Big steps in wireless: Applications, spectrum, and technology

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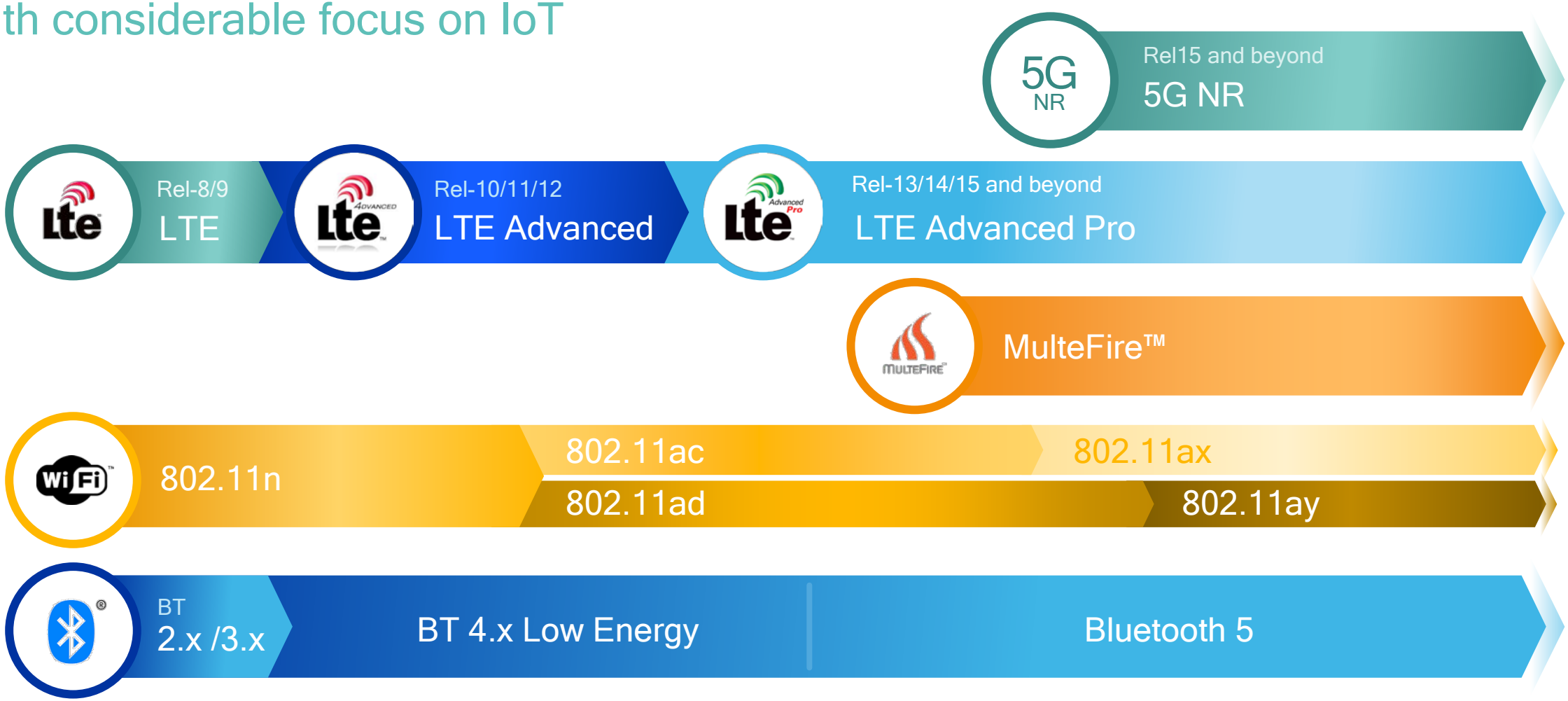
Key Wireless Technology Standardization Roadmaps

With considerable focus on IoT



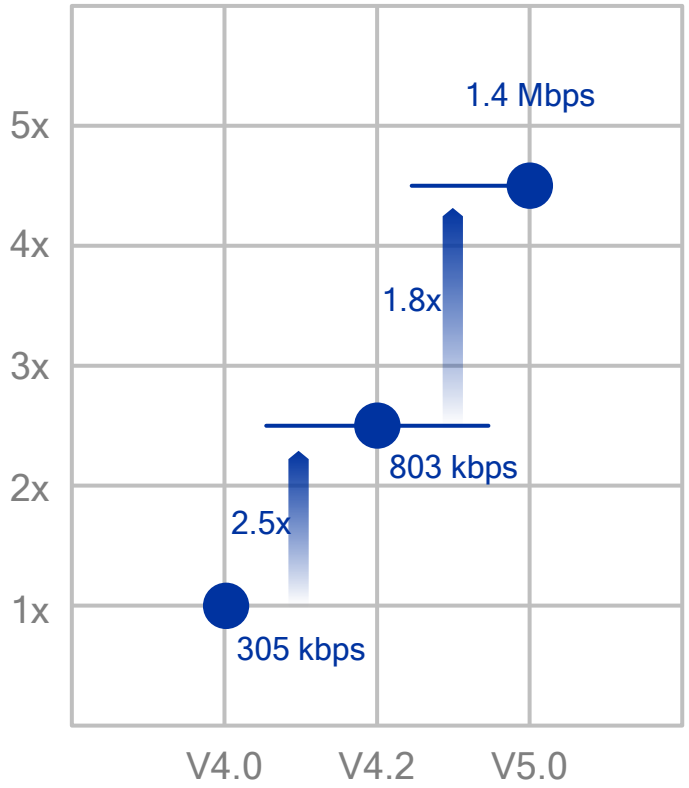
Note: Estimated standardization dates. 802.11ah specification expected to complete in 2016;
Supported 3G technologies not shown (WCDMA, HSPA/HSPA+, TD-SCDMA, CDMA2000 1x/1x Advanced, EV-DO/EV-DO Rev. B, DO Advanced, and GSM.)

