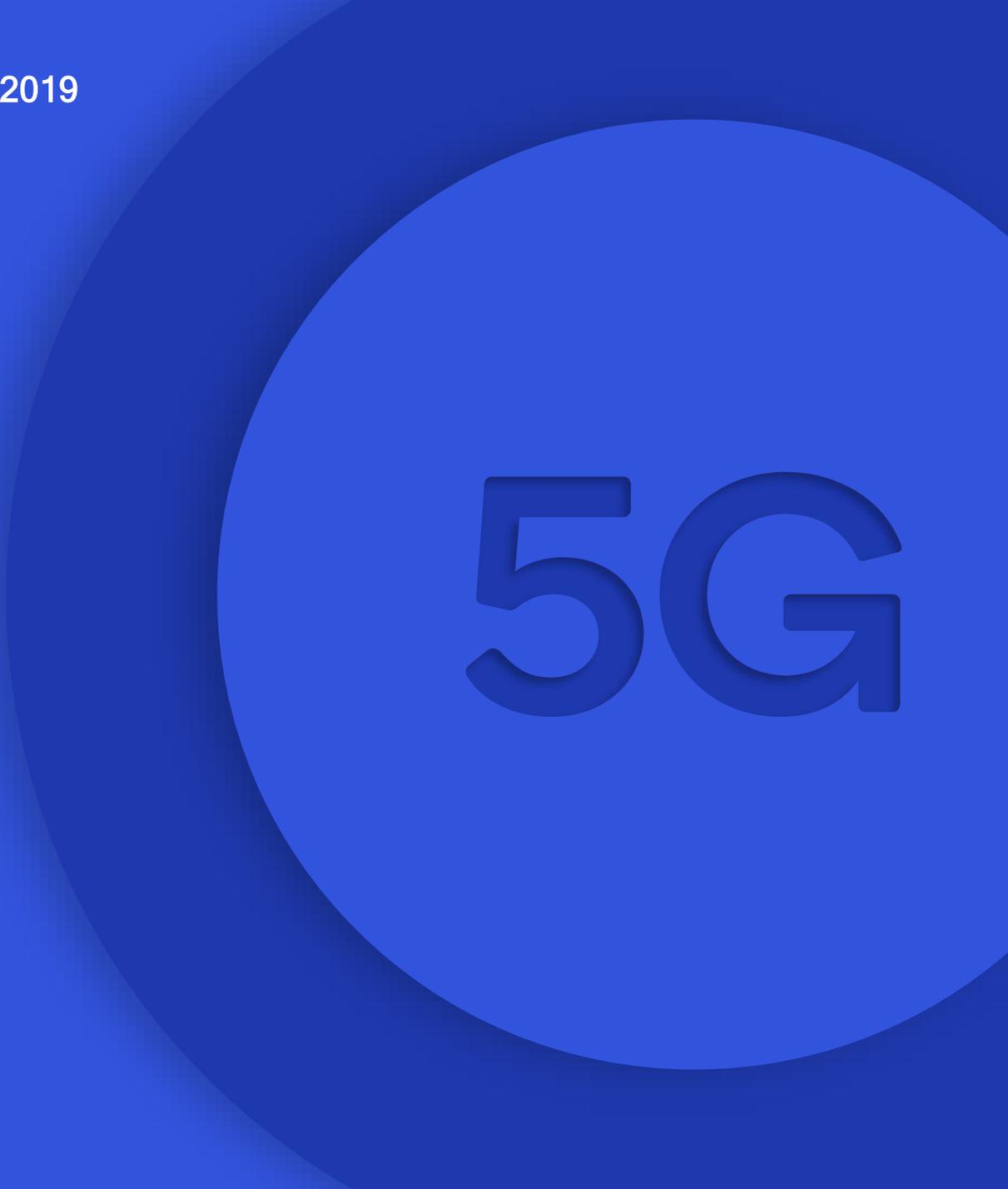
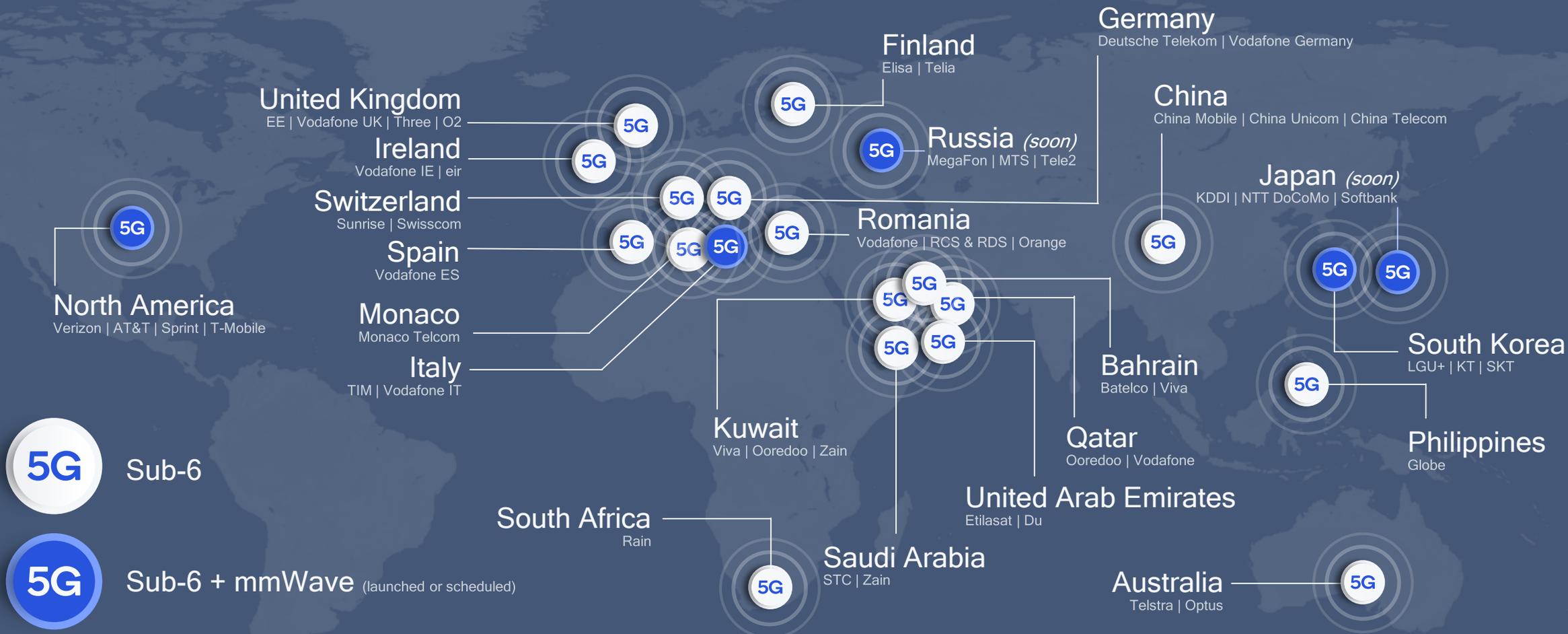


