

June 2020

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MIPI Alliance

Qualcomm

Global 5G spectrum update

Dean Brenner

SVP, Spectrum Strategy & Technology Policy



60+

Operators with 5G commercial deployed

380+

Operators investing in 5G globally

200M

5G smartphones to ship in 2020

750M+

5G smartphones to ship in 2022

1B+

5G connections by 2023 - 2 years faster than 4G

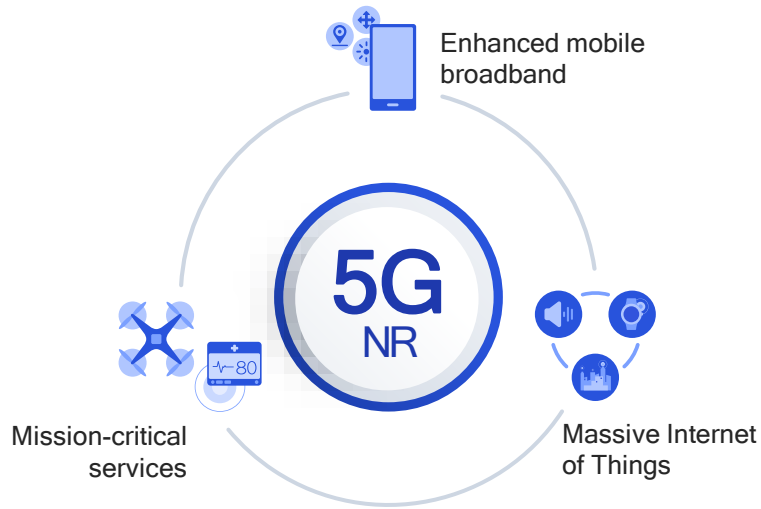
2.8B

5G connections by 2025

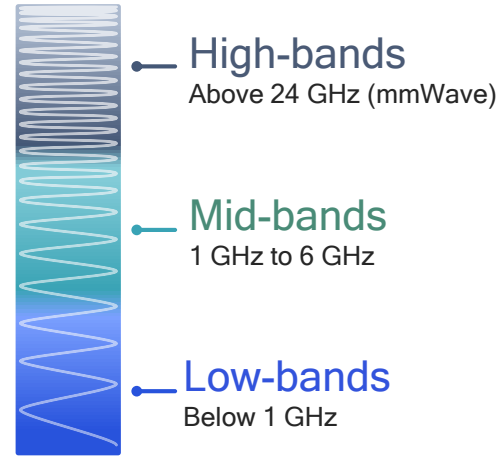
Sources - 5G commercial networks and operators investing in 5G: GSA and operator announcements, Apr. '19; 5G device shipment projections: Qualcomm estimates (2020 projection is at mid-point of guidance range), Nov. '19; 5G connection projections: 2023 - GSMA Intelligence (Dec. '19); ABI (Nov. '19); 2025 - ABI (Oct. '19), CCS Insight (Oct. '19), Ericsson (Nov. '19)