Bluetooth 5: December 2016

Bluetooth 4.0: June 2010, Bluetooth 4.1: December 2013, Bluetooth 4.2: December 2014

4.6x data rate increase

(over BLE 4.0)



10 dB higher max output power

LE Class 1	20 dBm
LE Class 1.5	10 dBm
LE Class 2	4 dBm
LE Class 3	0 dBm

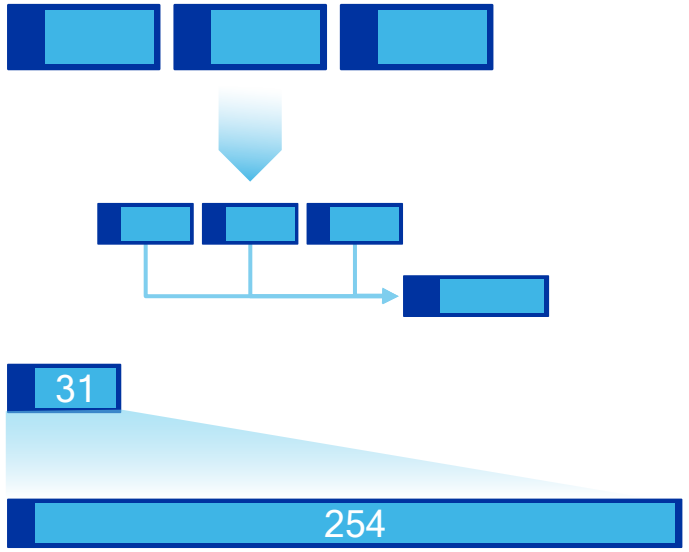
+

12 dB greater sensitivity

12 dB

~12x longer range

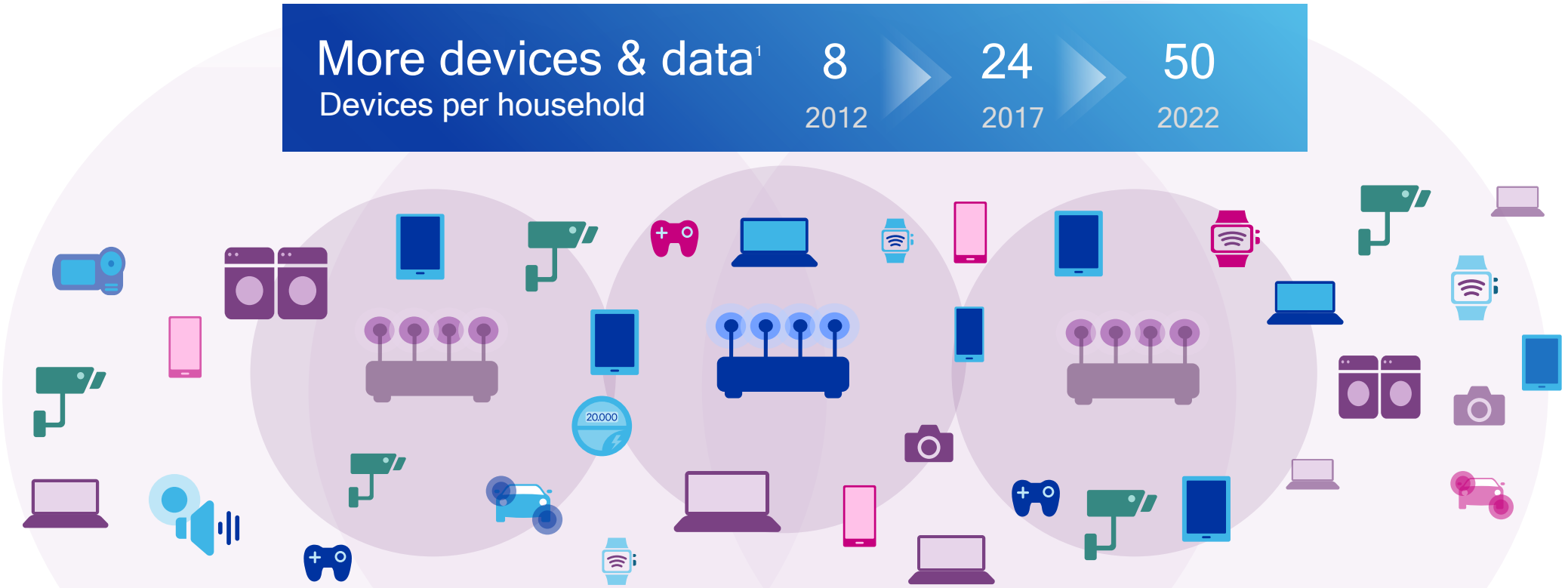
Advertising extensions



2.5x more efficient
8x more data
Better hopping

802.11ax : Designed for high density connectivity

Key 802.11 projects include 802.11ax, 802.11ay, 802.11az and SG WUR



Simultaneously serving lots of devices per AP

Few vs. dozens of devices

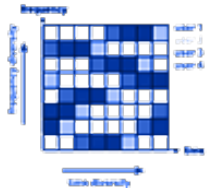
Better performance in dense environments with many APs

Multiple APs on shared channels

[1]Source: Connected devices–GSMA connected living 2015; Number of devices per home in home with a family of 4