# Global update on 5G spectrum

A large, stylized '5G' logo is centered on the right side of the slide. The logo is rendered in a dark blue color with a subtle 3D effect, appearing to float above a lighter blue circular background. The '5' and 'G' are bold and blocky, with the 'G' having a thick vertical bar. The entire logo is set against a background of two overlapping circles: a larger, darker blue circle behind a smaller, lighter blue circle.



# Comparison of Year 1 announcements



4 Operators launched  
3 OEMs launched



40+ Operators launching  
40+ OEMs launching

# Spectrum is critical for 5G success

Using all spectrum types and bands



5G

## Licensed spectrum

Exclusive use

Over 40 bands globally for LTE,  
remains the industry's top priority

## Shared spectrum

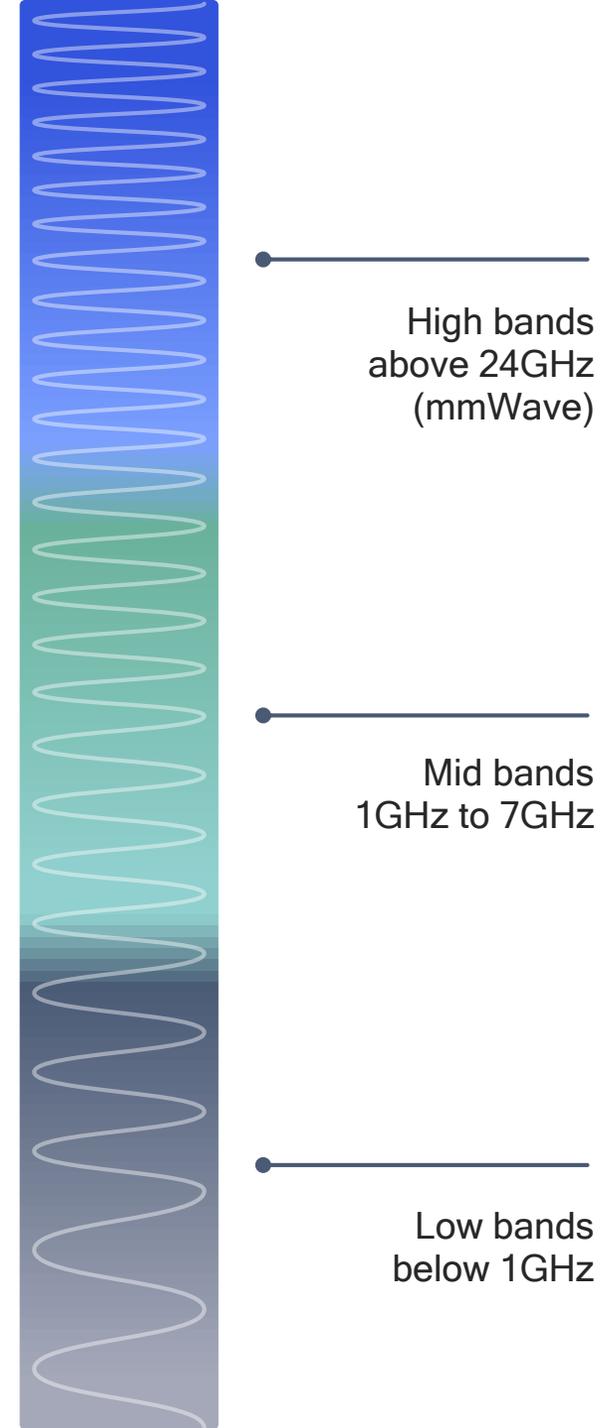
New shared spectrum paradigms

Ex: 3.5 GHz USA, 3.7 GHz Germany

## Unlicensed spectrum

Shared use

Ex: 2.4 GHz / 5.9-7.1 GHz / 57-71 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:

# Global Spectrum Status



	<1GHz	3GHz	4GHz	5GHz	24-28GHz	37-40GHz	64-71GHz	>95GHz
	600MHz (2x35MHz)	2.5/2.6GHz (B41/n41)	3.45-3.55GHz 3.55-3.7GHz 3.7-4.2GHz	5.9-7.1GHz	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 47.2-48.2GHz	64-71GHz	>95GHz
	600MHz (2x35MHz)		3.55-3.7 GHz		26.5-27.5GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz	64-71GHz	
	700MHz (2x30 MHz)		3.4-3.8GHz	5.9-6.4GHz	24.5-27.5GHz			
	700MHz (2x30 MHz)		3.4-3.8GHz		26GHz			
	700MHz (2x30 MHz)		3.4-3.8GHz		26GHz			
	700MHz (2x30 MHz)		3.46-3.8GHz		26GHz			
	700MHz (2x30 MHz)		3.6-3.8GHz		26.5-27.5GHz			
	700MHz	2.5/2.6GHz (B41/n41)	3.3-3.6GHz	4.8-5GHz	24.75-27.5GHz	37-42.5GHz		
			3.42-3.7GHz		26.5-28.9GHz			
			3.6-4.1GHz	4.5-4.9GHz 4.9-5GHz	26.6-27GHz 27-29.5GHz	39-43.5GHz		
	700MHz		3.3-3.6GHz		24.25-27.5GHz 27.5-29.5GHz	37-43.5GHz		
			3.4-3.7GHz		24.25-27.5GHz	39GHz		

# Global snapshot of allocated/targeted 5G spectrum

5G is being designed for diverse spectrum types/bands

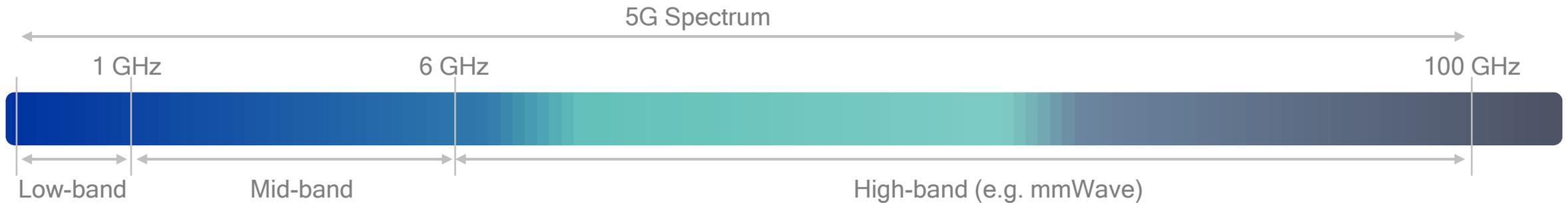
New 5G band

-  Licensed
-  Unlicensed / shared
-  Existing band



# 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
- Spectrum availability timing aligns with 5G

### Mid-band

CBRS<sup>1</sup>, 3.4-3.5 GHz and 3.7-4.2 GHz

- Opening up 150 MHz in 3.5 GHz band with 3-tier sharing with incumbents, PAL<sup>2</sup>, GAA<sup>3</sup>
- In Sept 2019, FCC approved initial GAA deployments
- In June 2020, FCC will auction PAL licenses (up to 70 MHz per county).
- Adopted NPRM of 3.7-4.2 GHz & 5.9-7.1 GHz
- NTIA is studying repurposing 3.45-3.55 GHz f& 3.1 to 3.45 GHz for commercial use.

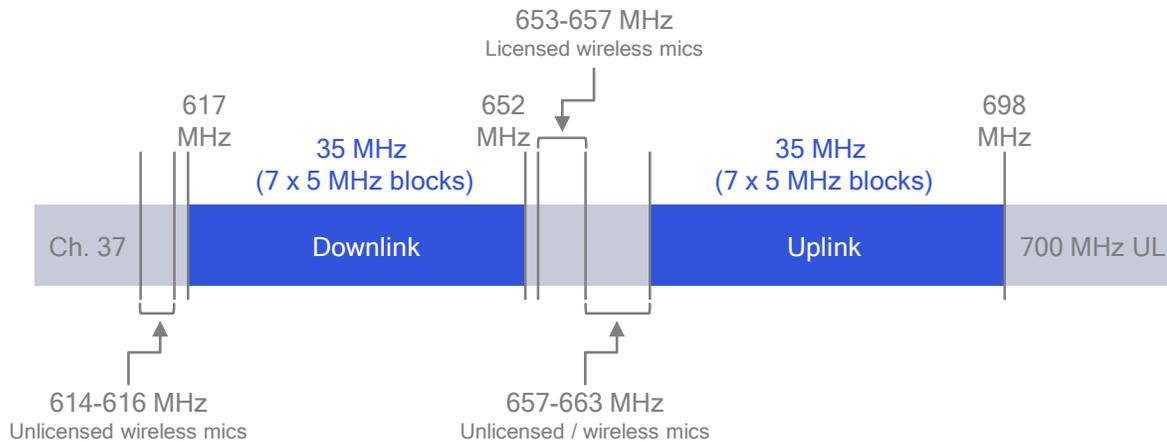
### High-band

FCC has allocated 12.55 GHz so far & its largest auction will occur in 2019

- 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 Dec. 2019, FCC will auction Upper 37, 39, & 47 GHz bands.