5G momentum accelerating globally

5G NR is a unified, more capable wireless platform



Diverse services



Licensed/shared/unlicensed

Diverse spectrum



Diverse deployments

10x
Decrease in
end-to-end latency

10x
Experienced
throughput

3x
Spectrum
efficiency

100x
Traffic
capacity

100x
Network
efficiency

10x
Connection
density

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

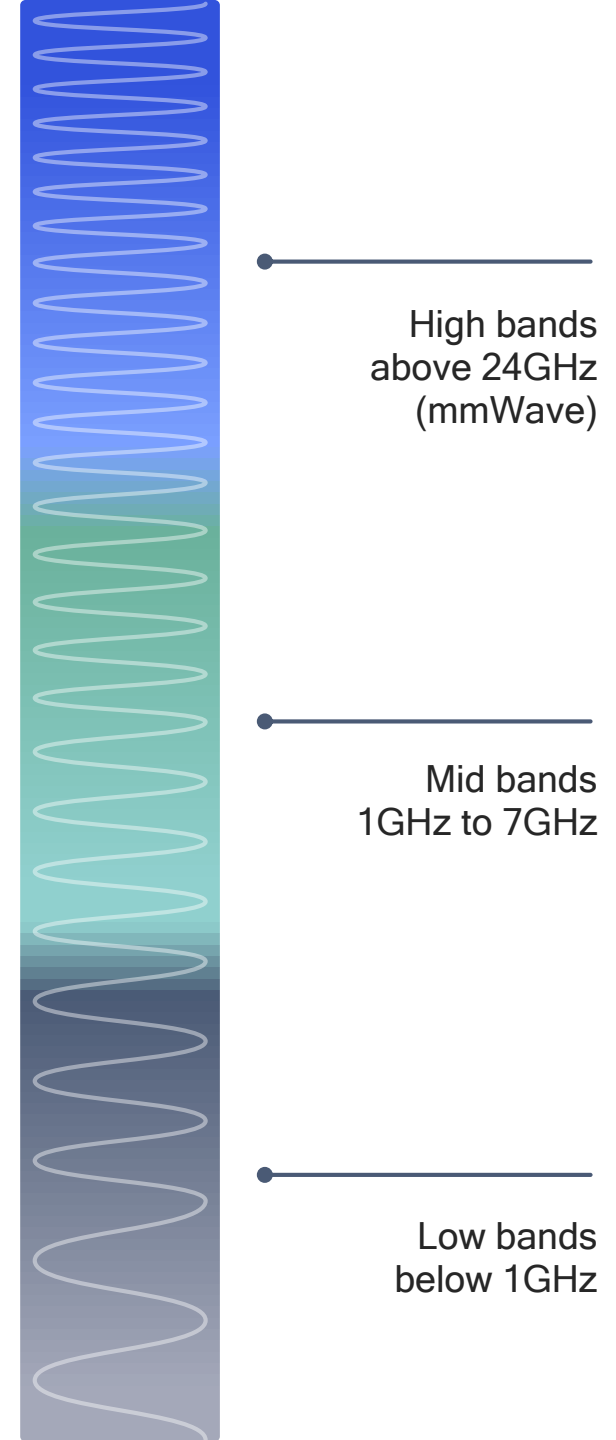
New shared spectrum paradigms

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

	<1GHz	3GHz	4GHz	5GHz	24-30GHz	37-50GHz	64-71GHz	>95GHz		
	600MHz (2x35MHz) <u> </u>	2.5/2.6GHz (B41/n41) <u> </u>	3.1-3.45GHz 3.45-3.55GHz 3.55-3.7GHz <u> </u>	3.7-4.2GHz <u> </u>	5.9-7.1GHz <u> </u>	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz <u> </u>	37-37.6GHz 37.6-40GHz 47.2-48.2GHz <u> </u>	57-64GHz <u> </u>	64-71GHz <u> </u>	>95GHz <u> </u>
	600MHz (2x35MHz) <u> </u>		3.475-3.65 GHz <u> </u>			26.5-27.5GHz 27.5-28.35GHz <u> </u>	37-37.6GHz 37.6-40GHz <u> </u>		64-71GHz <u> </u>	
	700MHz (2x30 MHz) <u> </u>		3.4-3.8GHz <u> </u>		5.9-6.4GHz <u> </u>	24.5-27.5GHz <u> </u>				
	700MHz (2x30 MHz) <u> </u>		3.4-3.8GHz <u> </u>			26GHz <u> </u>				
	700MHz (2x30 MHz) <u> </u>		3.4-3.8GHz <u> </u>			26GHz <u> </u>				
	700MHz (2x30 MHz) <u> </u>		3.46-3.8GHz <u> </u>			26GHz <u> </u>				
	700MHz (2x30 MHz) <u> </u>		3.6-3.8GHz <u> </u>			26.5-27.5GHz <u> </u>				
	700MHz <u> </u>	2.5/2.6GHz (B41/n41) <u> </u>	3.3-3.6GHz <u> </u>	4.8-5GHz <u> </u>		24.75-27.5GHz <u> </u>			40-43.5GHz <u> </u>	
	700/800MHz <u> </u>	2.3-2.39GHz <u> </u>	3.4-3.42GHz 3.42-3.7GHz 3.7-4.0GHz <u> </u>		5.9-7.1GHz <u> </u>	25.7-26.5GHz 26.5-28.9GHz 28.9-29.5GHz <u> </u>	37.5-38.7GHz <u> </u>			
			3.6-4.1GHz <u> </u>	4.5-4.9GHz <u> </u>		26.6-27GHz 27-29.5GHz <u> </u>	39-43.5GHz <u> </u>			
	700MHz <u> </u>		3.3-3.6GHz <u> </u>			24.25-27.5GHz 27.5-29.5GHz <u> </u>	37-43.5GHz <u> </u>			
			3.4-3.7GHz <u> </u>			24.25-27.5GHz <u> </u>	39GHz <u> </u>			













Global snapshot of allocated/targeted 5G spectrum

5G is being designed for diverse spectrum types/bands

New 5G band

-  Licensed
-  Unlicensed / shared
-  Existing band

Global mmWave spectrum targets

	24-28GHz	37-50GHz	50-71GHz	>95GHz
	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 47.2-48.2GHz	57-64GHz 64-71GHz	>95GHz
	26.5-27.5GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz	64-71GHz	
	24.5-27.5GHz			
	26GHz			
	26GHz			
	26GHz			
	26.5-27.5GHz			
	24.25-27.5GHz	40-43.5GHz		
	25.7-26.5GHz 26.5-28.9.5GHz 27.9-29.5GHz	37.5-38.7GHz		
	26.6-27GHz 27-29.5GHz	39-43.5GHz		
	24.25-27.5GHz 27.5-29.5GHz	37-43.5GHz		
	24.25-27.5GHz	39GHz		

5G NR mmWave spectrum highlights

Regions targeting deployments by 2020



U.S.

Allocated 12.55 GHz of mmWave spectrum so far
Auction completed for 28 GHz and 24 GHz bands;
37/39/47 GHz auction will start in Dec. 2019



South Korea

28 GHz auction completed in Jun. 2018; each operator (SKT, KT, LG U+) secured 800 MHz
Expected additional 3 GHz bandwidth in 2019+



Japan

Official 5G mmWave band in 28 GHz spectrum with maximum 2 GHz bandwidth
Assignment completed in April 2019



Italy

5G spectrum auction completed in Sep. 2018 with right of use starting January 1st, 2019



