



Spectrum for 4G and 5G

Qualcomm Technologies, Inc.
October, 2016



New spectrum sharing paradigms—opportunity to innovate

Using all spectrum: low-band, mid-band, & high-band for mobile broadband

Licensed spectrum

Exclusive use

Over 40 bands globally for LTE

Shared spectrum

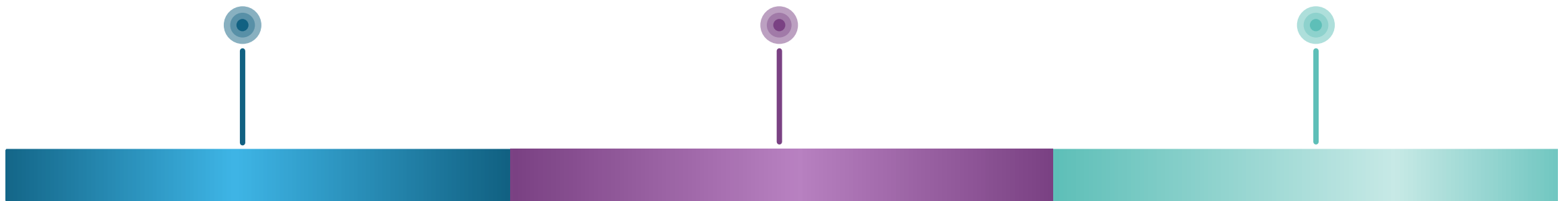
New shared spectrum paradigms

Example: 2.3 GHz Europe / 3.5 GHz USA

Unlicensed spectrum

Shared use

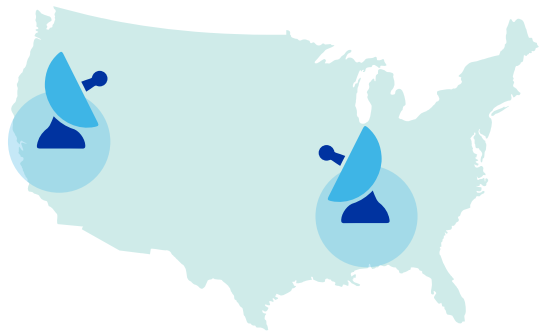
Example: 2.4 GHz / 5 GHz / 60 GHz global



Using all available spectrum—including shared & unlicensed for mobile broadband

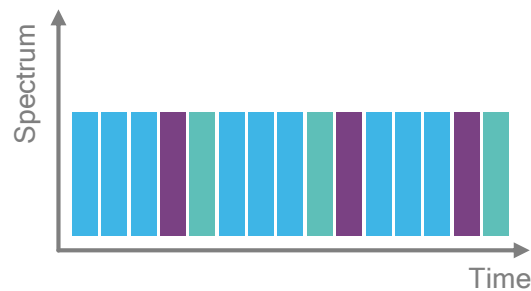
Unlocking more spectrum

Shared spectrum can unlock spectrum that is lightly used by incumbents



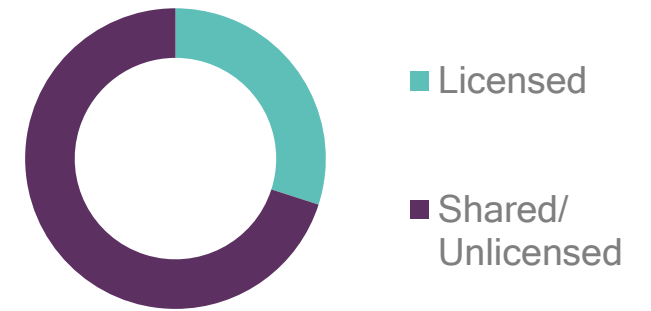
High spectrum utilization

Spectrum sharing has the potential to increase spectrum utilization



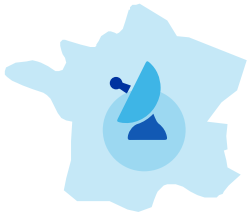
A lot of spectrum may be shared/unlicensed

FCC recent decision on high-band spectrum included a significant portion of shared/unlicensed¹



¹ FCC ruling FCC 16-89 on 7/14/2016 allocated 3.25 MHz of licensed spectrum and 7.6 MHz of shared/unlicensed spectrum.

