completed in August 2020

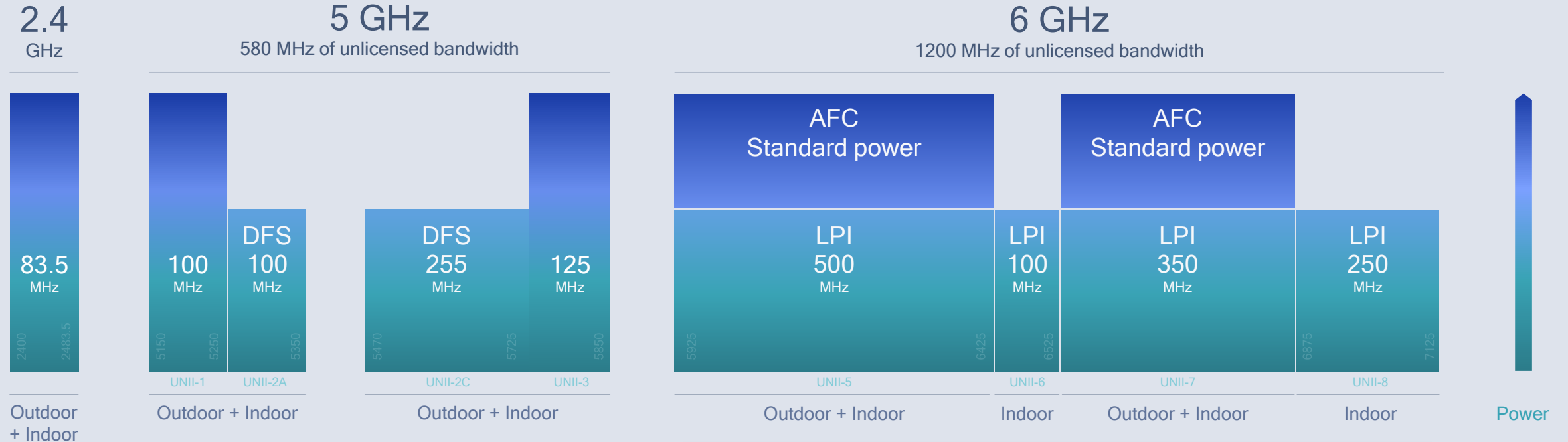
1 Wireless ISP transitioning from incumbent to PAL/GAA after 5 years; 2 Fixed satellite service - receiving only; 3) Citizen Broadband Radio Service (CBRS)

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



**1200 MHz**  

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



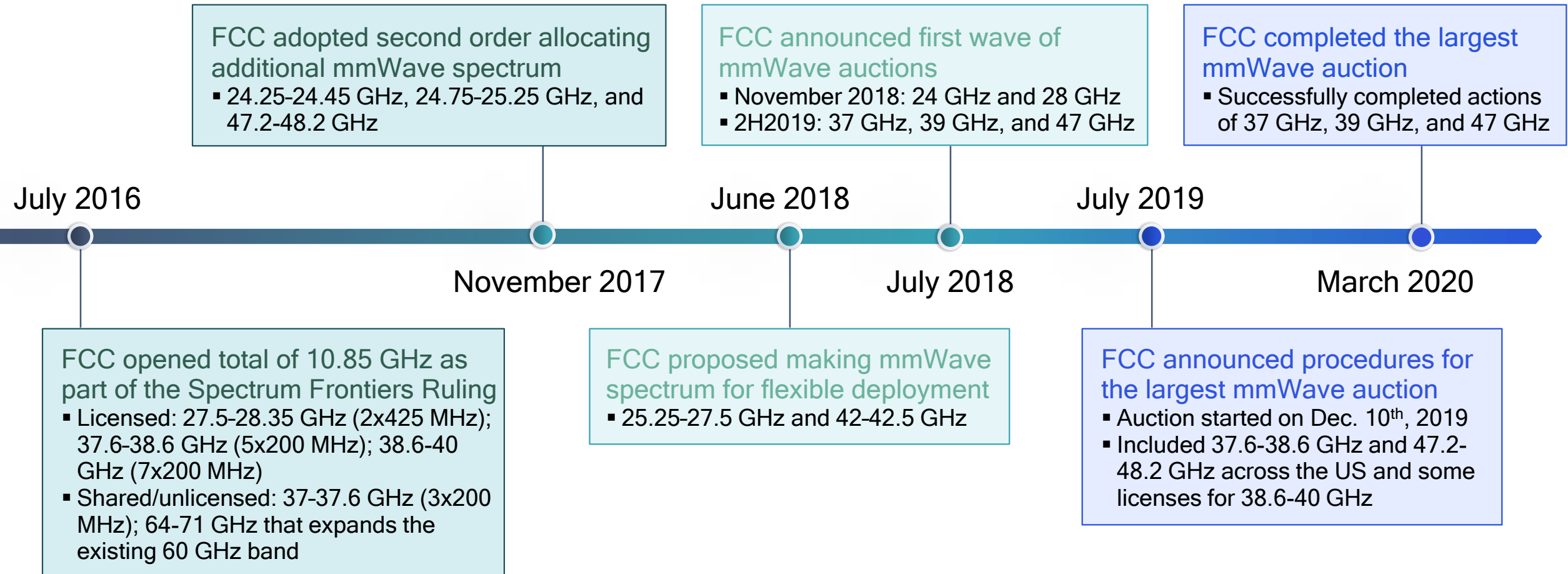
Technologies that will power  
the future of connectivity

