Making Mobile 5G a Commercial Reality

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Insatiable global data demand

First phase of 5G NR will focus on enhanced MBB

Enhanced mobile broadband

~50B Gigabytes

Monthly global mobile data traffic in 2021; >100x growth since 2011

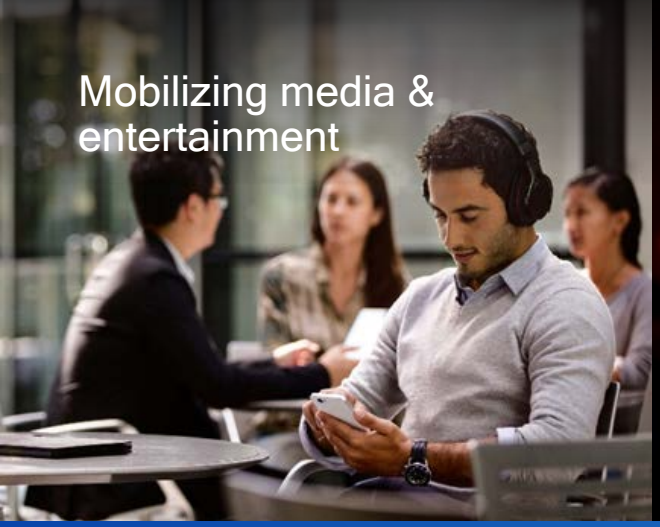
6.8 Gigabytes

Average smartphone traffic per month; up from 1.6GB in 2016

>75%

Of global mobile data traffic will be video by 2021

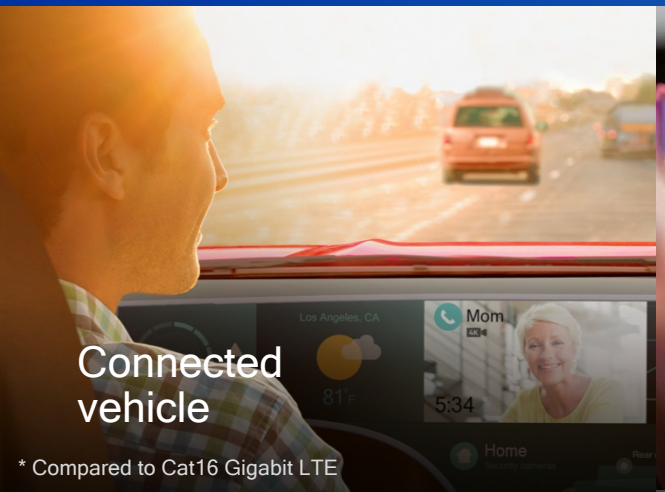
Source: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast (Feb'17)

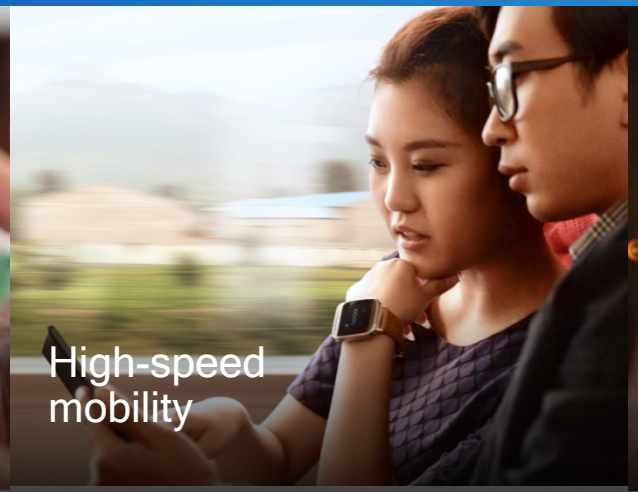


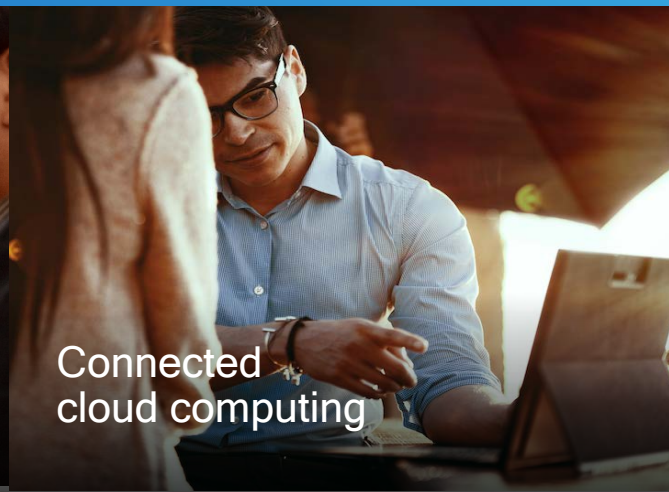
5G NR

Essential for next-gen mobile broadband experiences

- Faster upload and download*
- Massive capacity for unlimited data
- Ultra low latency for real-time interactivity







* Compared to Cat16 Gigabit LTE

5G Consumer Survey key findings

Surveyed smartphone owners from:

1,002	1,010	1,000	1,006	1,002	824	**5,844** WW total

>86%

Need or would like faster connectivity on next smartphone

~50%

Likely to purchase a phone that supports 5G when available

Top 3 reasons for 5G:

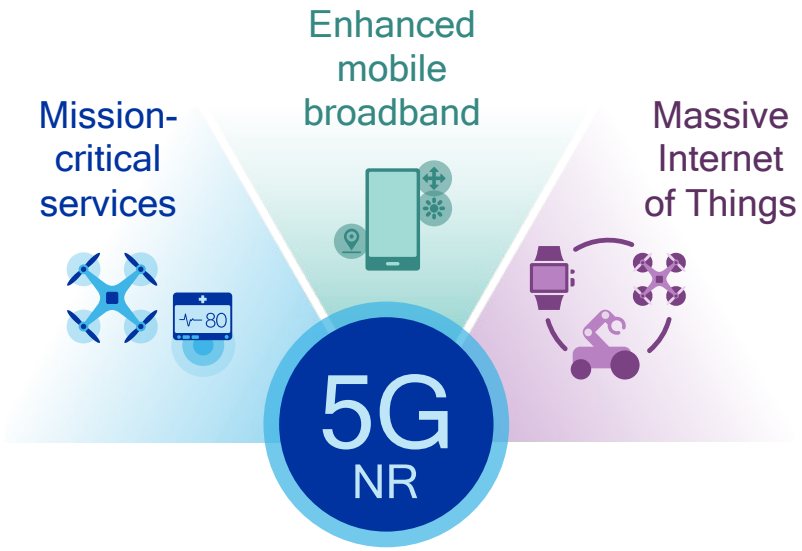
10x faster speeds

10x quicker response time

More **cost-effective** data plans

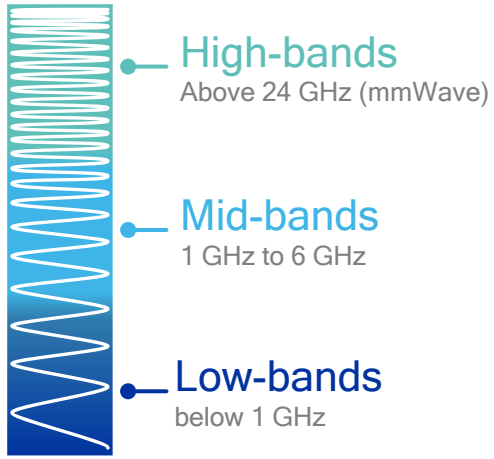
Source: “Making 5G a reality: Addressing the strong mobile broadband demand in 2019 and beyond,” September 2017, jointly published by Qualcomm Technologies, Inc. and Nokia.

The global 5G standard for a unified, more capable air interface



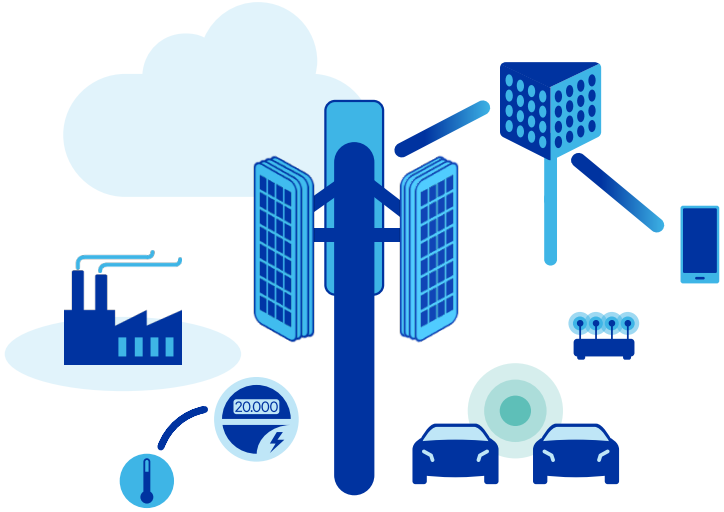
Diverse services

Scalability to address an extreme variation of requirements



Diverse spectrum

Getting the most out of a wide array of spectrum bands / types



Diverse deployments

From macro to indoor hotspots, with support for diverse topologies

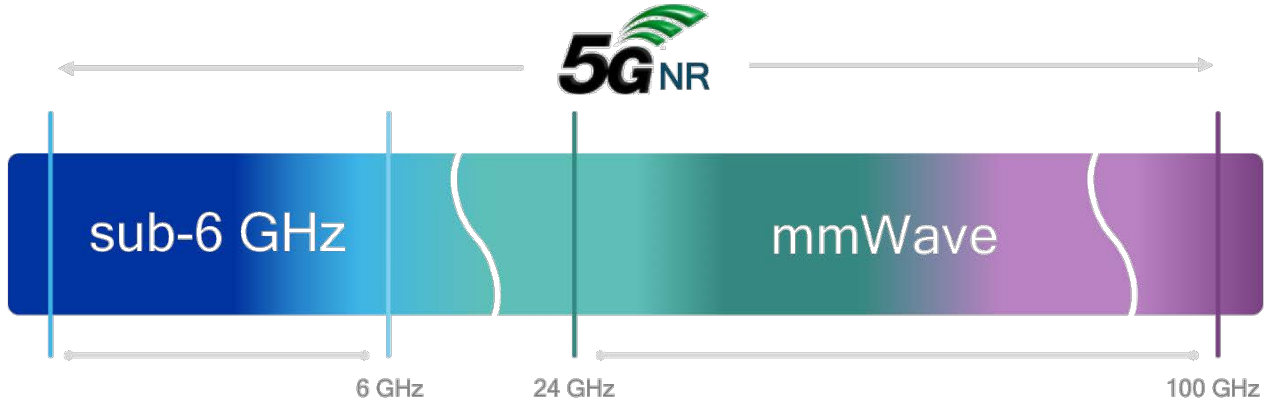
A unifying connectivity fabric for future innovation

A platform for existing, emerging, and unforeseen connected services

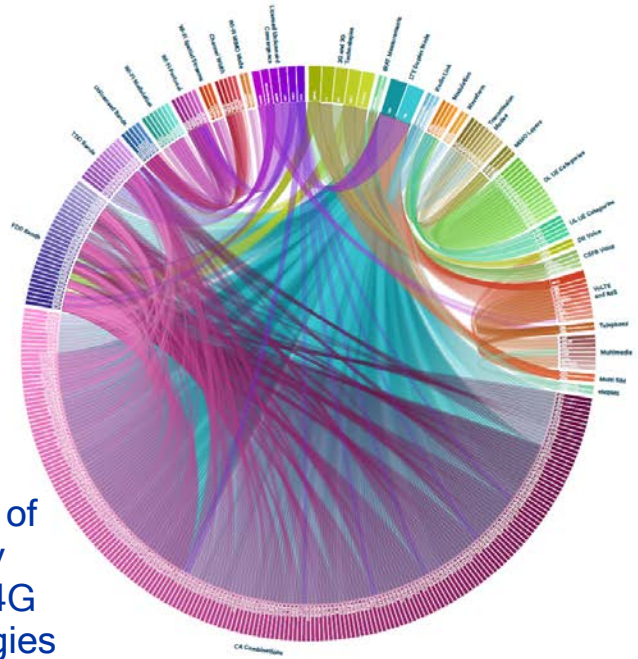
Complexity of mobile systems is accelerating