Pioneered shared/unlicensed spectrum in 4G LTE



LSA¹



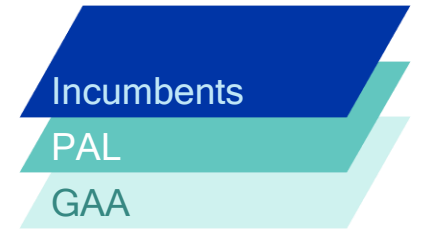
LTE-U



LAA²



MULTEFIRE



CBRS³

Extensive technical pilot in France/Italy with Ericsson, Nokia, Red Technologies, and the EC in 2016

We designed the original proposal, commercialized by the LTE-U forum

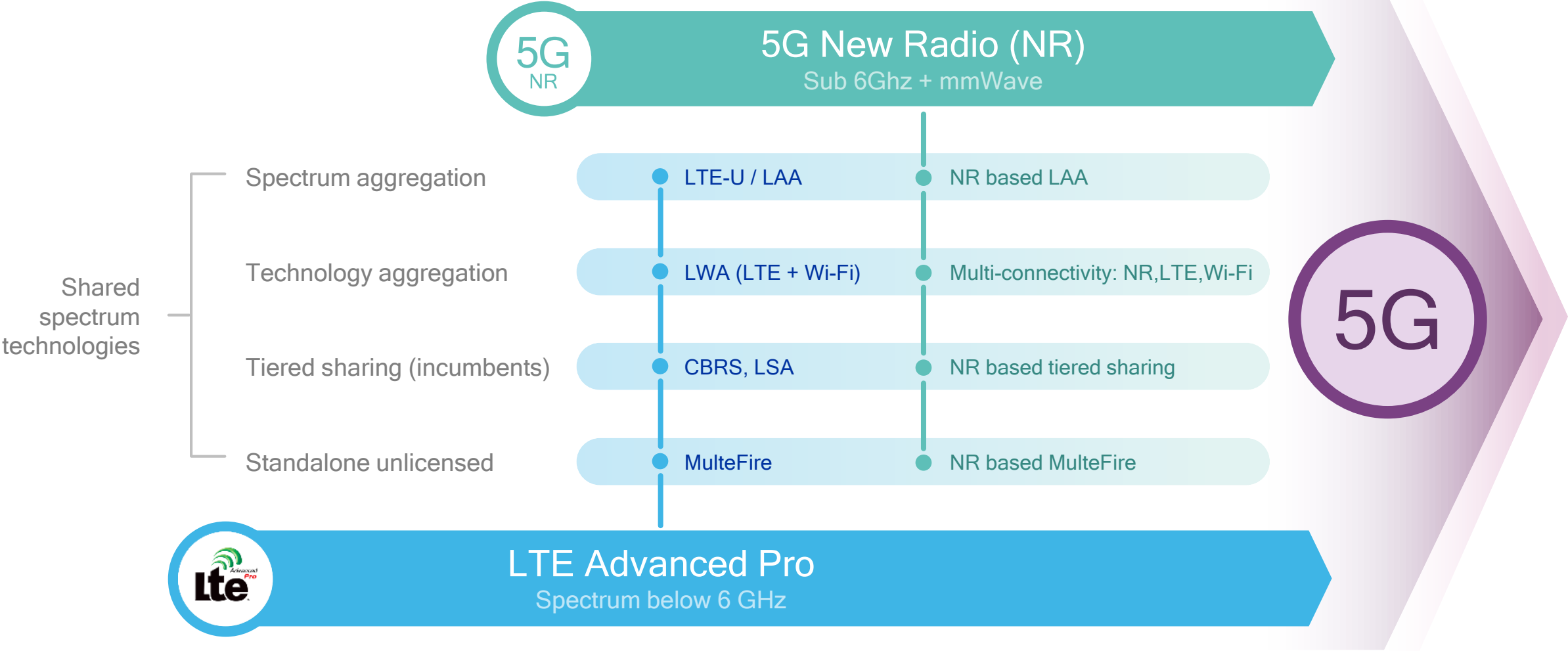
Performed world's first over-the-air trials; LAA with Deutsche Telekom Nov 2015 & eLAA with SKT Oct 2016