# Low-band: 600 MHz LTE initially deployed in areas already clear of TV stations – now will be 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

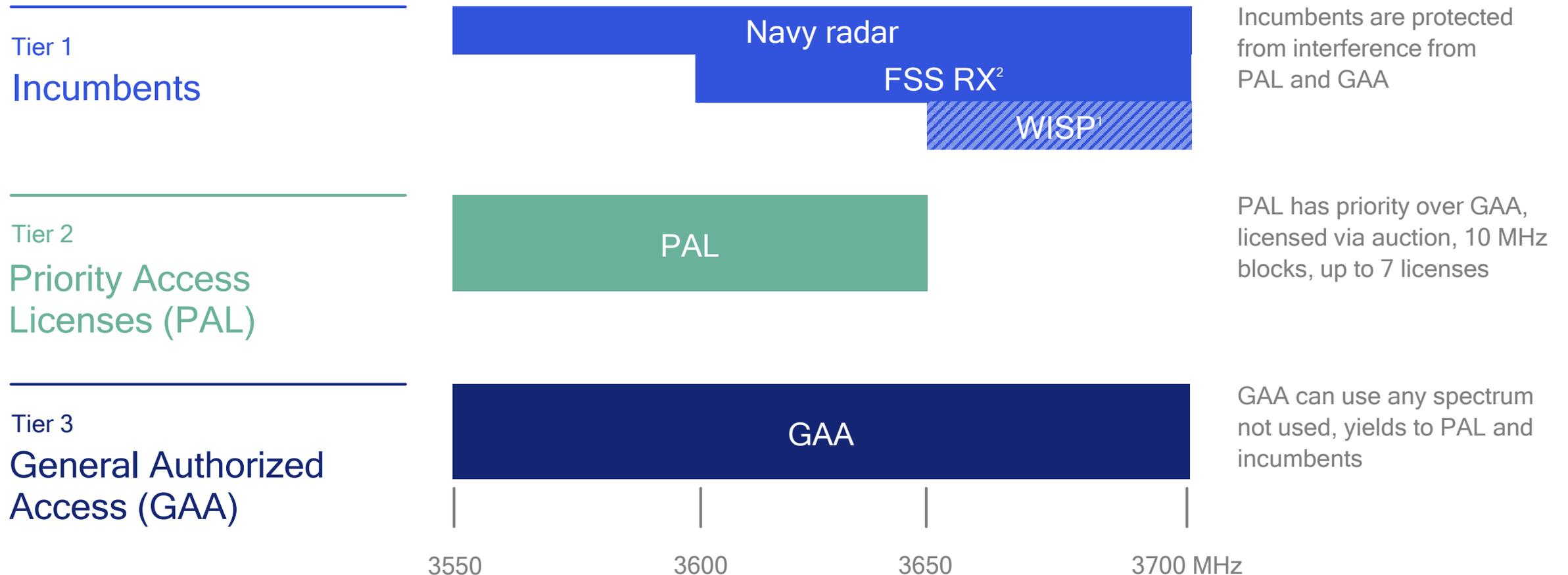
### Broad industry support

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



# Mid-band: CBRS introduces a 3-tiered shared spectrum

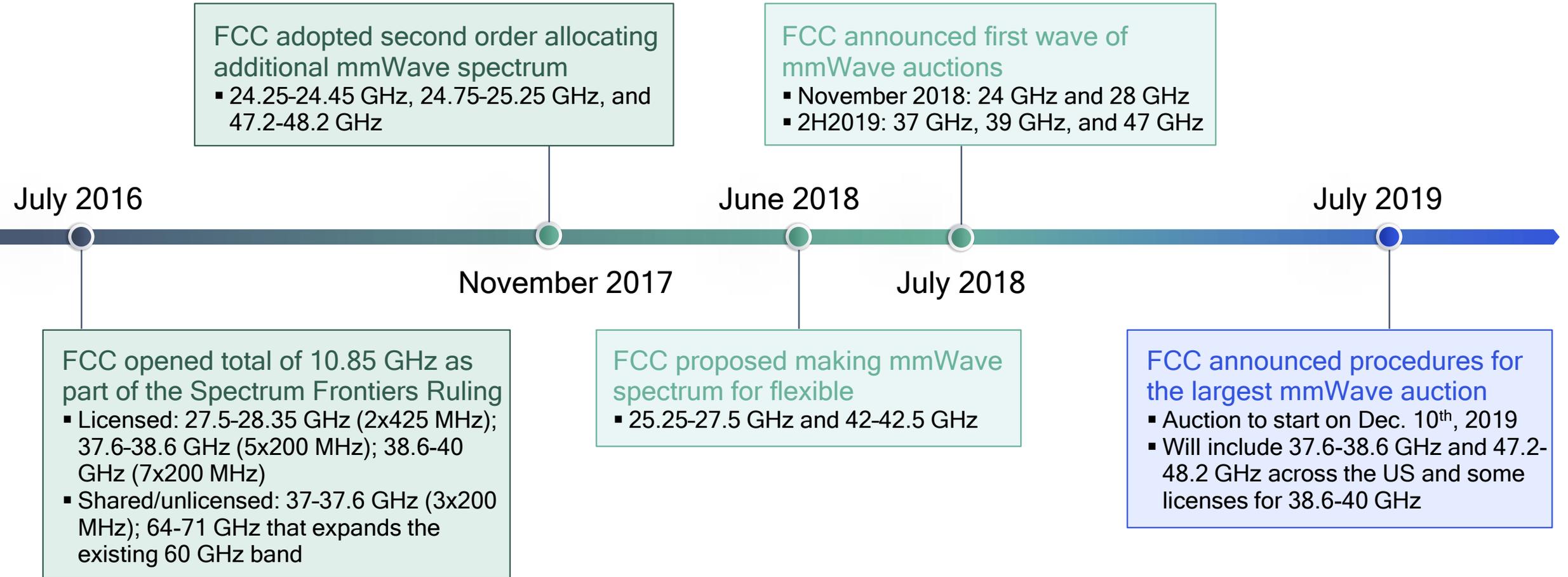
FCC optimized rules in Oct 2018, allowed initial GAA deployments in Sept 2019, and will hold PAL auction in June 2020