Russia

26 GHz auction completed in Q4 2018 to enable 2019+ commercial deployments

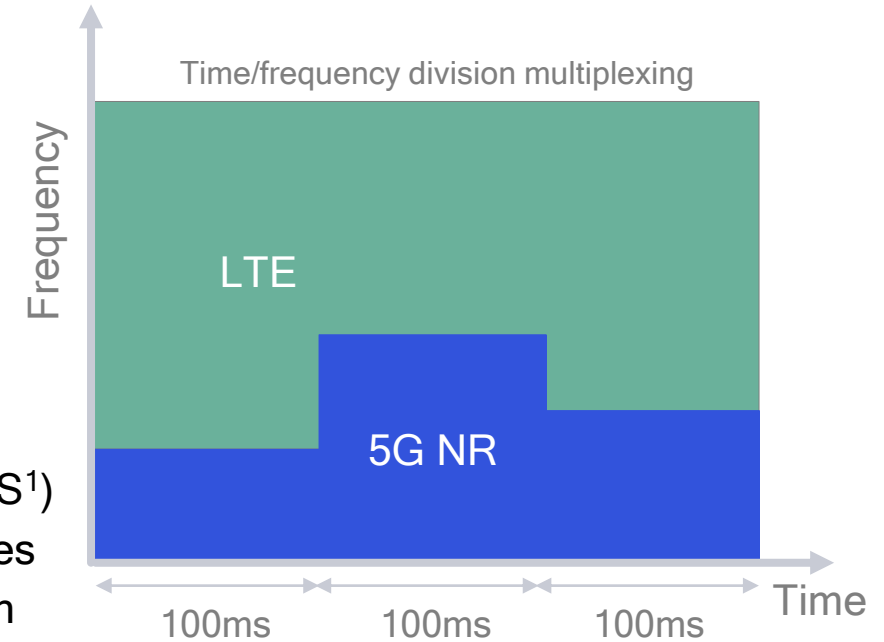
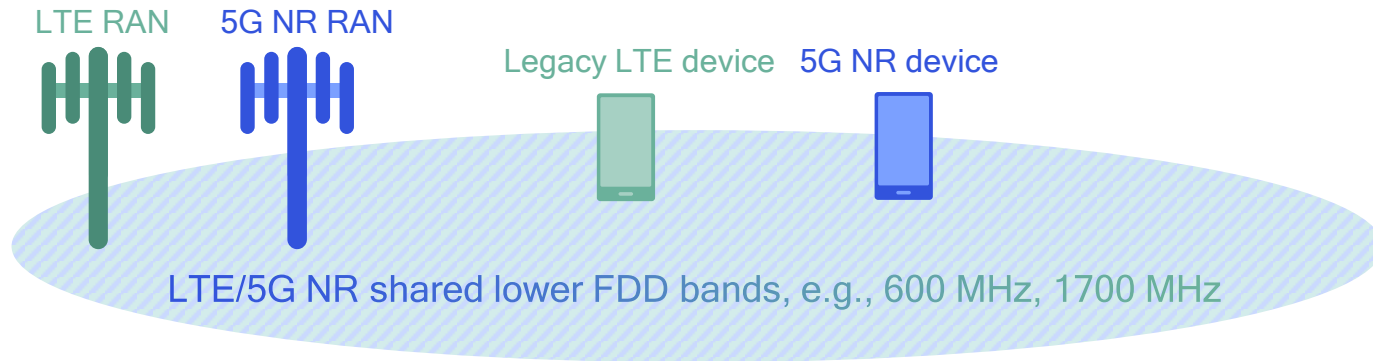


Germany

Regulator published draft proposed allocation procedure and condition of use for 26 GHz, expected to be released in 2020 for local use

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 CRS¹)
- 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

¹ 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

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

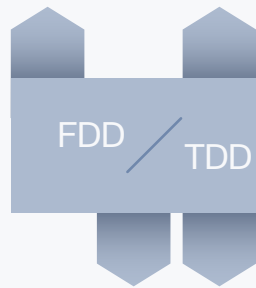
South East Asia / Oceania

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:

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

NR-U

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)



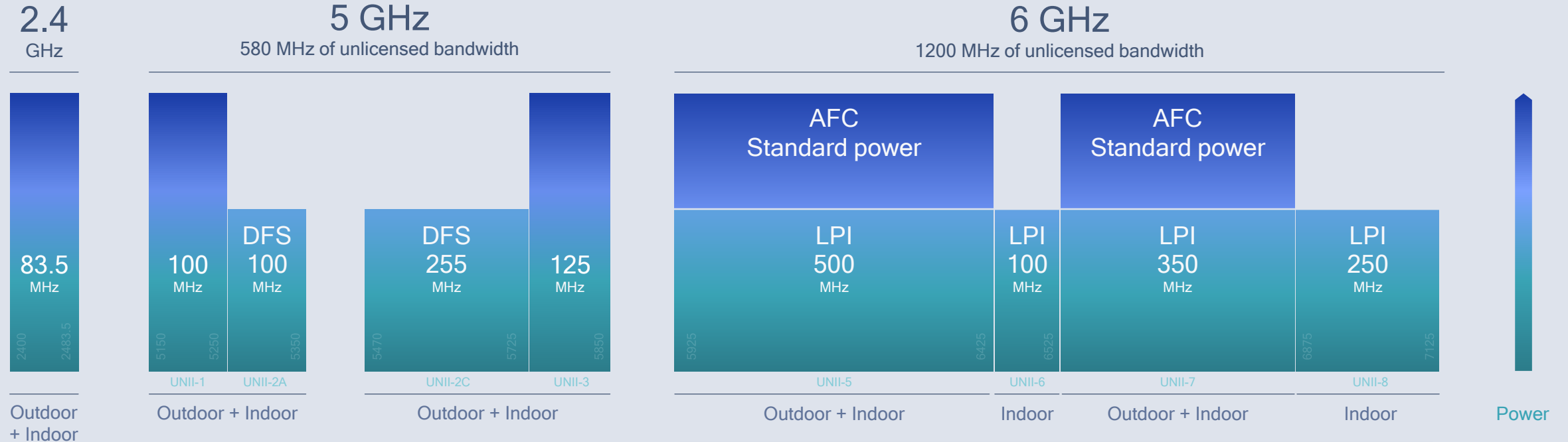
Unlicensed Spectrum Bands in 3GPP

— 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	Under study / review	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	Under study / review			
5.9-6.4GHz	Under study / review			

6 GHz brings new unlicensed bandwidth for Wi-Fi and 5G

United States






1200 MHz  

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

Questions?



Thank you!