5G NR massively impacts RF front end design

Extremely wide spectrum range

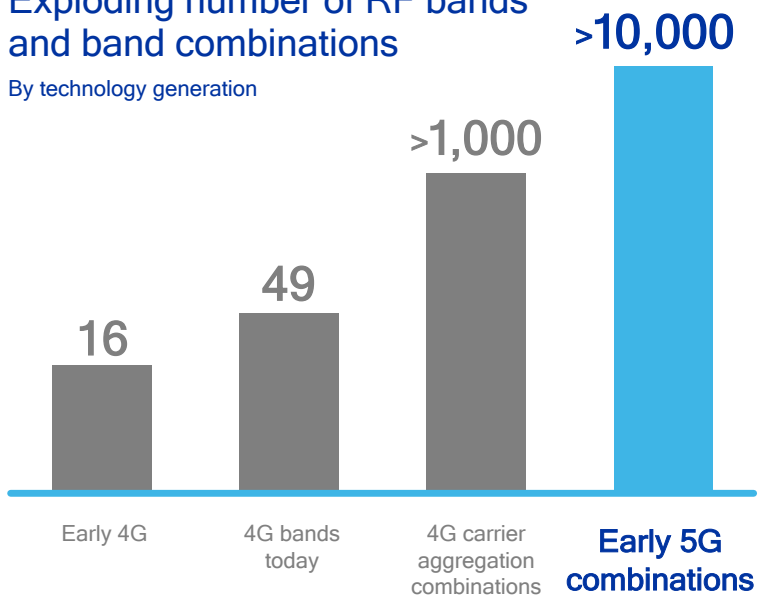


Support of legacy 2G/3G/4G technologies



Exploding number of RF bands and band combinations

By technology generation



Source: Qualcomm Technologies, Inc. internal analysis

World's first announced 5G data connection on a 5G modem chipset for mobile devices

Snapdragon X50 5G modem family

- Gigabit LTE multimode
- Sub-6 GHz and mmWave
- Premium smartphones expected in 2019

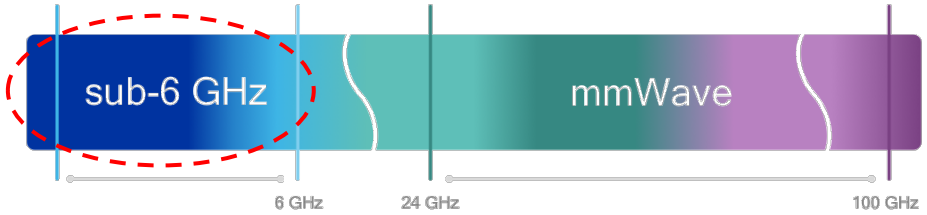
Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc.

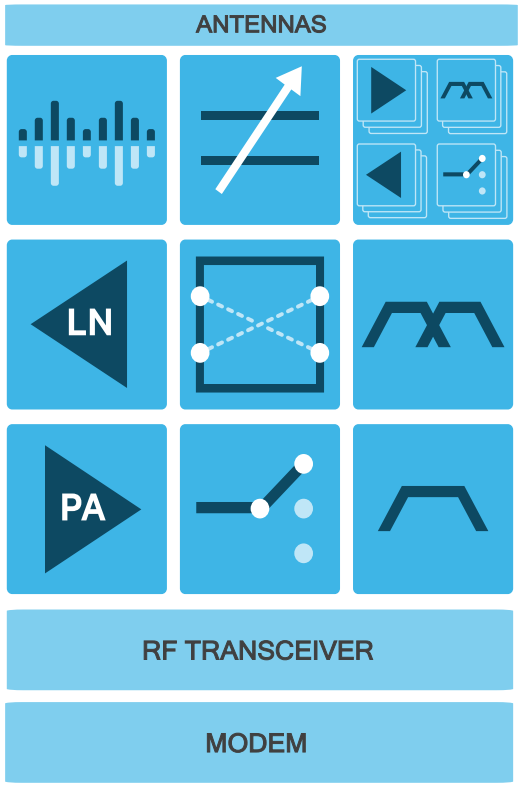
Qualcomm® Snapdragon™

X50

5G modem family

Qualcomm® RF Front End evolution





Frequency Bands

More aggregated carriers*

Adding cellular >3.5 GHz and below 700 MHz

Up to 100 MHz BW

Antennas

Wider bandwidths*

Wider frequency range*

Antenna sharing with Wi-Fi, GPS

Antenna tuning optimization

Power efficiency

High Tx power

High peak-to-avg power ratio

Wider-band ET*

Antenna tuning and power tracking key to achieving NR requirements

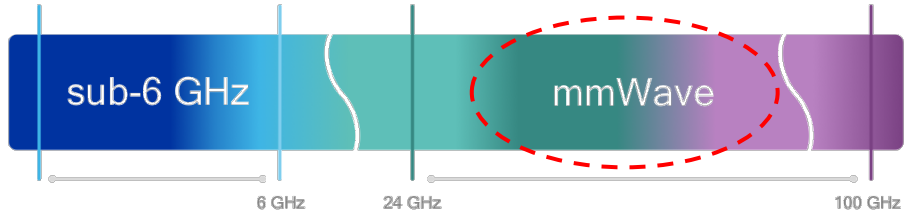
RFFE capabilities

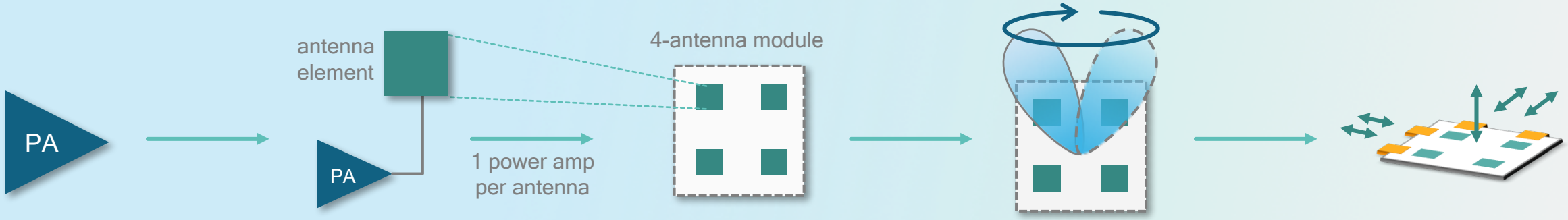
RFFE enhancements

*As compared to current commercially available solution

Realizing 5G mmWave in mobile devices

Achieving coverage, power efficiency and size





Power amp output + Antenna element gain + Power summation gain + Beamforming gain + Single polarization