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



# 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)

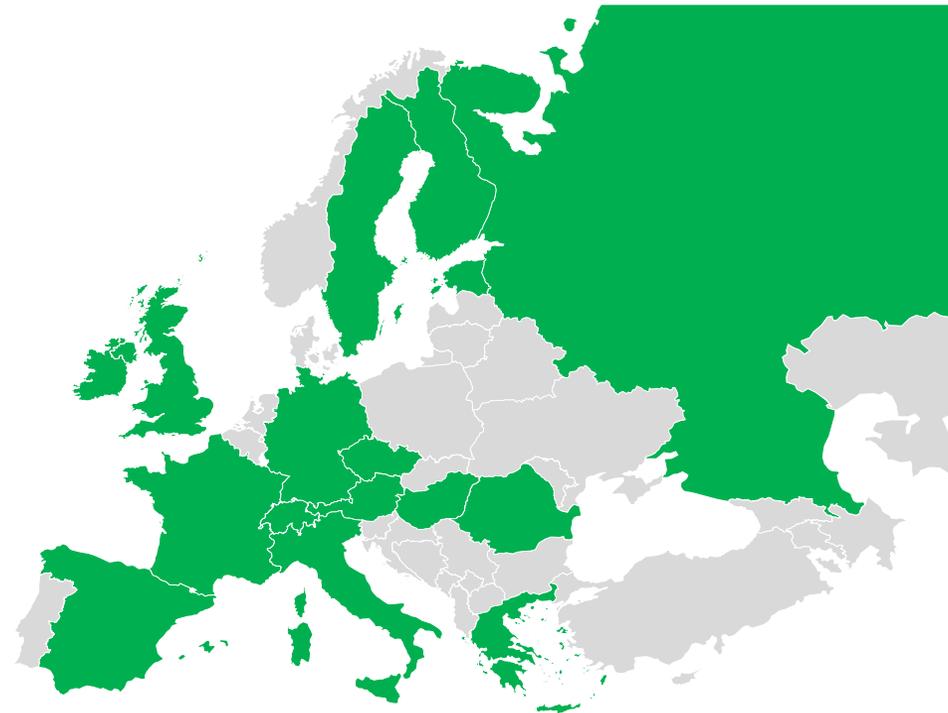
- EC Mandate to CEPT focusing on 3.5 GHz and 26 GHz pioneering bands – completed in 2018
- Additional EC Mandate to CEPT on extended L band (1427 - 1518 MHz) – completed in 2018
- CEPT harmonization of the 26 GHz band ahead of WRC-19 – completed in June 2018
- EC working on binding decision for EU Member 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 status dashboard in Europe

Commercial targets focusing on 3.4-3.8 GHz and/or 26 GHz



 U.K.	Status
3.4 - 3.6 GHz (150 MHz)	Auctioned
3.6 - 3.8 GHz (120 MHz)	Q1 2020
3.8 - 4.2 GHz	Q4 2019 - Local
24.25 - 26.5 GHz	Q4 2019 - Local
26.5 - 27.5 GHz	2020

 Italy	Status
3.6 - 3.8 GHz	Auctioned
26.5 - 27.5 GHz	Auctioned - Club Use

 France	Status
3.46 - 3.8 GHz	Q4 2019
26 GHz	2020

 Spain	Status
3.6-3.8 GHz	Auctioned
26.5 - 27.5 GHz	2020

 Switzerland	Status
3.4 - 3.8 GHz	Auctioned
26.5 - 27.5 GHz	2022

 Germany	Status
3.4 - 3.7 GHz	Auctioned
3.7 - 3.8 GHz	Q4 2019 - Local
26 GHz	2019/2020

 Russia	Status
26 GHz	Auctioned

 Greece	Status
3.4 - 3.8 GHz	Q4 2019
26.5 - 27.5 GHz	Q4 2019

 Sweden	Status
3.4 - 3.8 GHz	Q4 2019
26 GHz	2020

 Finland	Status
• 3.4 - 3.8 GHz	Auctioned
• 26 GHz	2020

 Romania	Status
3.6-3.8 GHz	Q4 2019
26.5 - 27.5 GHz	2020

 Hungary	Status
3.6 - 3.8 GHz	Q4 2019
26 GHz	2020

 Czech republic	Status
3.6 - 3.8 GHz	2020

 Ireland	Status
3.4 - 3.8 GHz	Auctioned



# 5G spectrum in Europe

## Focus on mid-band (3.4-3.8 GHz) and 26 GHz (24.25-27.5 GHz) for 2019+

EC RSC, CEPT, key European Member States are driving regulatory activities to accelerate 5G rollout in EU  
Intense regulatory activities for 3.4-3.8 GHz and 26 GHz with more auctions occurring in 2019 and 2020

U.K.



- Government 5G strategy for UK published in March 2017 - DCMS and HM Treasury
- Ofcom auctioned 150 MHz in 3.4-3.6 GHz in 2018, more spectrum (120MHz) in 3.6-3.8 GHz in Q1 2020
- Multi-band auction in Q1 2020 including (700MHz, 3.6-3.8GHz)
- For mmWave, Ofcom has initiated a work program on 26 GHz band availability for early 5G deployment
- Local licenses in 24.5-26.5 GHz from Q4 2019

Germany



- BenetzA auctioned 3.4-3.7 GHz
- 3.7-3.8 GHz for verticals to be released in Q4 2019
- 24.25-27.5 GHz expected to be released in 2020 for local use

France



- ARCEP to award 340 MHz (3.46 - 3.8GHz) of spectrum in Q419
- 26 GHz spectrum to be addressed in 2020

Italy



- Auction completed in 2018:700MHz, 3.6-3.8GHz, 26.5-27.5GHz

Ireland



- Ireland successful auction of 350 MHz of spectrum for 5G
- 26GHz auction in 2018

Spain



- In Spain, the 3.6-3.8 GHz band was auctioned in Q3 2018
- Organizing trials on 26 GHz band - at least 1.4 GHz available for release from 2019 depending on market demand