A founder of the MulteFire Alliance and a key contributor to its specification

A founder of the CBRS Alliance that facilitates the rollout of 3.5 GHz in the US

Shared spectrum will be important for 5G

Building on LTE-U/LAA, LWA, CBRS/LSA and MulteFire¹

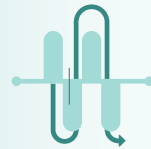


¹ Licensed-Assisted Access (LAA), LTE Wi-Fi Link Aggregation (LWA), Citizen Broadband Radio Service (CBRS), Licensed Shared Access (LSA)

5G NR

5G NR will natively support all different spectrum types

NR shared spectrum will support new shared spectrum paradigms



Licensed Spectrum
Exclusive use



Shared Spectrum
New shared spectrum paradigms



Unlicensed Spectrum
Shared use

High bands above 24 GHz (mmWave)
Extreme bandwidths

Mid bands 1GHz to 6 GHz
Wider bandwidths for e.g. eMBB and mission-critical

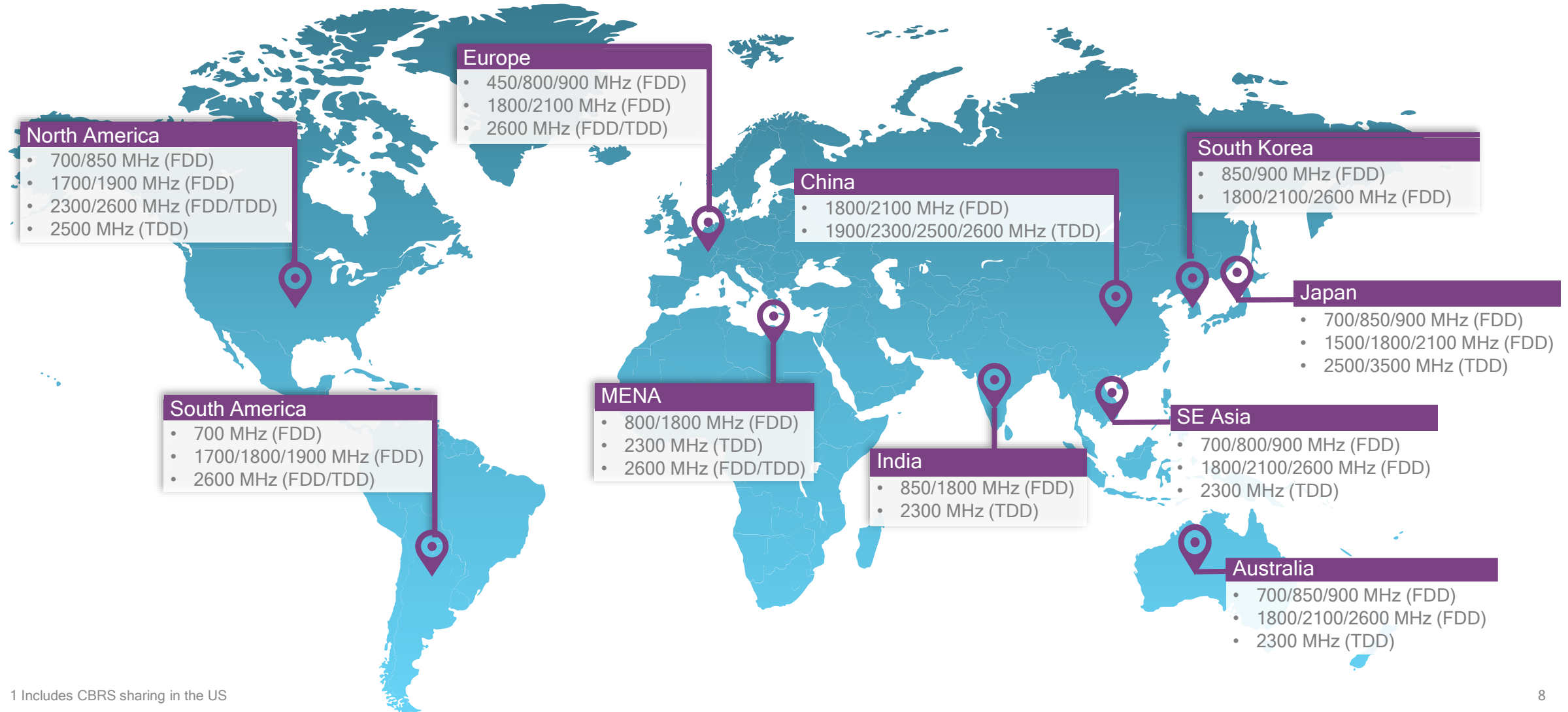
Low bands below 1 GHz
Longer range for e.g. mobile broadband and massive IOT