Physics dictates antenna size and spacing

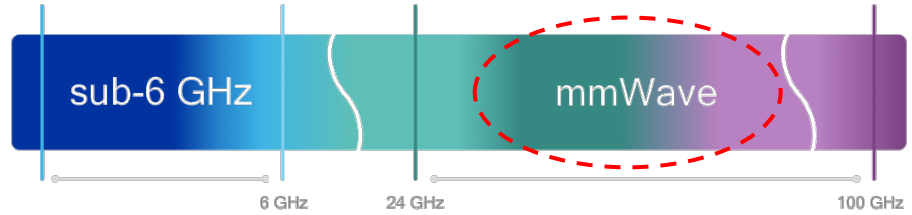
# of PAs and antennas determines max EIRP[1]

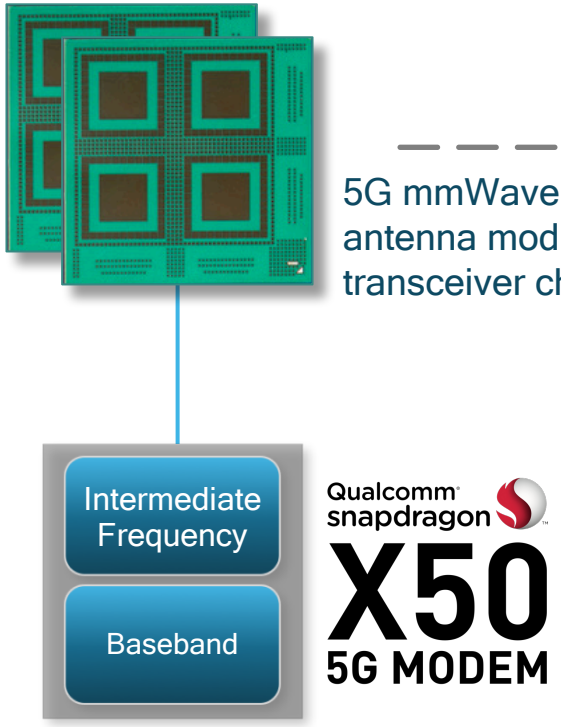
Beamforming and directional architectures allow more gain

Effective directional transmit power (aka EIRP[1])

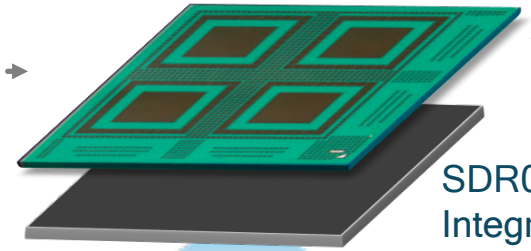
[1] EIRP = Effective Isotropic Radiated Power. Represents peak directional power transmitted from the antenna array relative to an isotropic transmission

Snapdragon X50 mmWave solution





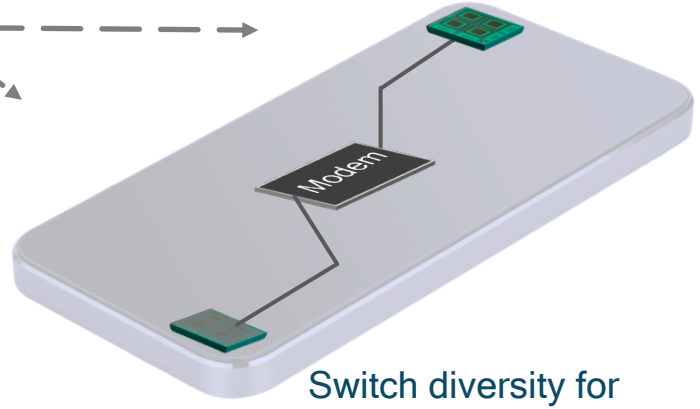
5G mmWave antenna modules & transceiver chips



Antenna module

SDR051 Integrated Circuit

Digital | Trans-ceiver | Power Amps | Low Noise Amps | Switches



Switch diversity for mmWave coverage

Snapdragon X50 5G mmWave architecture

Integrated antenna array and RFFE for performance and ease-of-use

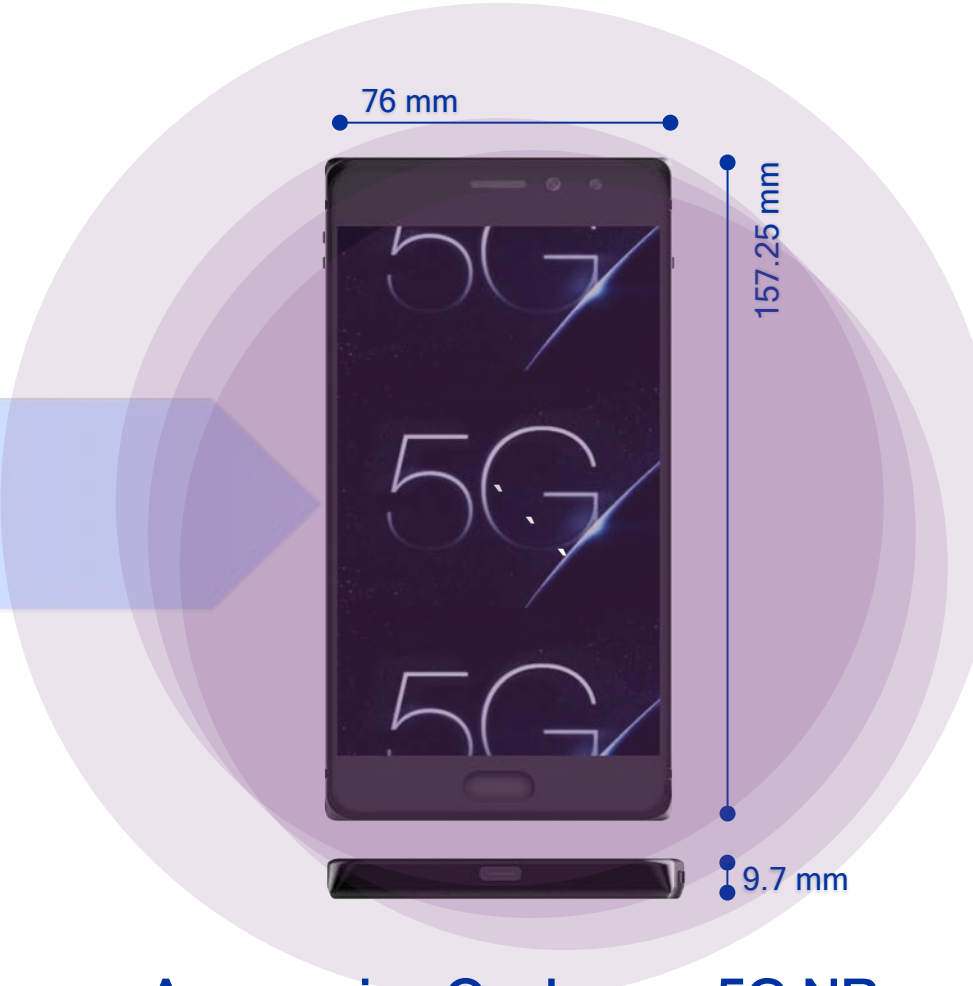
Architecture allows flexible placements and multiple modules