Finland



- Auction completed in Sept. 2018: 3410-3800 MHz
- Ficora is looking at "large-scale 5G tests" in 26 GHz, decided to make available up to 1 GHz for it in 2017—commercial in 2020

Sweden



- PTS is looking at "large-scale 5G tests" in 26 GHz, decided to make available up to 1 GHz for it in 2017
- Commitment to make available pioneering bands starting in Q419

Switzerland



- 3.5-3.8 GHz auction completed, for commercial use from Q219

Austria



- Spectrum auction completed, 3.6-3.8 GHz for commercial use starting from Q219

# 5G spectrum status in China, South Korea, and Japan



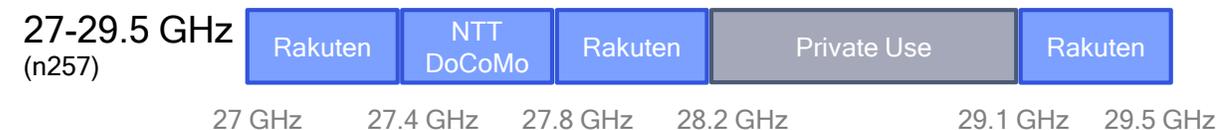
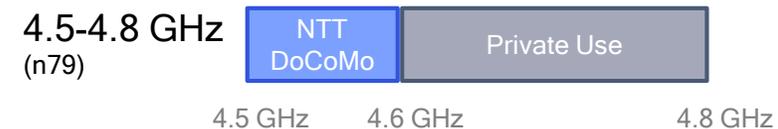
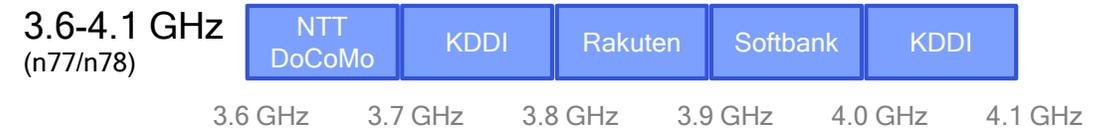
- MIIT officially allocated 3.3-3.6 GHz & 4.8-5.0 GHz as official 5G bands; in addition, in Dec'18, 2.6 GHz (Band n41) has been allowed for both 4G & 5G deployments
- mmWave in longer term. Chinese gov't solicited public opinion for candidate bands of 24.25-27.5 GHz & 37-42.5 GHz non-exclusively in Jun'17
- 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



- 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. Carriers plan to launch mmWave service in 1H 2020
- Achieved over 3 million 5G subscribers as of Sep'19



- Technical rules for licensed bands in 3.6 - 4.2 GHz, 4.4 - 4.9 GHz and 27 - 29.5 GHz have been specified
- In Apr'19, MIC assigned 5G spectrum to operators
- Technical rules for private network bands in 2575-2595 GHz (NSA) and 28.2-28.3 GHz have also been specified. New regulations will be enacted by Dec'19
- Technical rules for additional licensed spectrum (4.8-5 GHz, 26.5-27 GHz, 37-43.5 GHz) & private spectrum (4.6-4.8 GHz, 28.3-29.1 GHz) are being developed



# 5G spectrum status in Oceania, South East Asia, and India

## Australia



- 3.6 GHz: remaining 125 MHz auctioned in Oct'18 (total 3.4-3.7 GHz) and 5G has been commercially deployed
- 26 GHz: government has proposed:
  - unlicensed access to 24.25-25.1 GHz
  - area defined spectrum & apparatus licenses in 25.1-27.5 GHz
  - national apparatus licenses in 24.7-25.1 GHz
  - auction spectrum licenses 26 GHz in 2020
- 28 GHz: regulator has consulted on 28 GHz spectrum, and will announce a planning decision in 3Q19

## New Zealand



- 3.5 GHz: 3400-3590 MHz assigned until 2022
- 5G commercial deployment started in 2019
- Longer term access to be provided prior to 2022, access to 3590-3800 MHz will be provided in 2020

## Hong Kong



- 3.5 GHz: 5G Spectrum auction scheduled for Oct'19
- 26/28 GHz: 3 operators awarded 400 MHz each, with 400 MHz reserved for local licensing

## Taiwan



- 3.5 GHz: auction planned for 4Q19
- 28 GHz: auction planned for 4Q19

## Singapore



- Completed second round of consultation in Jul'19, proposing release of spectrum in 3.5 GHz and 26/28 GHz in initial tranche, and plan to finalize policy decision in 2019

## Indonesia



- All operators conducted 5G trials in 26-28 GHz in 2018-2019. Government plans to conduct trial in 3.5 GHz
- Government announced that it will consult on 5G policy and 3.5 GHz, 26 GHz and other spectrum bands in 2019, and finalize policy in 2020.

## Malaysia



- Regulator and Industry recommendations to government:
  - 3.5 GHz: 5G access in 1H21
  - 26/28 GHz: 5G access in 1H21

## Philippines



- 3.5 GHz band assigned

## Thailand



- 3.5 GHz: Auction planned for 2H20
- 26/28 GHz: Auction planned for 1H20

## Vietnam



- Government has announced timeframe for planned commercialization in 2020
- Proposed consideration of portions of 3.5 GHz band and 26/28 GHz in ongoing consultation process

## India



- High Level Forum submitted 5G recommendation in Aug'18
- 617-698 MHz in planning; 698-803 MHz auction in Q1'20
- 3.3-3.6 GHz auction in Q1'20
- 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