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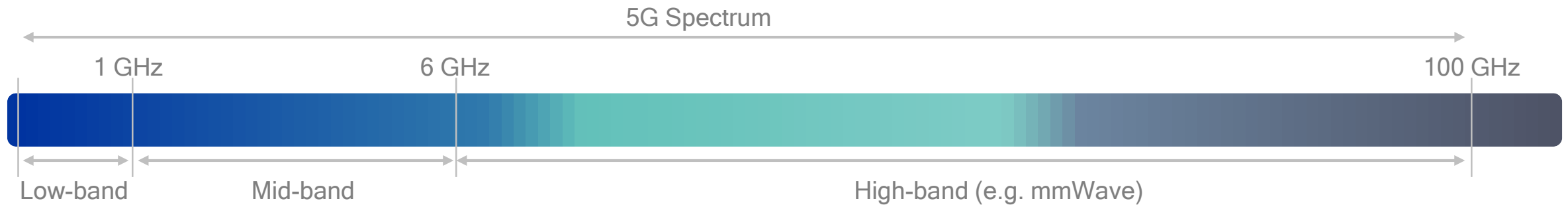
Global Spectrum Status





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

CBRS¹, 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, PAL², GAA³
- 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.

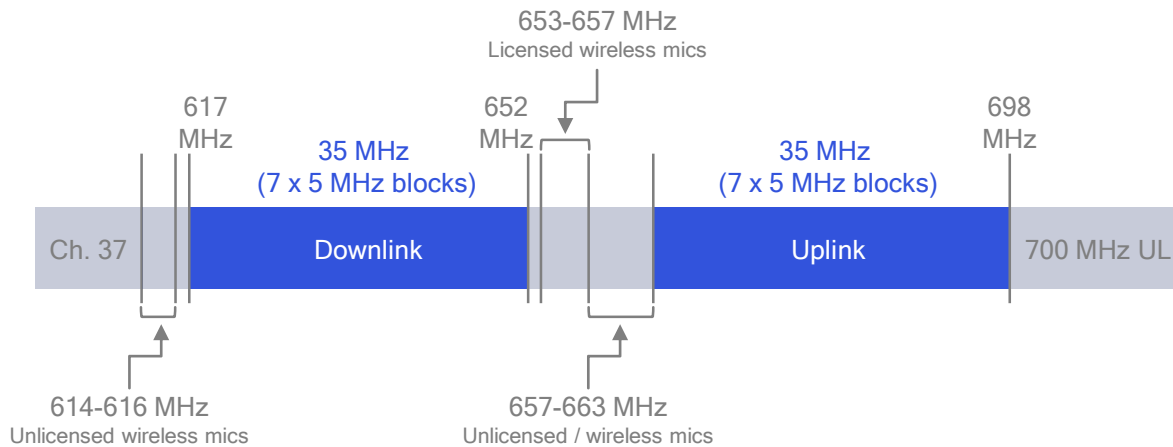
High-band

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 bands⁴, 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