Commercializing mmWave in a smartphone form factor

11ad in Asus Zenfone 4 Pro

mmWave (60 GHz) in commercial smartphone

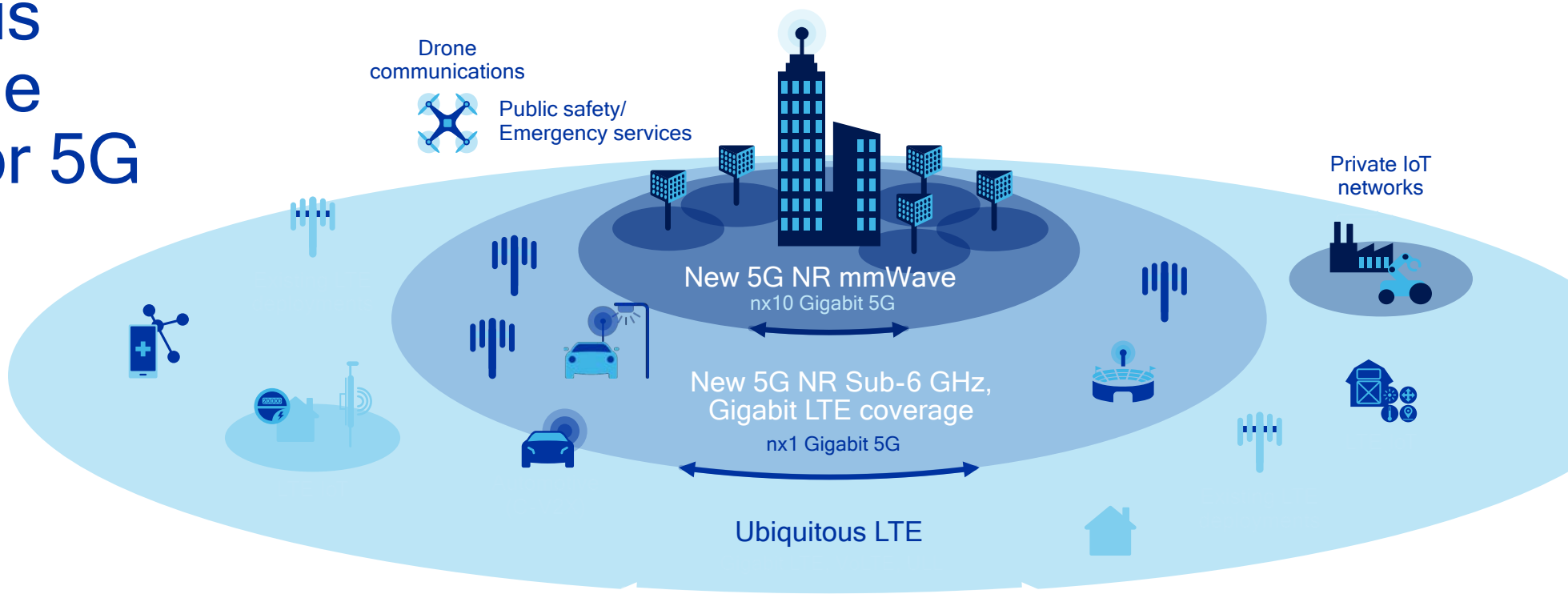
Qualcomm 5G NR mmWave prototype



Announcing Qualcomm 5G NR mmWave Reference Design

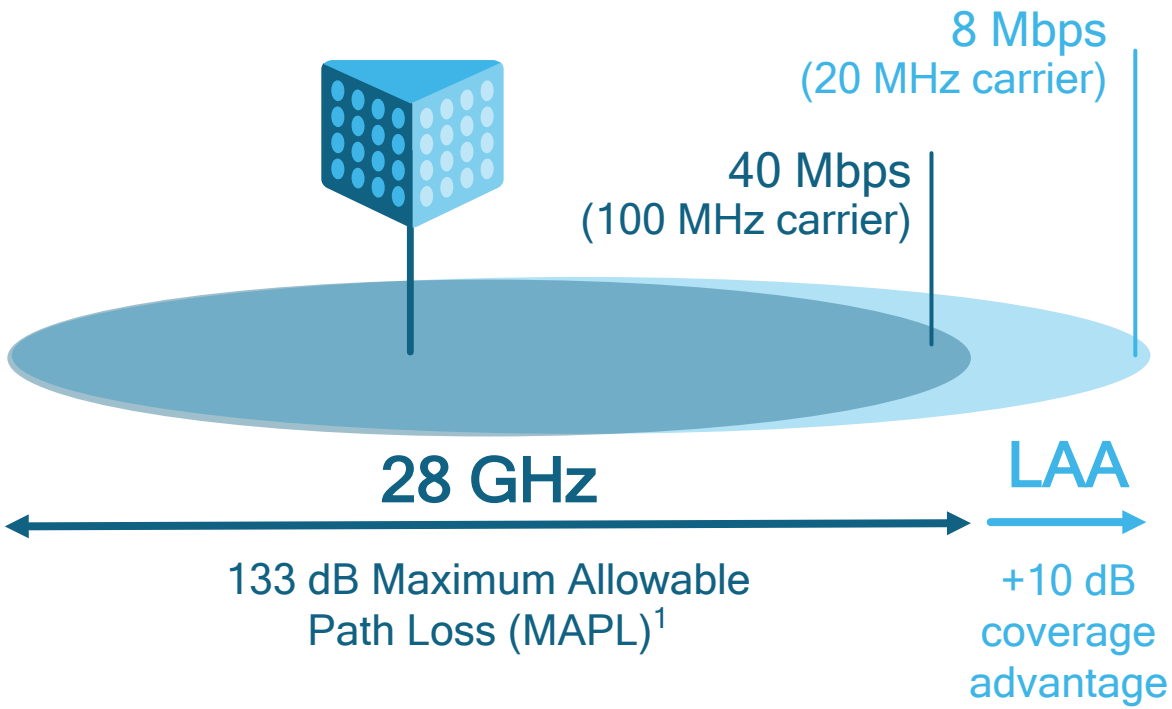
Gigabit LTE is the multimode foundation for 5G