# 5G update in LATAM

Studies under way for both C-Band & mmWave spectrum in key countries



Brazil has auction of C-band & 26 GHz planned for March 2020



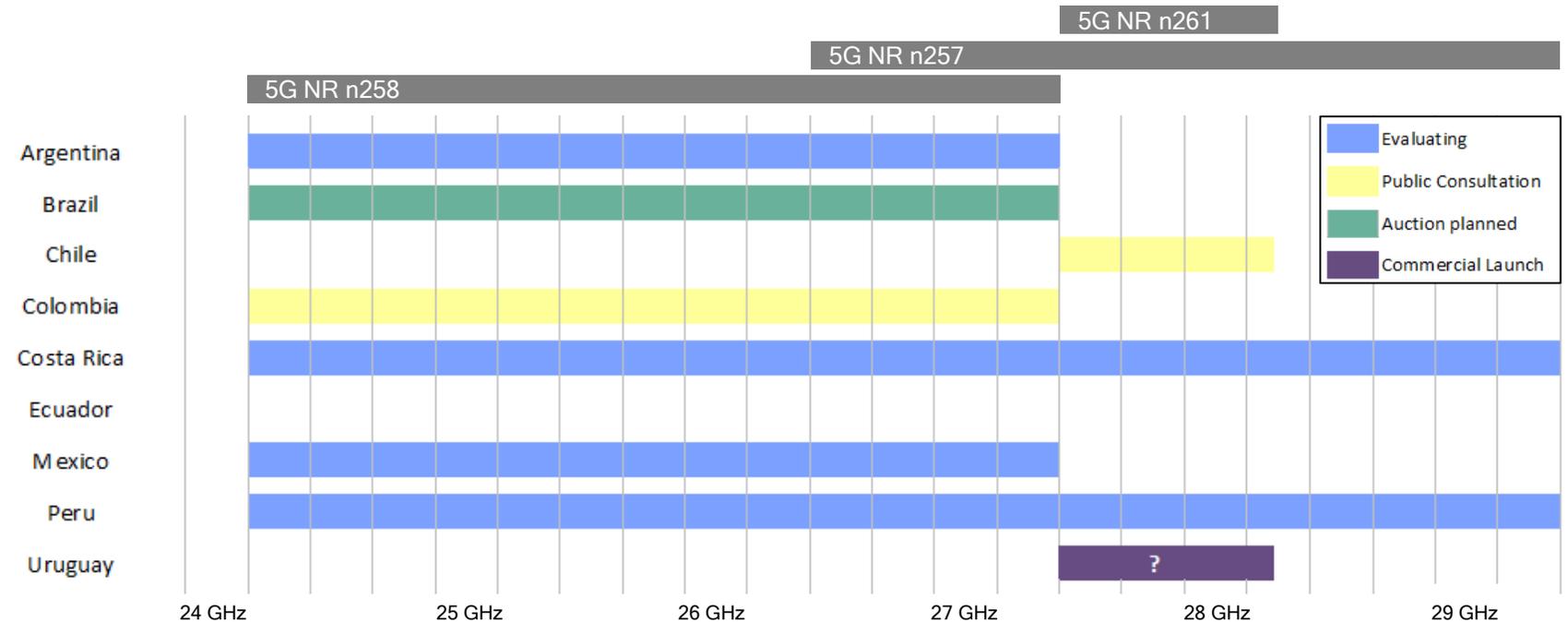
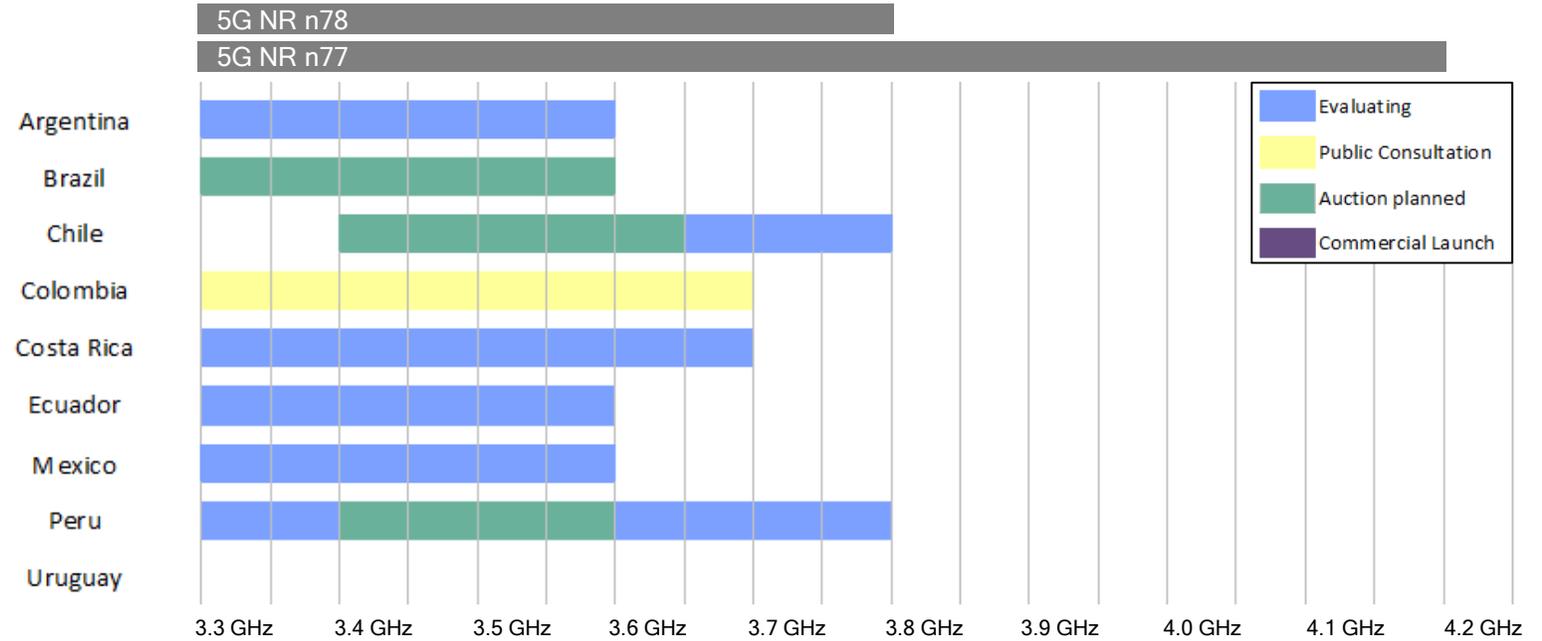
Peru has C-Band auction planned for 2020