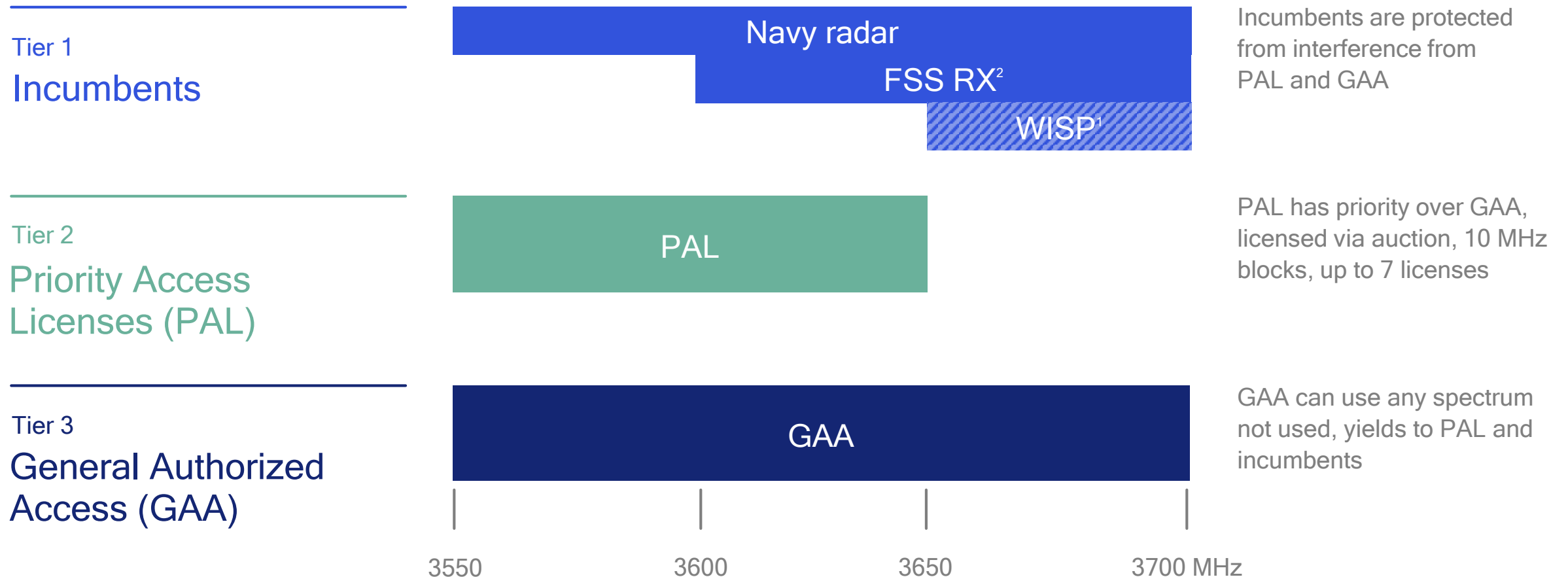
Broad industry support

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

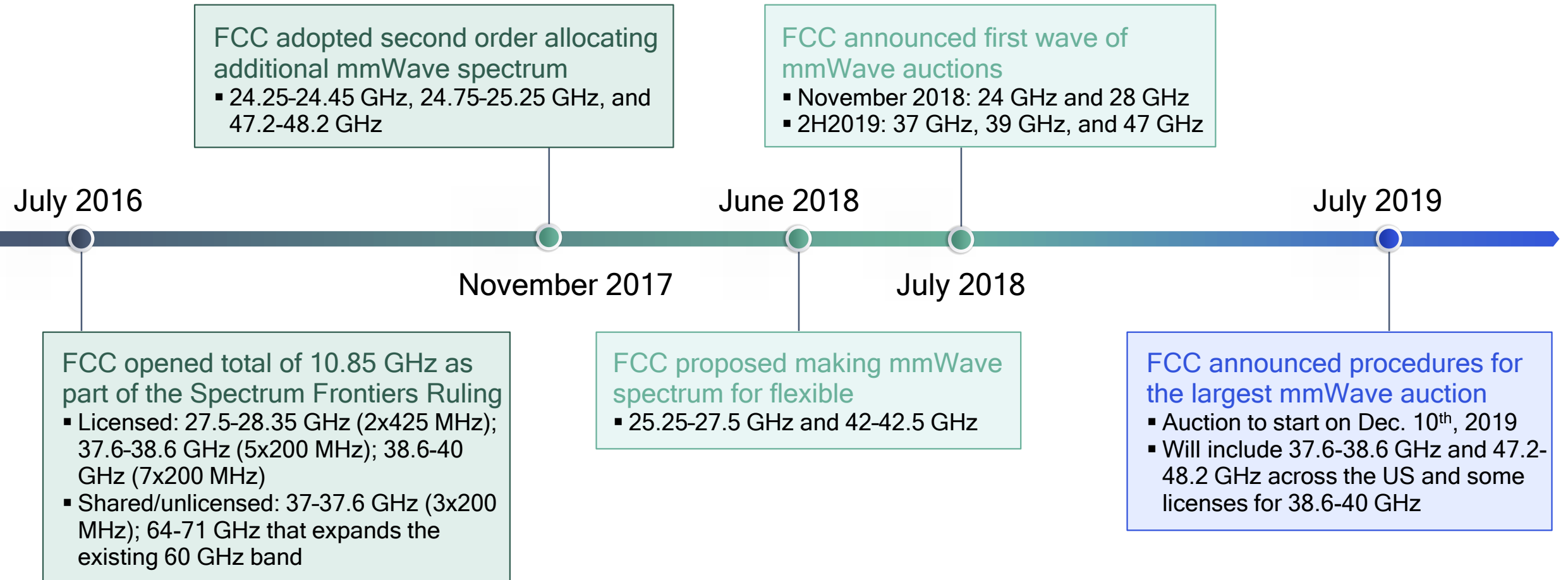
FCC optimized rules in Oct 2018, allowed initial GAA deployments in Sept 2019, and will hold PAL auction in June 2020



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 Society¹

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)

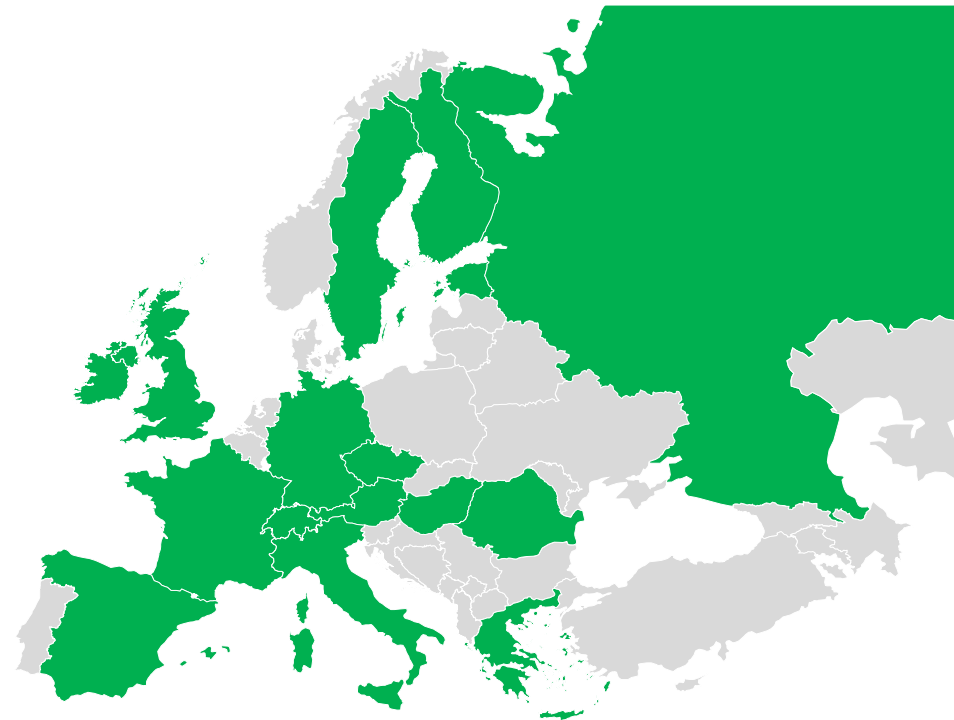
- EC Mandate to CEPT focusing on 3.5 GHz and 26 GHz pioneering bands – completed in 2018
- Additional EC Mandate to CEPT on extended L band (1427 - 1518 MHz) – completed in 2018
- CEPT harmonization of the 26 GHz band ahead of WRC-19 – completed in June 2018
- EC working on binding decision for EU Member 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
- RSPG² 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 MBB³