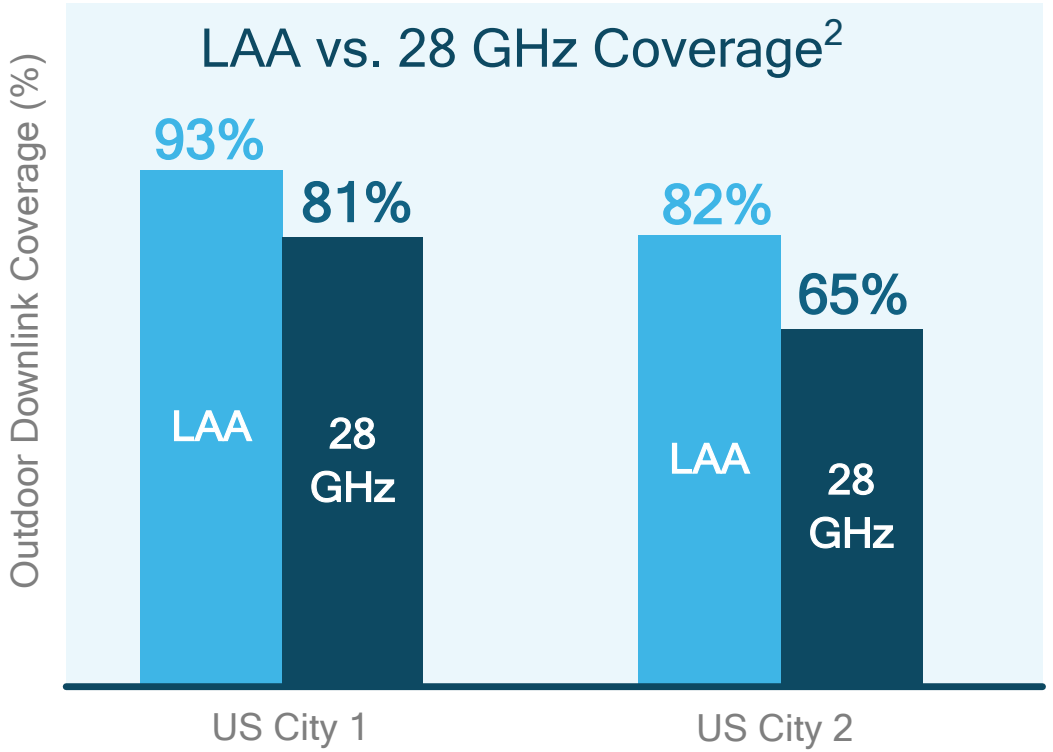
5G NR dual connectivity fully utilizes mature / ubiquitous existing LTE infrastructure



Significant coverage by co-siting 5G mmWave at existing LTE sites

See: https://www.qualcomm.com/documents/white-paper-5g-nr-millimeter-wave-network-coverage-simulation