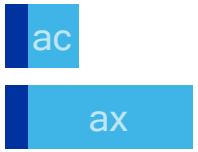
Technology building blocks of 802.11ax

8x8
MU-MIMO
DL/UL

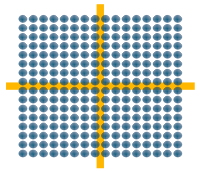


OFDMA
DL/UL

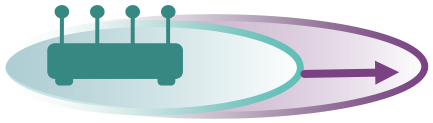
Up link resource scheduling



Long OFDM symbol

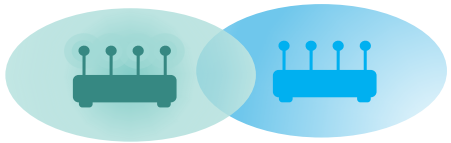


1024 QAM

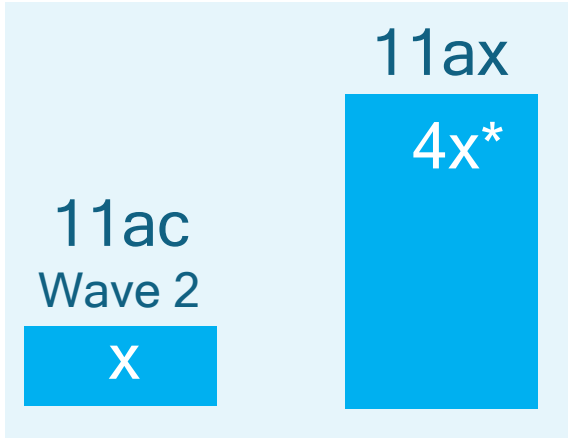


Extended range

More spatial streams



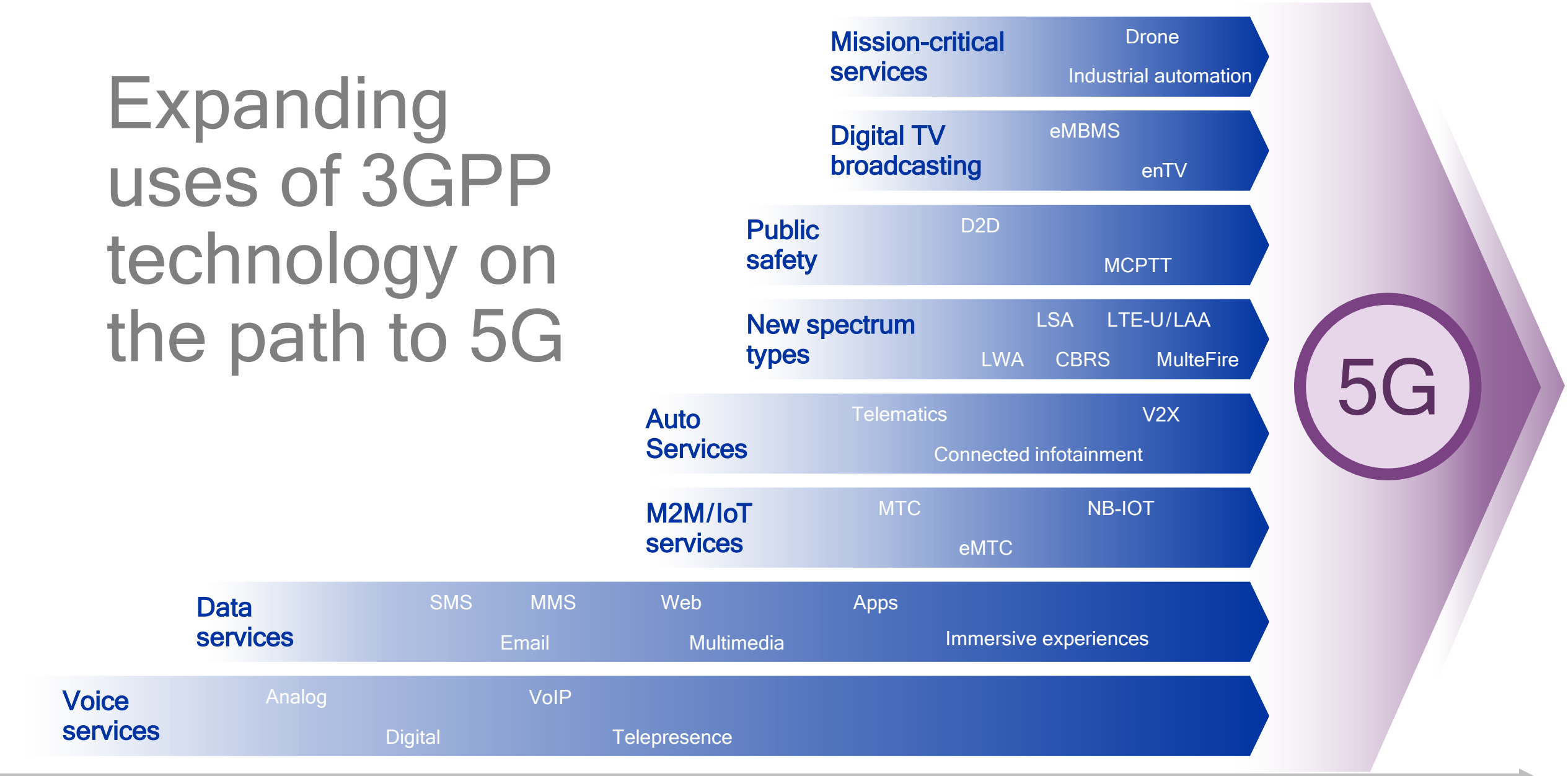
BSS color



Current 802.11ax Schedule	
Draft 1.0	Nov 2016
Draft 2.0	May 2017
Final	~2019

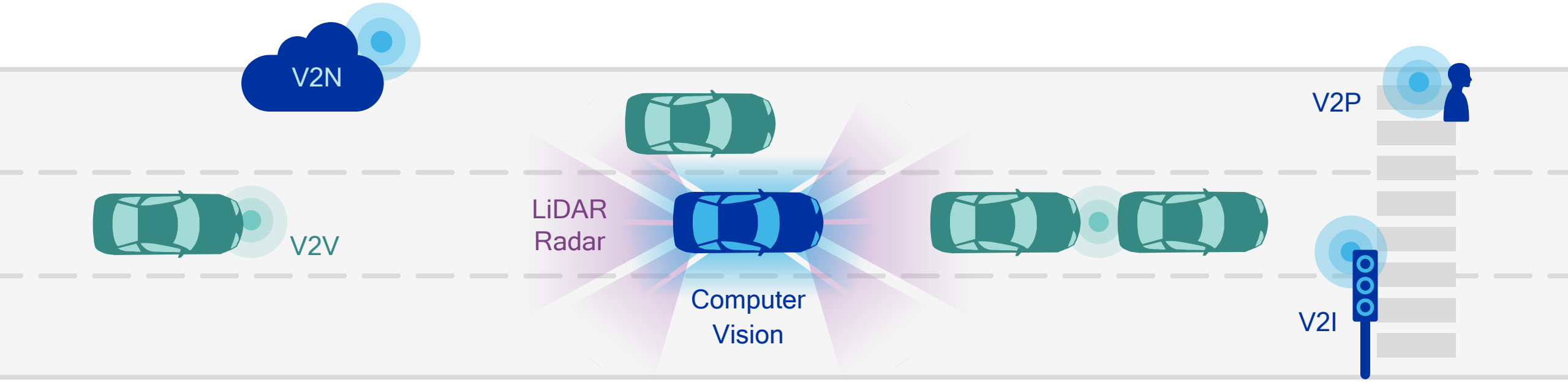
*Based on Qualcomm Technologies simulations
Up to 4x increase in median throughputs in dense scenarios compared to 4x4 11ac wave 2
Assumptions: 11ax with 8x8 AP and 2x2 clients; UL and DL MU-MIMO; long OFDM symbol

Expanding uses of 3GPP technology on the path to 5G



V2X is a key technology enabler to enhanced ADAS

Bringing significant value to Advanced Driver Assistance Systems (ADAS)



Improved active safety

Provides 360° non-line-of-sight awareness, e.g. intersections and on-ramps, environmental conditions