Uruguay has very small fixed wireless deployment



Colombia and Chile have consultations underway





USA

- 3.5 GHz CBRS band, exclusive and shared licenses, deployments in 2H 2019
  - 37-37.6 GHz shared spectrum/local licenses, under evaluation
- 

Germany



- 3.7 - 3.8 GHz
  - Local licenses. Assignment complete; available 2H 2019
- 

U.K.



- 3.8-4.2 GHz
  - Local licenses (50 meters square); regulator database; decision formalized; applications invited from end 2019
- 

Sweden



- 3.7-3.8 GHz
  - In consultations
- 

Finland



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

Netherland



- 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 and approval. 20 MHz approved for Professional Mobile Radio
- 

Australia



- 24.25-27.5 GHz
  - Under evaluation
- 

Hong Kong



- 24.25-28.35 (400 MHz)
  - Local licenses; regulator approval. Approved; available 3Q 2019
- 

Japan

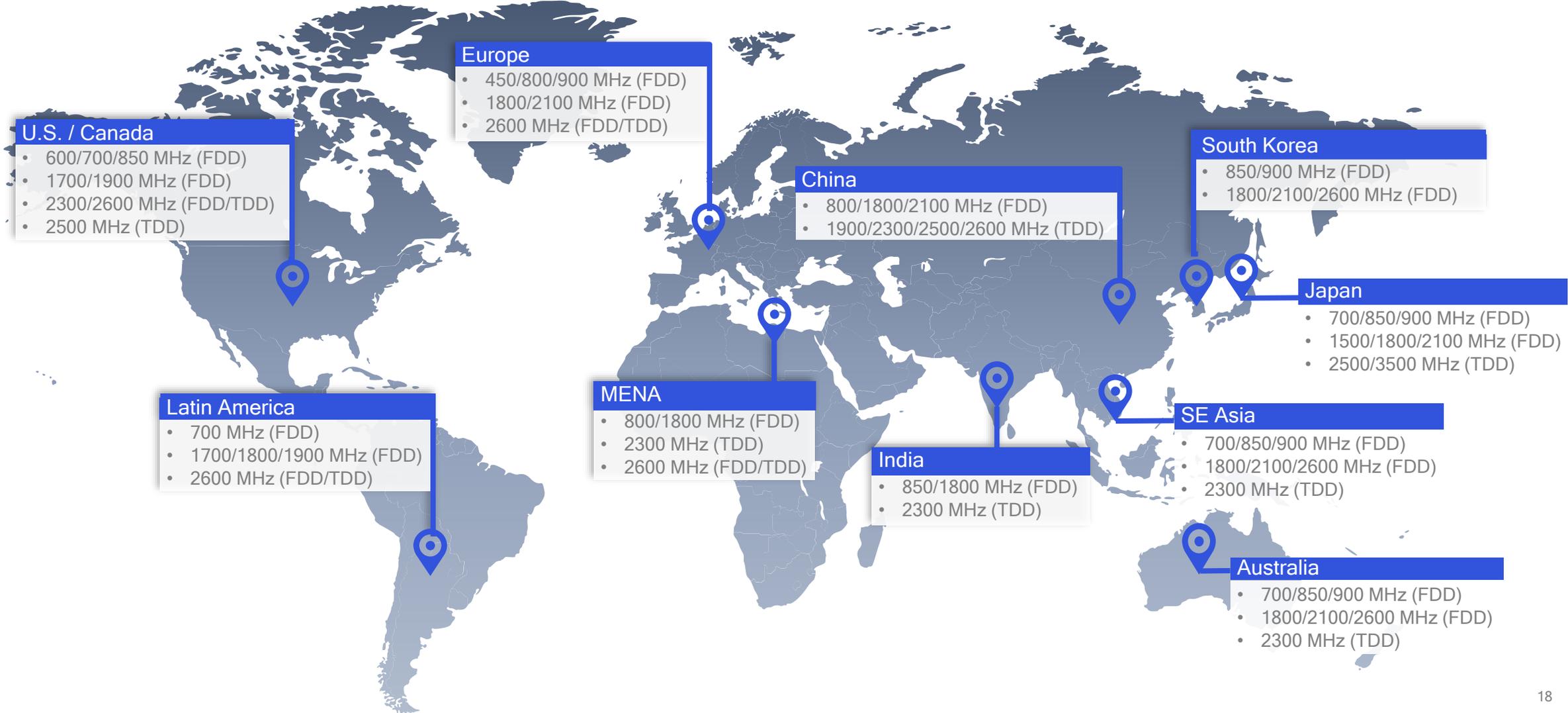


- Phase 1: 2,575-2,595 MHz (as NSA anchor) and 28.2-28.3 GHz; Local licenses, legislation planned in December 2019.
- Phase 2: 4.6-4.8 GHz & 28.3-29.1 GHz; local license, possible regulator database. Consultation planned October 2019, legislation planned 3Q 2020

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

# Global 4G LTE spectrum landscape

Over 1,000 band combinations now supported for LTE





# Thank you!

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