Global 4G & 5G spectrum update



Global 4G LTE spectrum landscape

Mostly sub-3 GHz with some operators now testing/deploying in 3.5 GHz band¹



¹ Includes CBRS sharing in the US

Opening more spectrum for 5G is a global effort

5G spectrum status in key Asian markets and Australia

China



- Currently focusing on sub-6 GHz spectrum bands
- Approved trials at 3.4-3.6 GHz, looking at opening 3.3-3.4 GHz & 4.8-4.99 GHz
- Also working on mmWave, initially 24.25-27.5 GHz and longer term 27.5-29.5 GHz

Korea



- Initially focusing on higher frequency mmWave bands
- 27.5-28.3 GHz for 2018 Olympics trial, can be targeted for early deployments after trial
- Also looking at 37.5-40 GHz

Japan



- Focusing on both Sub-6 GHz and mmWave bands
- Sub-6 GHz: 3.6-4.2 GHz & 4.4-4.9 GHz
- mmWave: 27.5 GHz-29.5 GHz

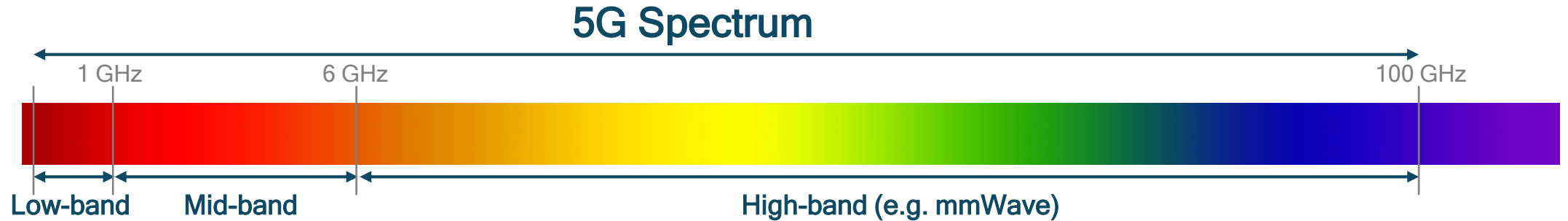
Australia



- Investigating Sub-6 GHz, primarily 3.4-3.7 GHz, and monitoring mmWave bands

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

- First stage auction opened up 126 MHz in 600 MHz band, auction failed to close with clearing cost set at \$88.4B
- Second stage auction opens up 114 MHz, auction started on 9/13
- Spectrum availability timing aligns with 5G