**Multi-gigabit Throughput**  
**Ultra Low Latency**  
**Massive Capacity**





# High-band: FCC rapidly bringing mmWave spectrum to market





# European Commission driving a Gigabit Society<sup>1</sup>

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



## EC 5G Action Plan – published in Sept. 2016

- 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<sup>2</sup> 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<sup>3</sup>

# 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



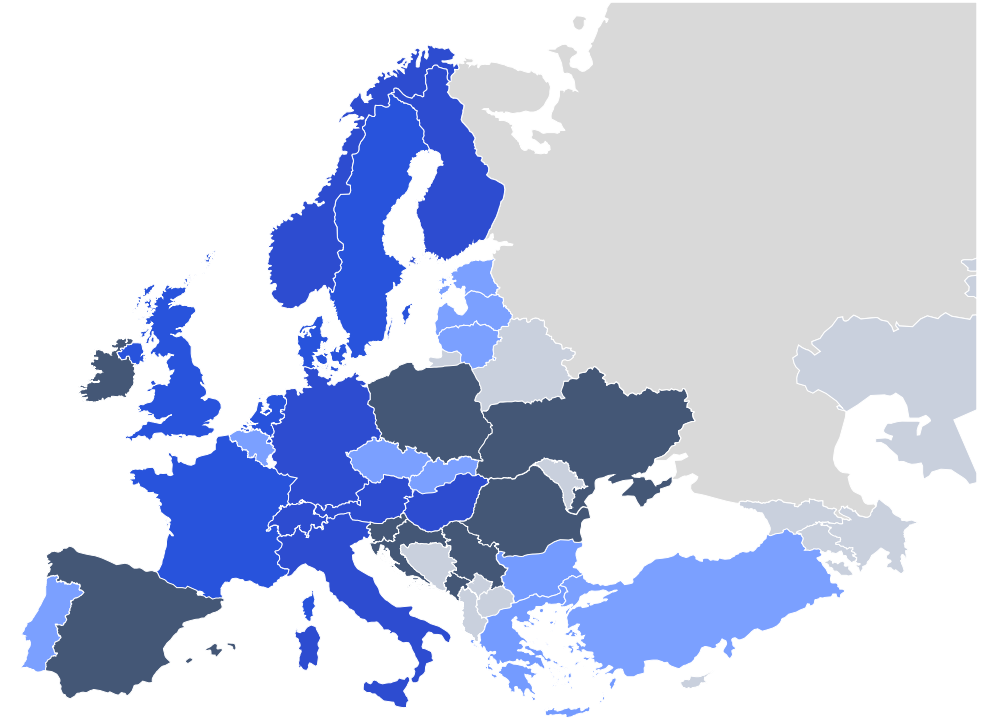
## Expected to be awarded in 2020

- 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



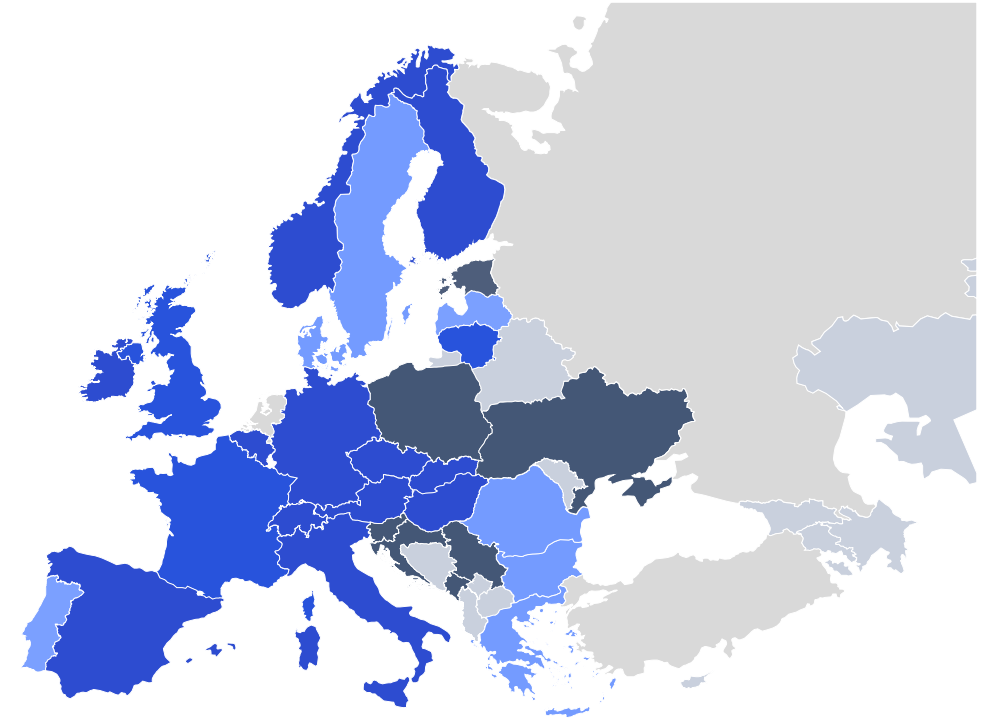
## Expected to be awarded in 2020

- 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

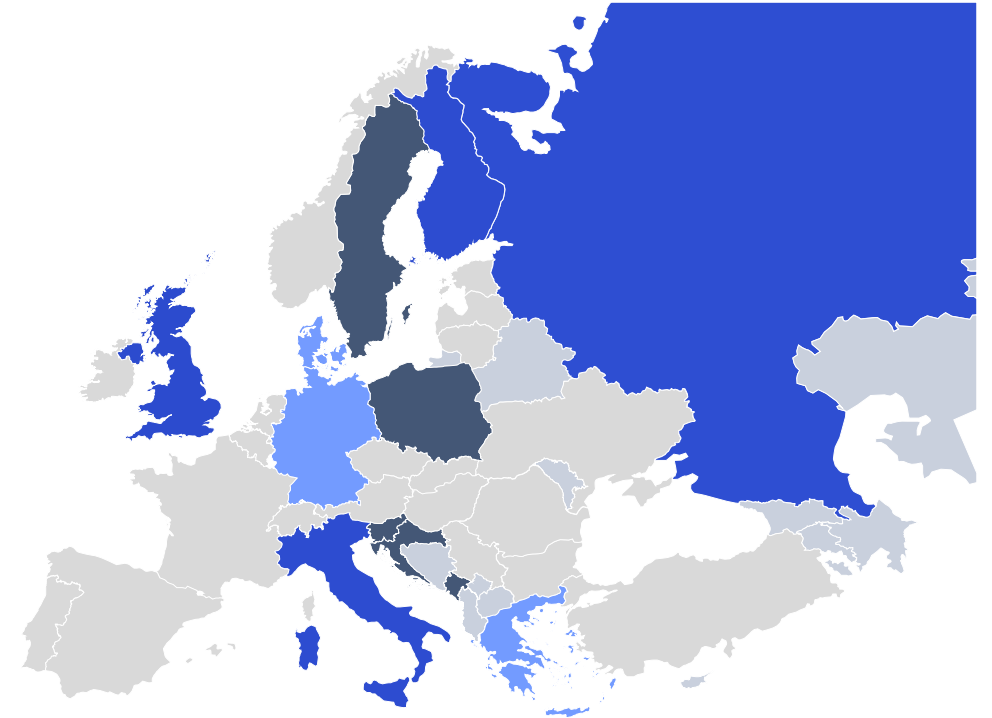
- Italy, Finland and Russia have awarded 26 GHz
- UK has made available based on market demand and indoor only, 24.5 - 26.5 GHz – the whole 26 GHz band expected in 2021