Better traffic efficiency

Allows vehicles to safely drive closer to each other and enables optimization of overall traffic flow

Increased situational awareness

Provides ability to gather data from further ahead to deliver a more predictable driving experience

Cellular V2X (C-V2X)

A unified connectivity platform for the connected vehicle of the future

5GAA Automotive Association

Part of release 14 of the global 3GPP standard

Target C-V2X specification completion end of 2016[1]

Builds upon existing LTE connectivity platform for automotive

LTE already delivering key services today, e.g. telematics, eCall, connected infotainment

Enhances LTE Direct for V2X direct communications

Improvements over 802.11p – up to a few additional seconds of alert latency and 2x range[2]

Leverages existing LTE networks for V2X network communications

Using LTE Broadcast optimized for V2X to offer additional applications/services

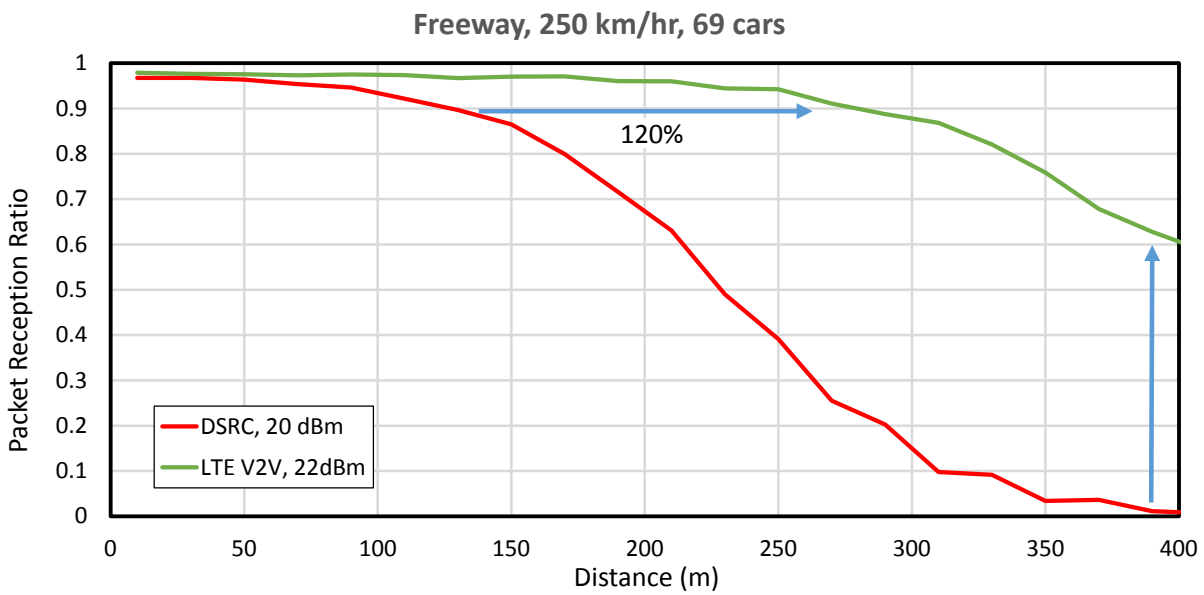
Rich roadmap towards 5G with strong ecosystem support