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

China



- 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

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

Japan

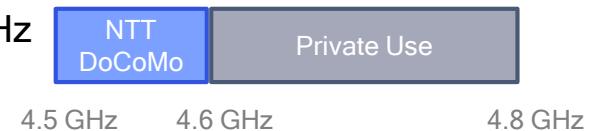


- Technical rules for licensed bands in 3.6 - 4.2 GHz, 4.4 - 4.9 GHz and 27 - 29.5 GHz have been specified
- In Apr'19, MIC assigned 5G spectrum to operators
- Technical rules for private network bands in 2575-2595 GHz (NSA) and 28.2-28.3 GHz have also been specified. New regulations will be enacted 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

3.6-4.1 GHz (n77/n78)



4.5-4.8 GHz (n79)



27-29.5 GHz (n257)



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: final consultation in 1H20:
 - 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: final consultation in 1H20; unlicensed, local apparatus and regional spectrum licenses under evaluation

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



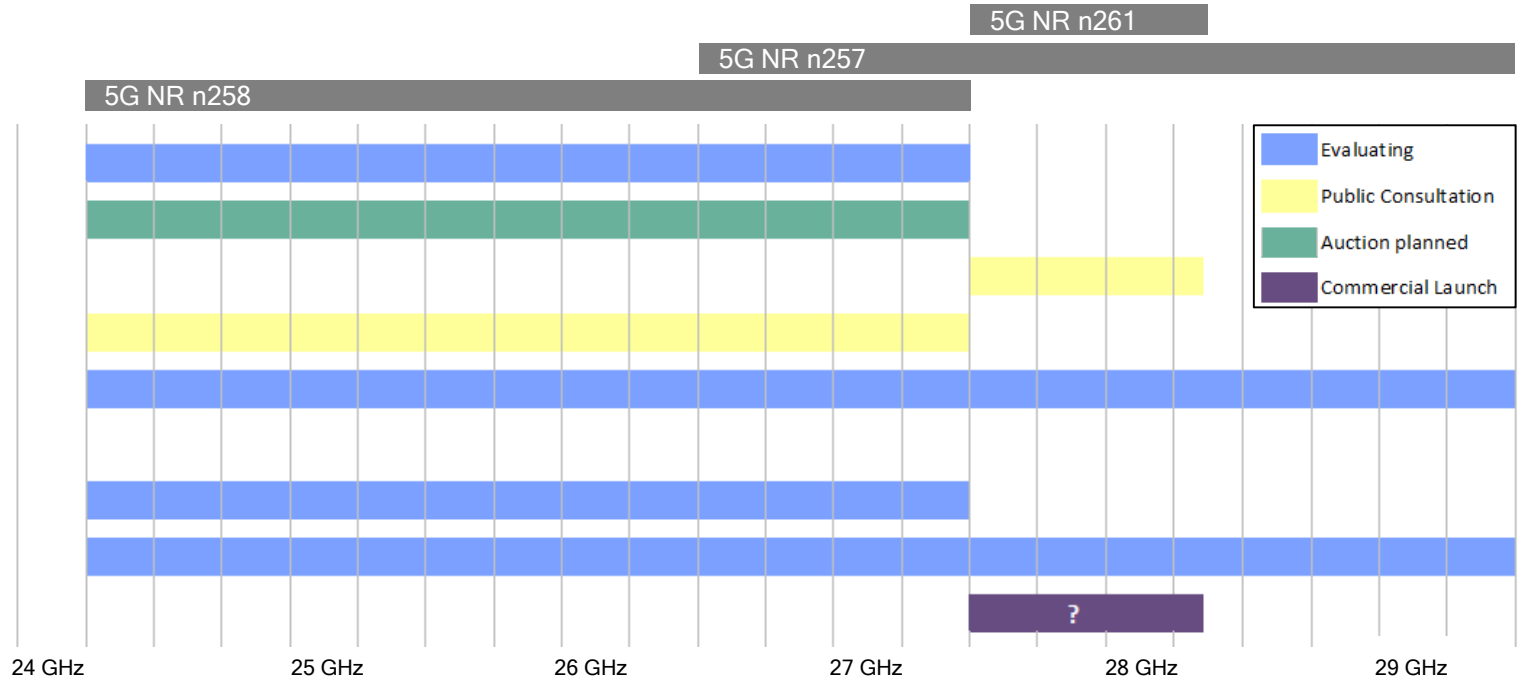
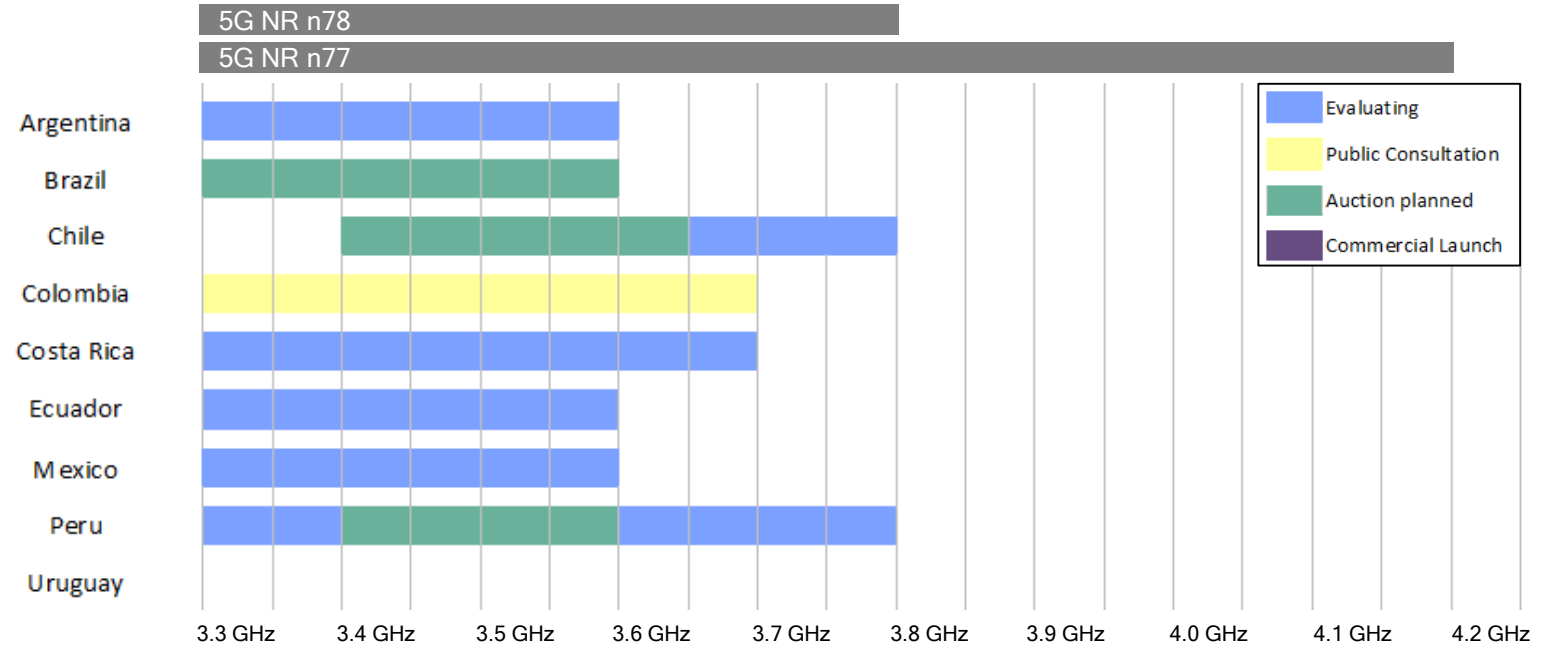
Peru has C-Band auction planned for 2020



