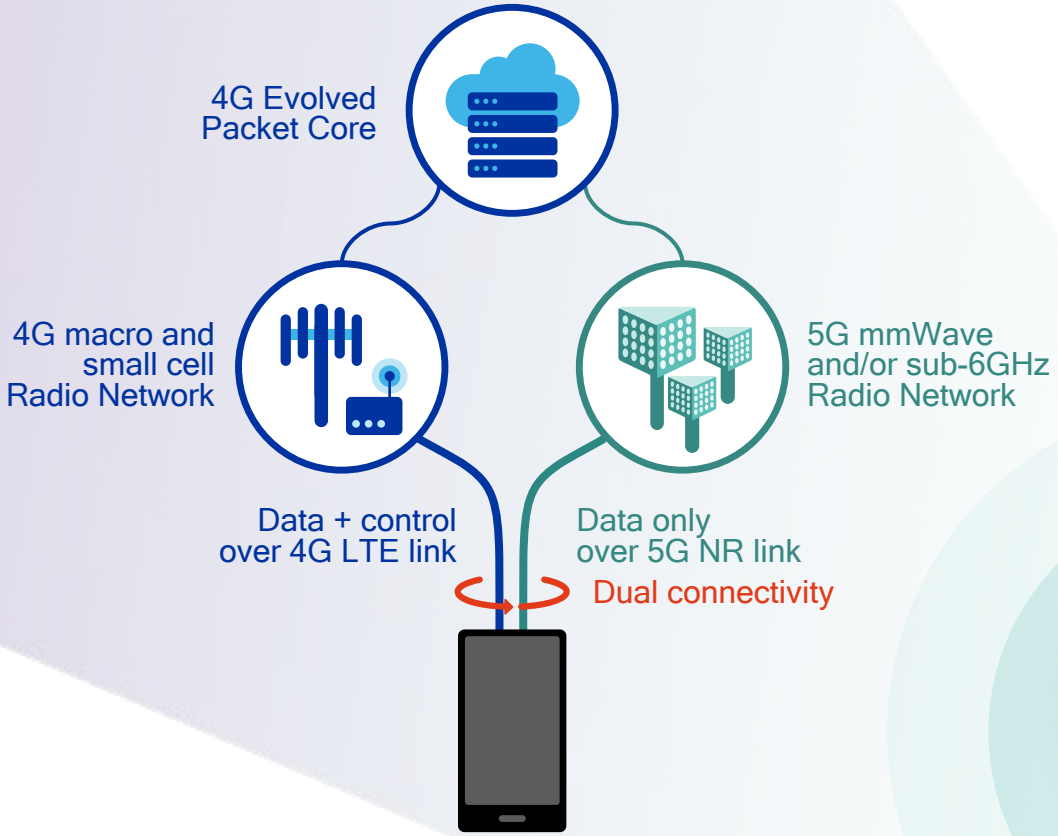


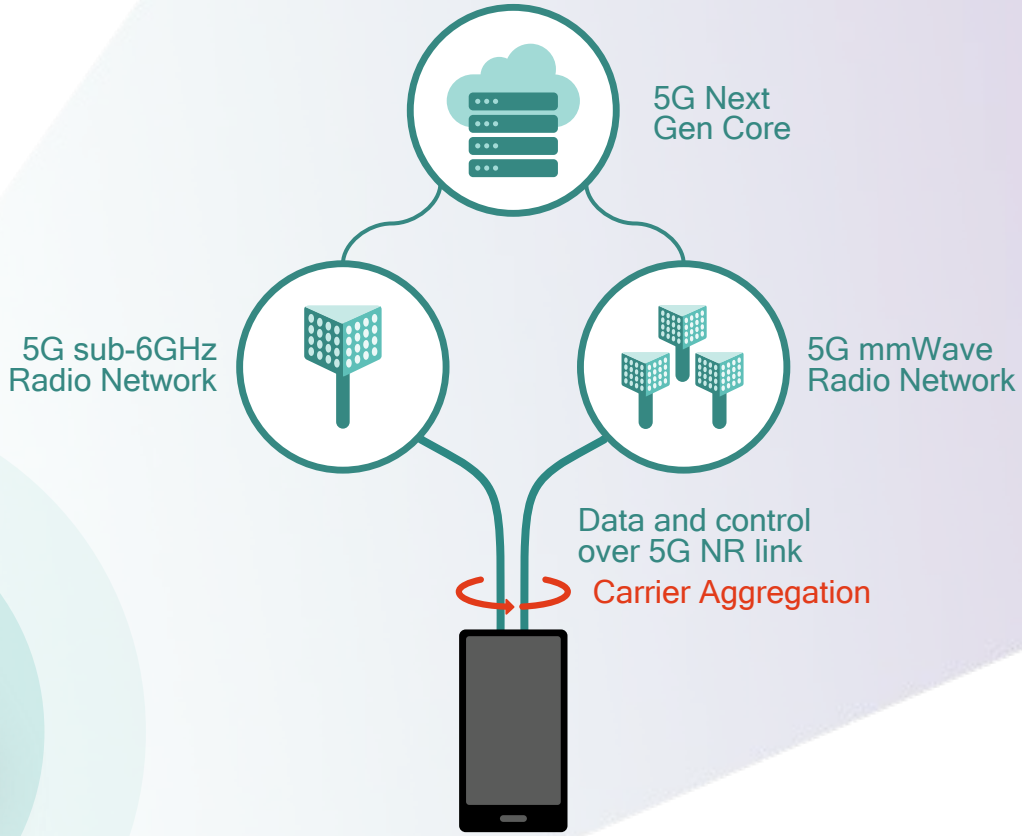
5G NR can utilize LAA deployments for Gigabit LTE

Source: Qualcomm Technologies, Inc. 5G NR mmWave Network Coverage Simulation

1 Link budget based on assumptions; additional variations possible due to temporary blockage – field measurements to follow; 2 Target spectral efficiency of 0.4 bps / Hz

Network architecture options for 5G NR





Non-Standalone (NSA) option

Fast-to-launch | Higher BW & UX* | VoLTE & CS voice

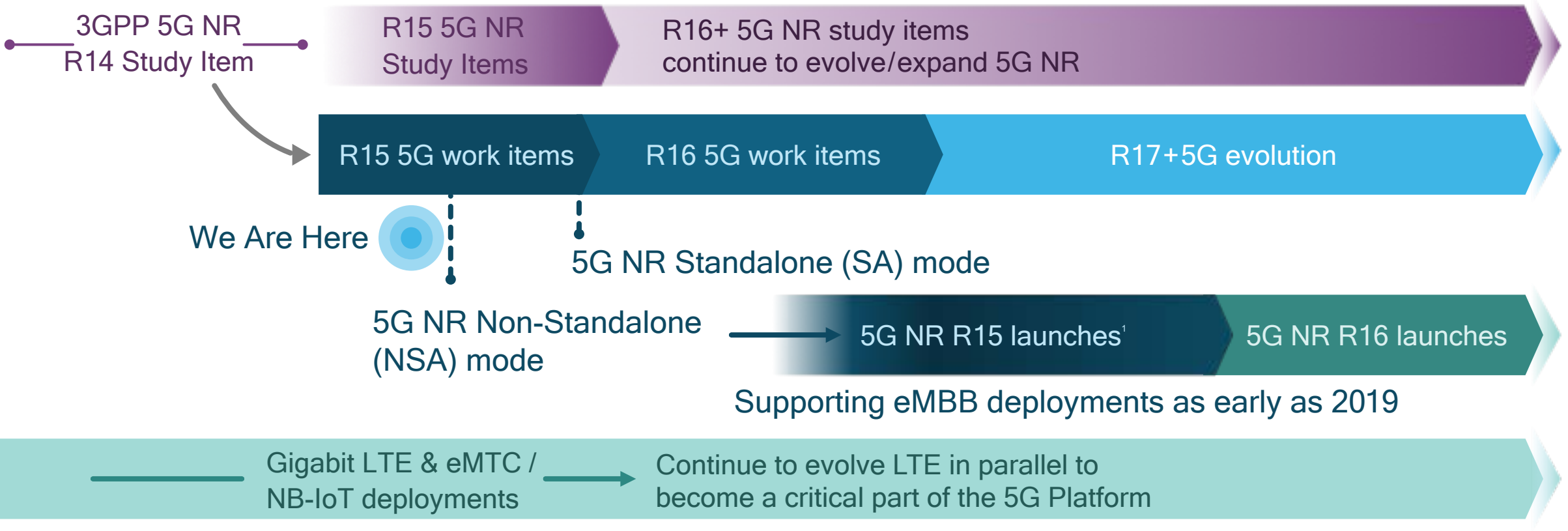
Standalone (SA) option

Network slicing | New services | VoNR & 4G fallback

*Initial NSA bandwidth and user experience in 2019-2020 5G NR launches as compared to SA launches in the same timeframe. Source: Qualcomm Technologies, Inc.