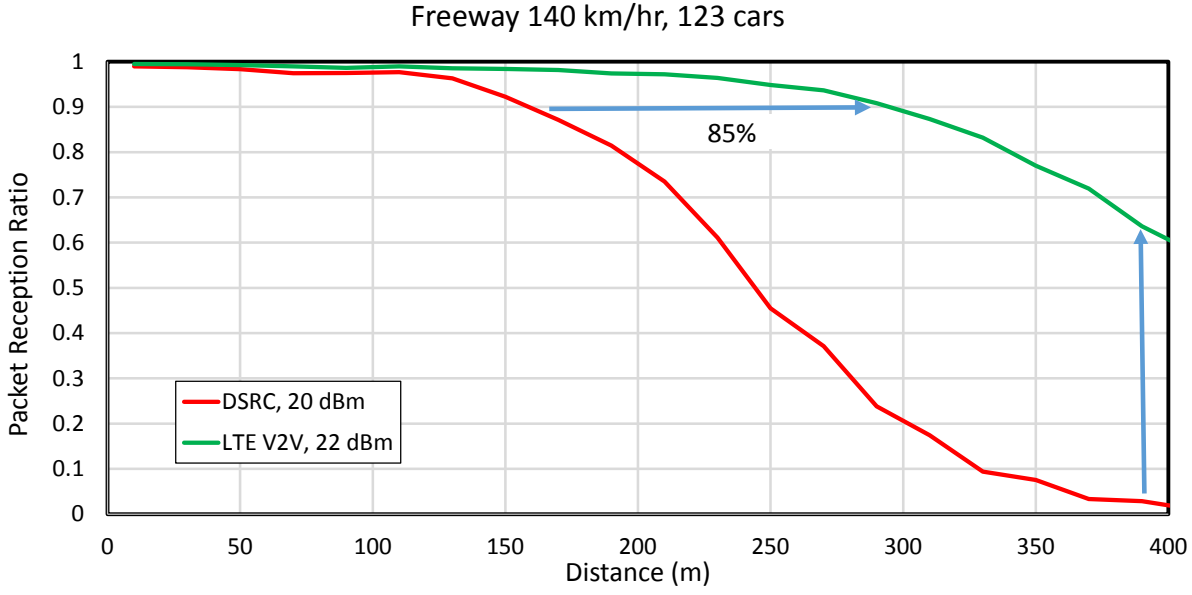
Technology evolution to address expanding capabilities/use cases

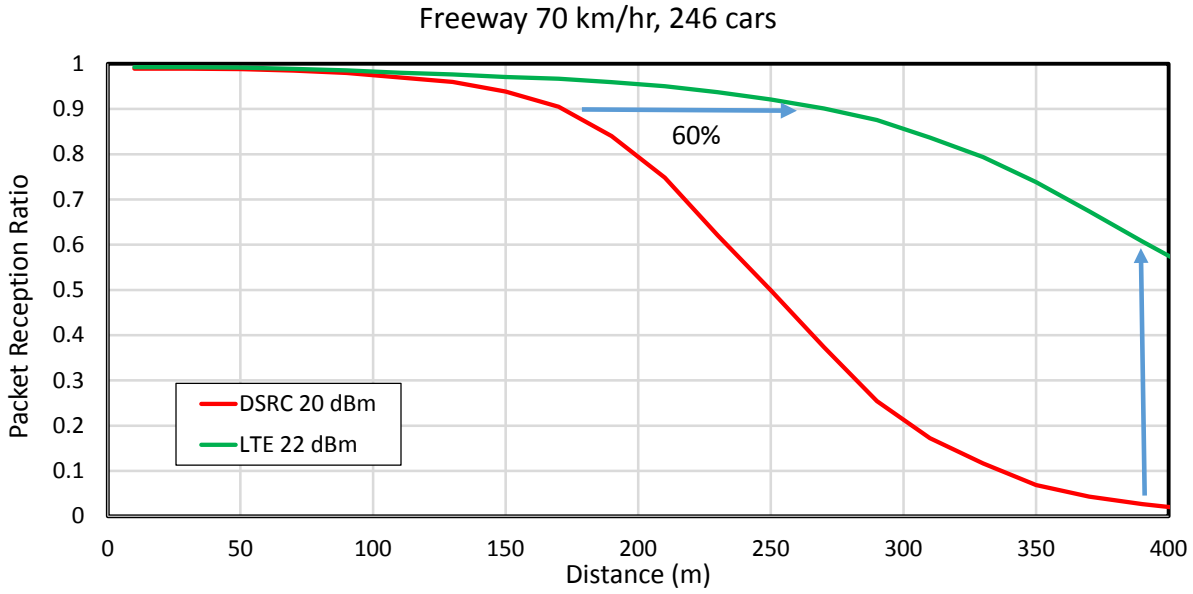
[1] For Direct communications component (enhancements to LTE Direct) – overall spec completion expected mid-2017; 2 Based on Qualcomm Research simulations