Uruguay has very small fixed wireless deployment



Colombia and Chile have consultations underway



<p>USA</p>  <ul style="list-style-type: none"> • 3.5 GHz CBRS, exclusive & shared licenses, deployments in 2H19 • 37 - 37.6 GHz shared spectrum/local licenses, under evaluation 	<p>Brazil</p>  <ul style="list-style-type: none"> • 3.7 - 3.8 GHz, under consideration • 27.5 - 27.9 GHz, allocation completed
<p>Germany</p>  <ul style="list-style-type: none"> • 3.7 - 3.8 GHz • 24.25 - 27.5 GHz, local licenses, under consultation • Local licenses. Assignment complete; available 2H 2019 	<p>Chile</p>  <ul style="list-style-type: none"> • 3.75 - 3.8 GHz, allocation completed at end of 2019
<p>U.K.</p>  <ul style="list-style-type: none"> • 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 	<p>Australia</p>  <ul style="list-style-type: none"> • 24.25 - 27.5 GHz and 27.5 - 29.5 for final consultation in 1H20
<p>Sweden</p>  <ul style="list-style-type: none"> • 3.72 - 3.8 GHz, in consultations 	<p>New Zealand</p>  <ul style="list-style-type: none"> • Licenses in 2575 - 2620 MHz may be assigned for localized use
<p>Finland</p>  <ul style="list-style-type: none"> • Sub-licensing of 3.4 - 3.8 GHz • Local permission via operator lease; assignment complete 	<p>Malaysia</p>  <ul style="list-style-type: none"> • 26.5 - 28.1 GHz will be assigned for the deployment of local/private networks
<p>Netherlands</p>  <ul style="list-style-type: none"> • 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 	<p>Singapore</p>  <ul style="list-style-type: none"> • Each operator will be allowed to acquire 800 MHz of 26/28 GHz spectrum to deploy local networks
<p>France</p>  <ul style="list-style-type: none"> • 2.6 GHz, regulator database & approval. Up to 40 MHz approved for Professional Mobile Radio 	<p>Hong Kong</p>  <ul style="list-style-type: none"> • 24.25 - 28.35 (400 MHz), local licenses; regulator approval. Approved; available 3Q19
<p>Czech Republic</p>  <ul style="list-style-type: none"> • 3.4 - 3.44 GHz for private networks 	<p>Japan</p>  <ul style="list-style-type: none"> • 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. Consultation 3Q20, legislation 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