Mid-band

Citizens Broadband Radio Service

- Opening up 150 MHz in 3.5 GHz band
- 3-tier spectrum sharing with incumbents, PAL¹, and GAA²
- CBRS Alliance formally launched to drive an LTE-based ecosystem

High-band

Spectrum Frontiers Ruling³

- Opening up 11 GHz in multiple mmWave bands
- 70% of newly opened spectrum is shared or unlicensed
- Unanimously approved by FCC with additional candidate bands identified for IMT-2020

Spectrum Frontiers ruling for 5G mmWave

Shared and unlicensed spectrum is key for more bandwidths

Licensed access

- 27.5 - 28.35 GHz: 850 MHz (2x425 MHz)
- 37.6 - 38.6 GHz: 1 GHz (5x200 MHz)
- 38.6 - 40 GHz: 1.4 GHz (7x200 MHz)

Shared and unlicensed access

- 37 - 37.6 GHz: 600 MHz (3x200 MHz)
- 64 - 71 GHz: 7 GHz expansion of existing 60 GHz band

Total spectrum
= ~11 GHz

FCC also identified additional candidate bands for IMT-2020

Including 24.25-24.35, 24.75-25.25, 31.8-33.4, 42-42.5, 47.2-50.2, 50.4-52.6, 71-76 GHz

The FCC's July 14th Spectrum Frontiers ruling is “ the final piece in the spectrum trifecta of low-band, mid-band, and high-band airwaves that will open up unprecedented amounts of spectrum, speed the rollout of next-generation wireless networks and re-define network connectivity for years to come.”

- FCC Chairman Tom Wheeler, June 20, 2016



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 - identify by 2016/E

- Low-band (700 MHz), mid-band (3.4-3.8 GHz), high-band (24.25-27.5 GHz)

Full set of 5G spectrum bands - agree on by 2017/E

- Works towards a recommended approach for the authorization of the specific 5G spectrum bands above 6 GHz - focus on the bands for WRC-19 (e.g., 31.8 - 33.4 GHz, 40.5 - 43.5 GHz in addition to 24.25 - 27.5 GHz)
- Maximizes spectrum sharing opportunities - sharing as regulatory tool central to European Electronic Communications Code

Asia Pacific Telecommunity also driving 4G & 5G spectrum

Working on regional spectrum allocation, harmonization, and innovation



- Established in 1979, headquartered in Bangkok, Thailand
 - Founded on joint initiative of the UNESCAP¹ and ITU
 - 38 member countries and 130+ associate/affiliate members
- We are working within APG² with our ecosystem partners and regulators on planning for the next World Radio Conference (WRC-19) to develop regional proposals.
 - Also actively working within AWG³ to help drive regional spectrum harmonization, spectrum sharing studies, and to encourage innovation.

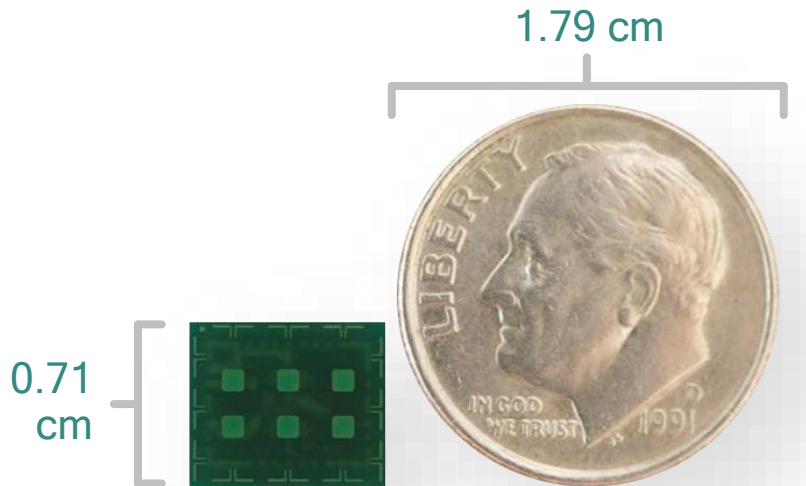
Anyone can talk
about 5G.
We are creating it.