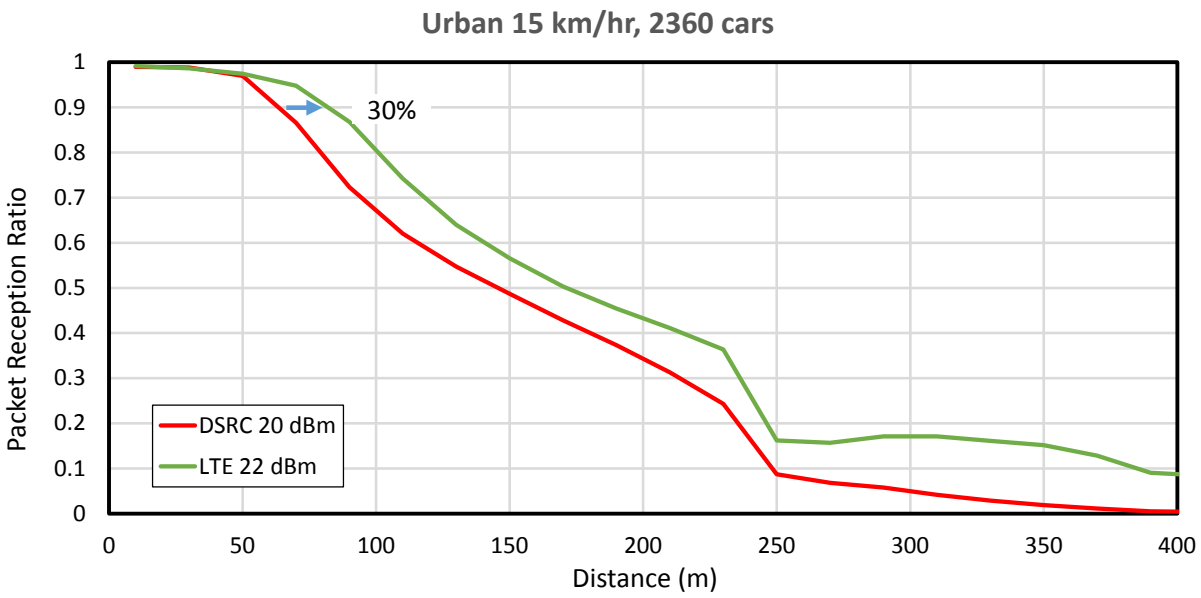
Enhanced Performance of C-V2V versus DSRC

Higher reliability and greater distance for detection









New spectrum sharing paradigms—opportunity to innovate

Can enable more efficient utilization of, and access to, scarce resources

Licensed spectrum

Exclusive use

Example: 2.1 GHz

Shared spectrum

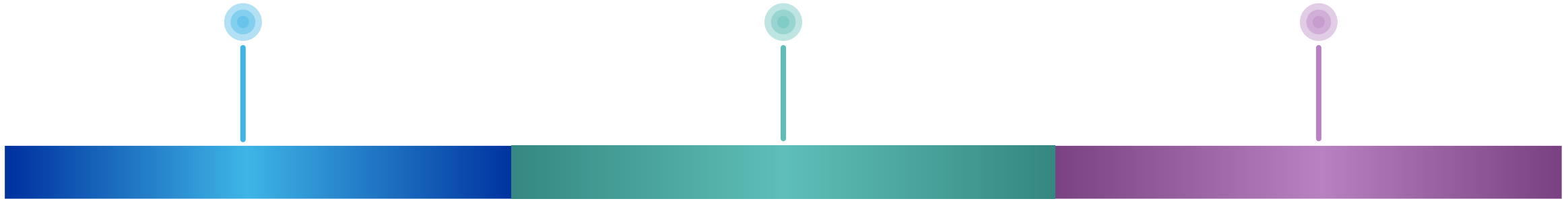
New shared spectrum paradigms

Example: 2.3 GHz Europe / 3.5 GHz USA

Unlicensed spectrum

Shared use

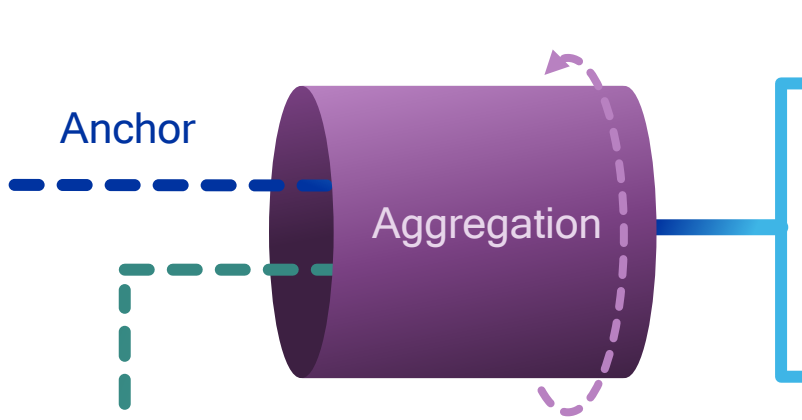
Example: 2.4 GHz global / 5 GHz global



Multiple technologies will coexist in unlicensed spectrum

Licensed spectrum
Exclusive use

Unlicensed spectrum
Shared use



LTE-U/LAA[1]

Targeting mobile operators using LTE in unlicensed spectrum for new small cell deployments

LWA[2]/LWIP[3]

Targeting mobile operators leveraging existing carrier Wi-Fi deployments

MulteFire

Broadens LTE ecosystem to enhanced and new deployment opportunities, suitable for neutral host

Wi-Fi[4]

Evolving for enhanced performance and expanding to new usage models, used today as neutral host

1) Licensed-Assisted Access (LAA), also includes enhanced LAA (eLAA); 2) LTE Wi-Fi Link Aggregation (LWA); 3) LTE Wi-Fi radio level integration with IPsec tunnel (LWIP); 4) 802.11ac / .11ad / .11ax / .11ay