Leading mobile innovation for over 30 years



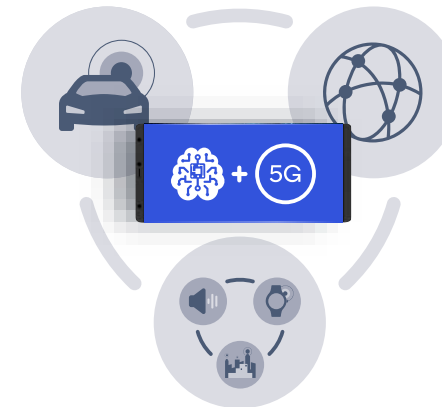
Digitized mobile communications

Analog to digital



Redefined computing

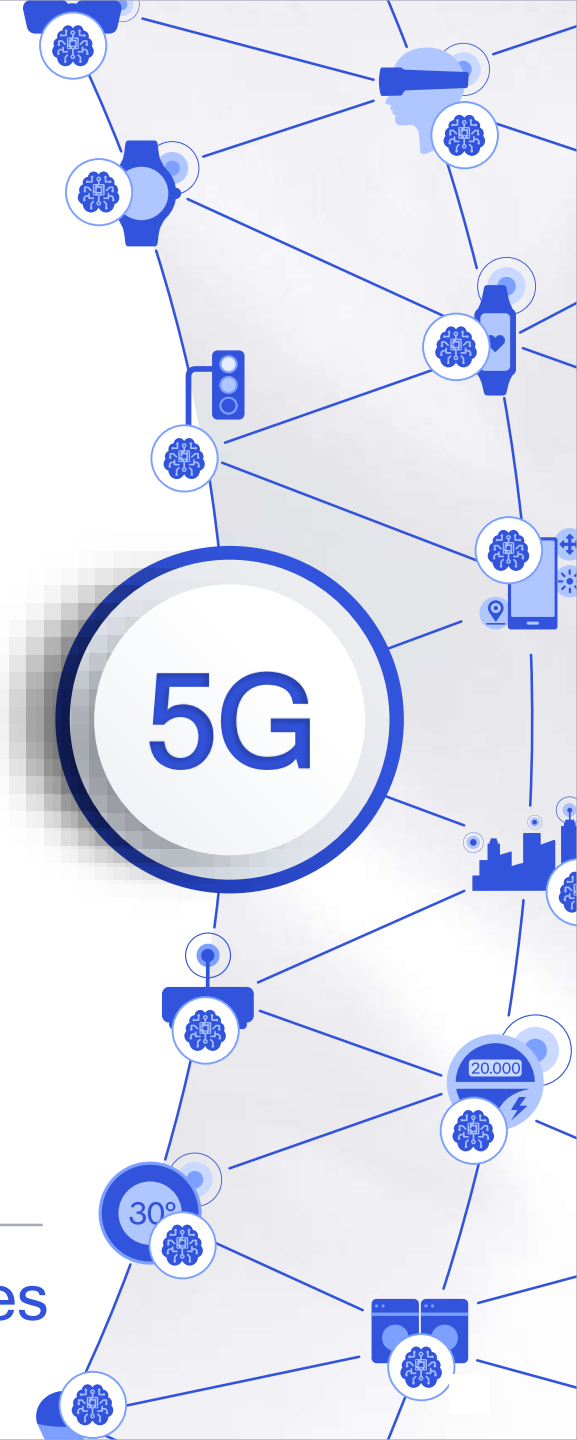
Desktop to smartphones



Transforming industries

Connecting virtually everything at the wireless edge

Transforming how the world connects, computes and communicates



5G smartphones



5G embedded modules



Hotspots and CPEs



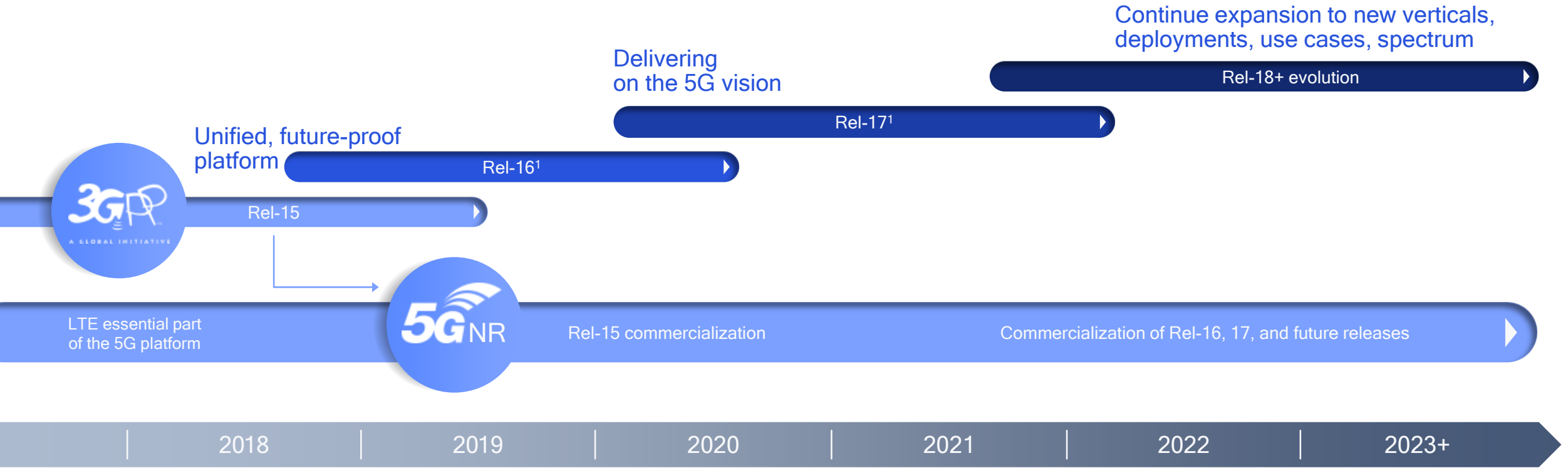
Qualcomm
snapdragon

375+

5G devices
launched or in
development

Qualcomm Snapdragon is a product of
Qualcomm Technologies, Inc. and/or its
subsidiaries.

Driving the 5G technology evolution



Continue expansion to new verticals, deployments, use cases, spectrum

Delivering on the 5G vision

Unified, future-proof platform



LTE essential part of the 5G platform



Rel-15 eMBB focus

- 5G NR foundation
- Smartphones, FWA, PC
- Expanding to venues, enterprises

Rel-16 industry expansion

- eURLLC and TSN for IIoT
- NR in unlicensed (NR-U)
- Positioning
- 5G V2X sidelink multicast
- In-band eMTC/NB-IoT

Rel-17+ long-term expansion

- Lower complexity NR-Light
- Boundless extended reality (XR)
- Higher precision positioning and more...

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1