Driving technology innovations to mobilize mmWave

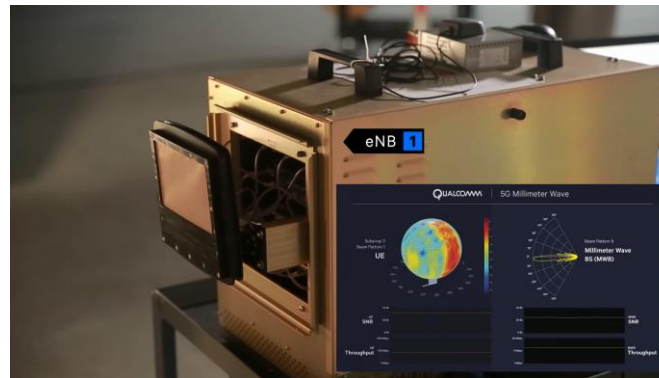
Operator trials & early deployments expected to start late 2017/early 2018¹

802.11ad 60 GHz chipset commercial for mobile devices



Qualcomm® 802.11ad 60 GHz technology with a 32-antenna array

5G mmWave prototype system and trial platform



End-to-end system operating at 28 GHz demonstrating NLOS operation and robust mobility

Qualcomm Technologies' First 5G Modem

Qualcomm® Snapdragon™

X50

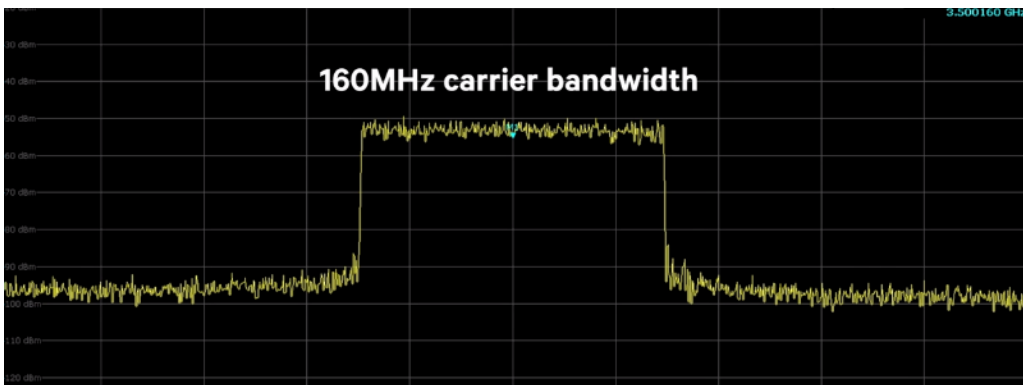
28 GHz support, 4G/5G Multi-mode with dual connectivity, up to 5 Gbps download speed

Snapdragon™ is a trademark of Qualcomm Technologies, Inc. X50 sampling expected 2H 2017 Commercial devices expected in 1H 2018

¹ For limited regional fixed wireless deployments, e.g. Korea and US (VZ 5GTF and KT 5G-SIG) operating at 28 and 39 GHz; also will be utilized for mobile wireless access trials to drive 5G NR standardization

Bringing new level of performance for sub-6 GHz

5G NR sub-6 GHz prototype system and trial platform



Operating in sub-6 GHz spectrum bands

Allows for flexible deployments with ubiquitous network coverage and a wide range of use cases

Achieving multi-Gbps at low latency

Showcases innovative Qualcomm® 5G designs to efficiently achieve multi-gigabit per second data rates and low latency

Driving standardization on 5G NR

OFDM-based designs implemented on the prototype system are being utilized to drive 3GPP standardization

Will enable impactful 5G NR trials

Designed to flexibly track 3GPP standardization and be utilized as a trial platform for impactful and timely 5G NR trials

Watch the demo video at: <https://www.qualcomm.com/videos/5g-nr-sub-6ghz-prototype-system>

Thank you

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