MulteFire Technology is based on 3GPP LAA and eLAA

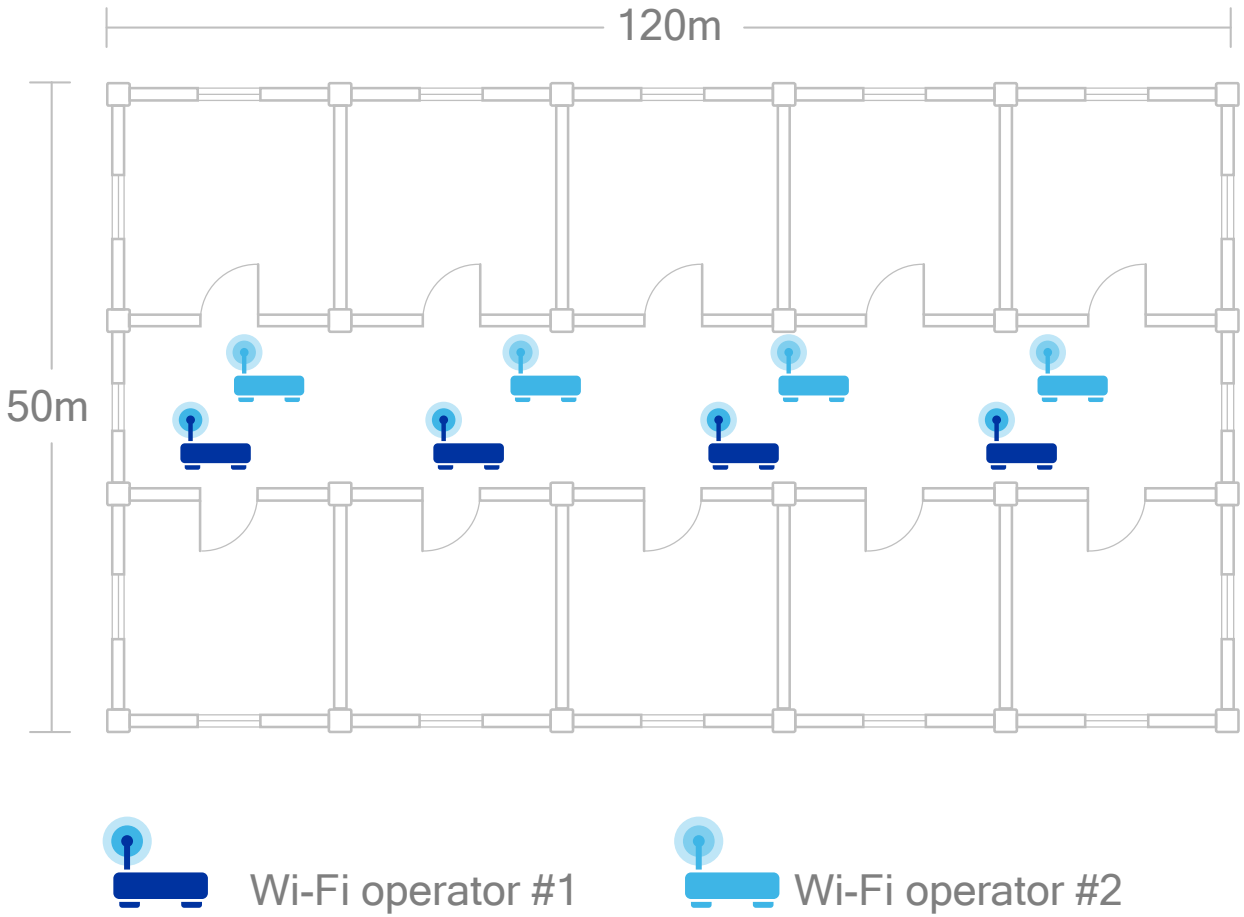
Extends eLAA–uplink and downlink–to operate without anchor in licensed spectrum

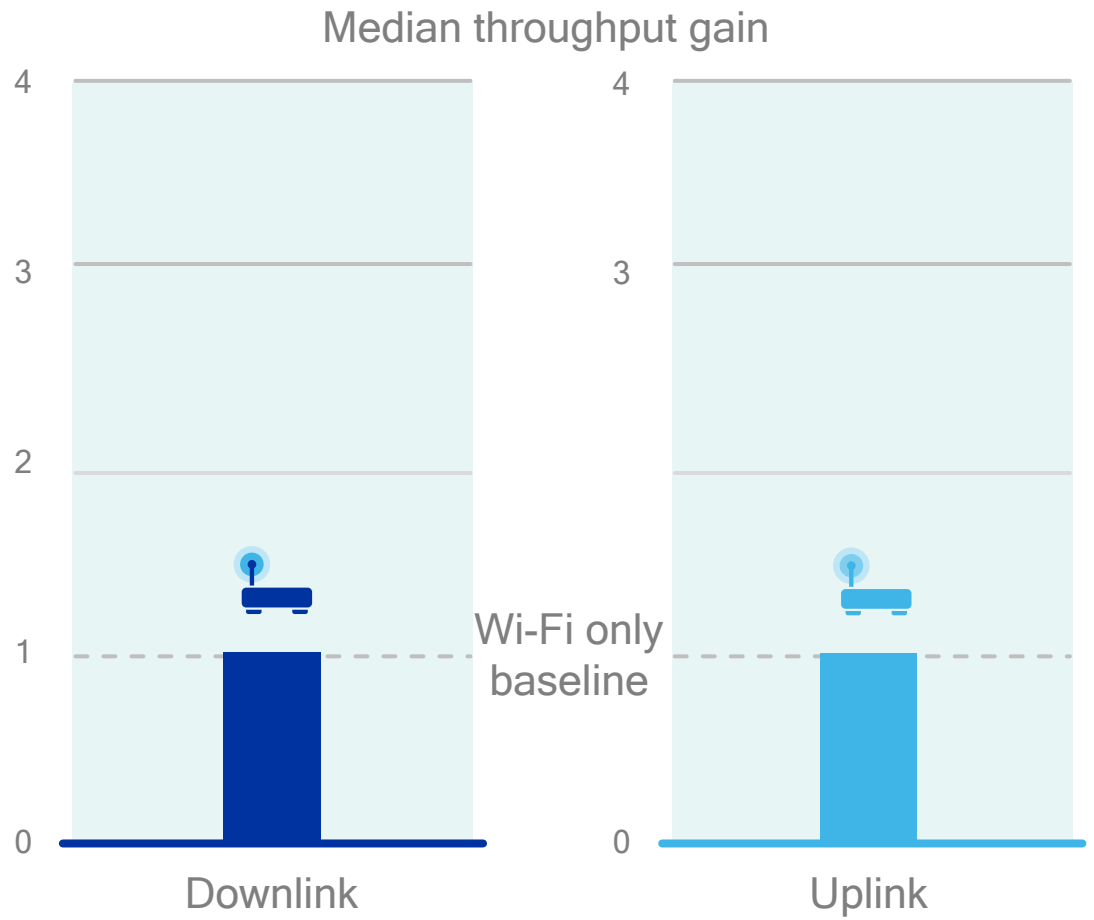
MulteFire Alliance	Operate without licensed anchor	Enhanced discovery signals Robust procedures: mobility, paging, RA[1]... Robust and efficient UL[2] control channels
3GPP Rel 14	eLAA: +Uplink	Uplink waveform and channels Flexible frame structure UL[2] HARQ[3], scheduling enhancements
3GPP Rel 13	LAA: Downlink	Supplemental downlink + HARQ[3] LBT[4] coexistence in unlicensed Multi-carrier operation
	LTE	Advanced LTE air-interface LTE TDD