Accelerating 5G NR – the global 5G standard

To meet the global demand for enhanced mobile broadband



1. Forward compatibility with R16 and beyond. Source: 3GPP and Qualcomm Technologies, Inc.

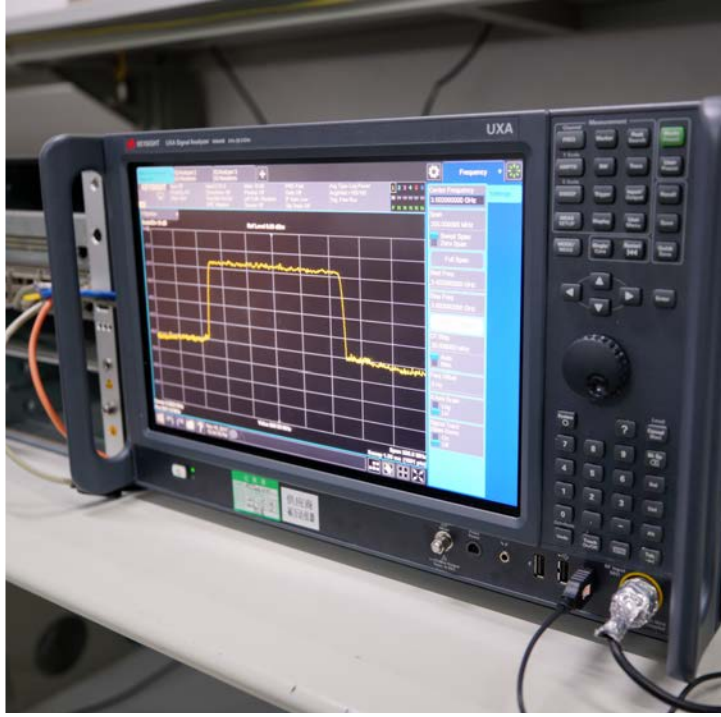
The world's first

end-to-end 5G NR sub-6 GHz interoperable connection based on 3GPP standard

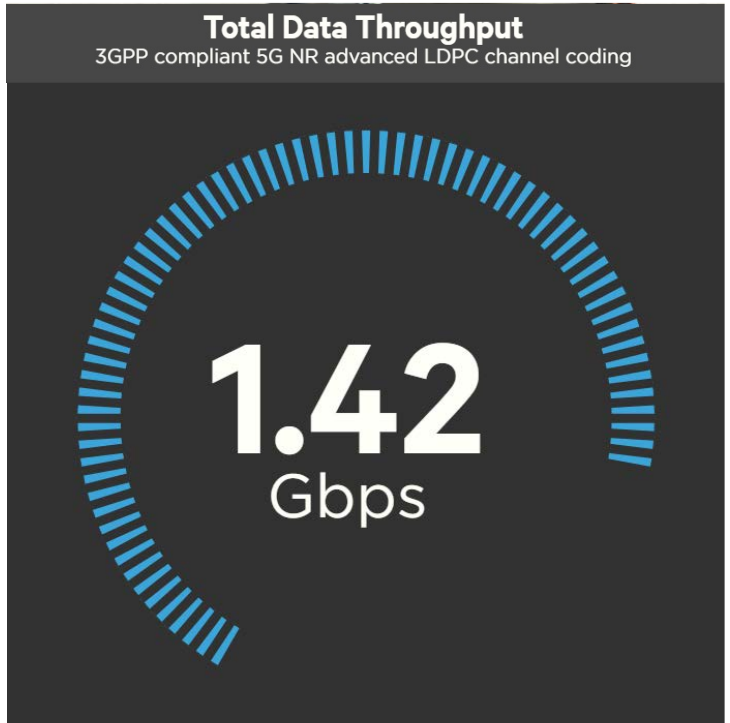
中国移动 China Mobile ZTE中兴 QUALCOMM

Compliant with the 5G NR layer 1 standard currently being finalized by 3GPP

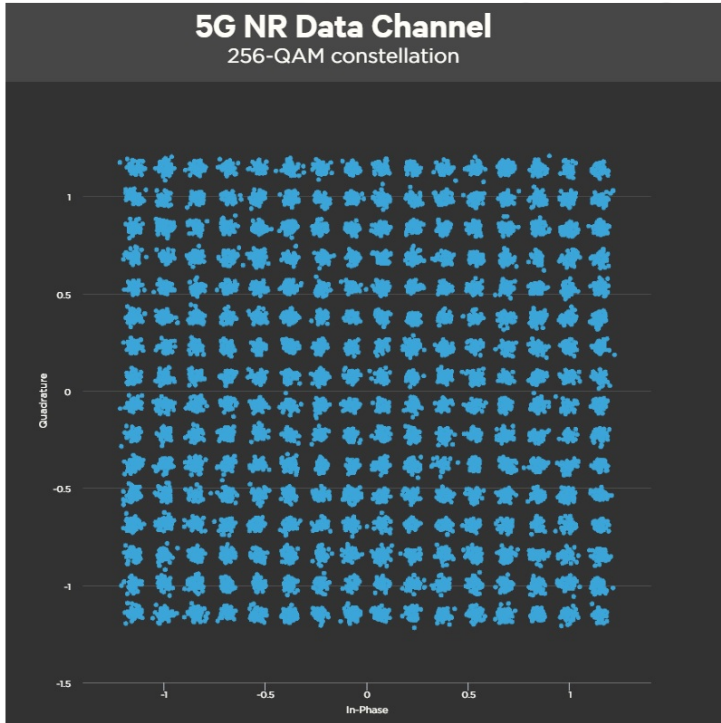
- ☑ 5G NR scalable OFDM air interface
- ☑ 5G NR low-latency slot-based framework
- ☑ 5G NR advanced channel coding
- ☑ 100 MHz bandwidth, operating at 3.5 GHz



Total Data Throughput
3GPP compliant 5G NR advanced LDPC channel coding



5G NR Data Channel
256-QAM constellation



Making 5G NR a commercial reality for 2019

For standard-compliant networks and devices

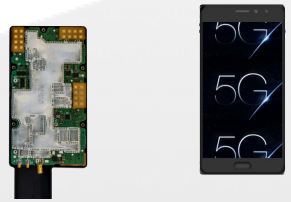
Best-in-class 5G prototype systems

Designing and testing 5G technologies for many years

3GPP™ A GLOBAL INITIATIVE

5G NR standards and technology leadership

Our technology inventions are driving the 5G NR standard



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5G NR interoperability testing and trials

Utilizing prototype systems and our global network experience

Modem, RFFE and platform leadership

Snapdragon X50 5G modem supporting anticipated 2019 mobile device launches

LTE foundational technologies

QUALCOMM®

Anyone can talk about 5G.
We are making it a reality.

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