## ● 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

## Malaysia



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

## 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

## Vietnam



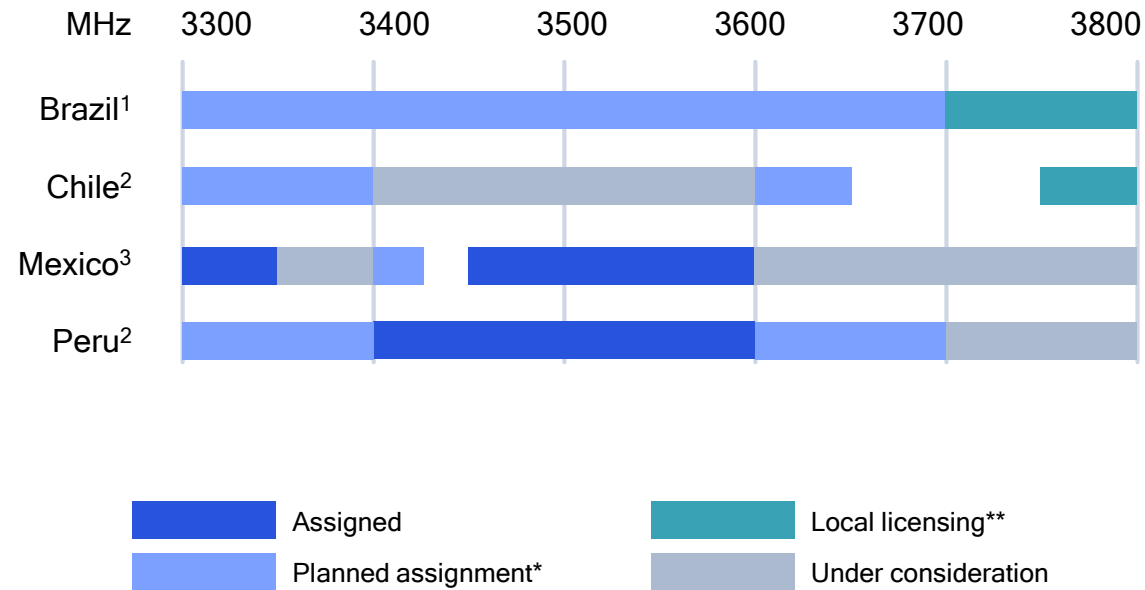
- Government has announced timeframe for planned commercialization in 2020
- 3.8 GHz and 4.8 GHz bands are under consultation
- 26/28 GHz in ongoing consultation process
- 5G trials underway by all 3 mobile network operators

## India

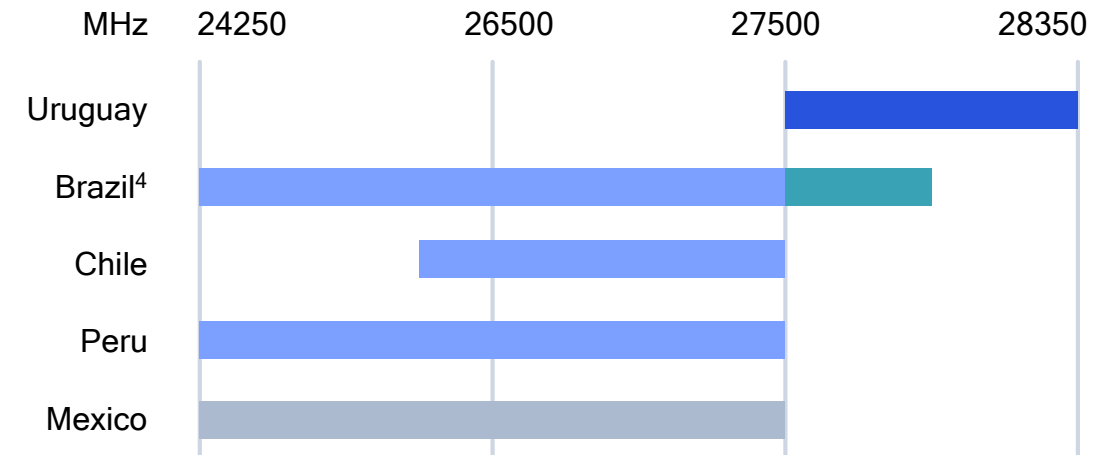


- High Level Forum submitted 5G recommendation in Aug'18
- 617-698 MHz in planning; 698-803 MHz auction in Q4'20
- 3.3-3.6 GHz and 24.25-27.5 GHz auction expected in Q3'21
- 24.25-27.5 GHz, 27.5-29.5 GHz preferred mmWave bands – two years free for trials; also looking at 37-43.5 GHz

## 3.5 GHz



## 26/28 GHz



\* 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 GHz 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

# 5G update in LATAM



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 2<sup>nd</sup> 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



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

Hong Kong



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

Japan



- 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

Global snapshot of spectrum optimized for industrial IoT / vertical / private network use – local licensing or sharing

Questions?



# Thank you!

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