1) Random Access; 2) Uplink; 3) Hybrid automatic retransmission request; 4) Listen before talk

Indoor simulations results

Baseline with 2 Wi-Fi operators in an office building, each with 4 access points[1]

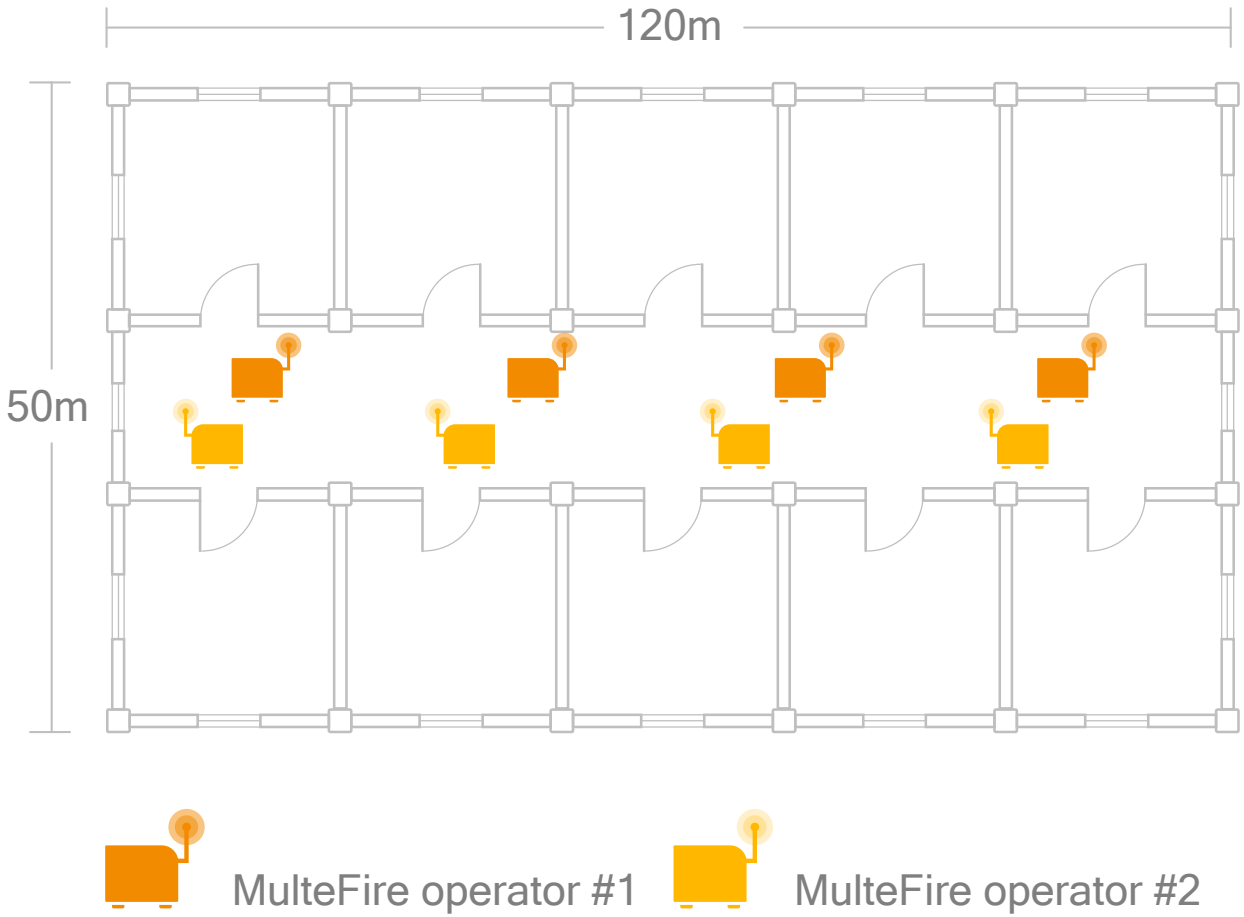


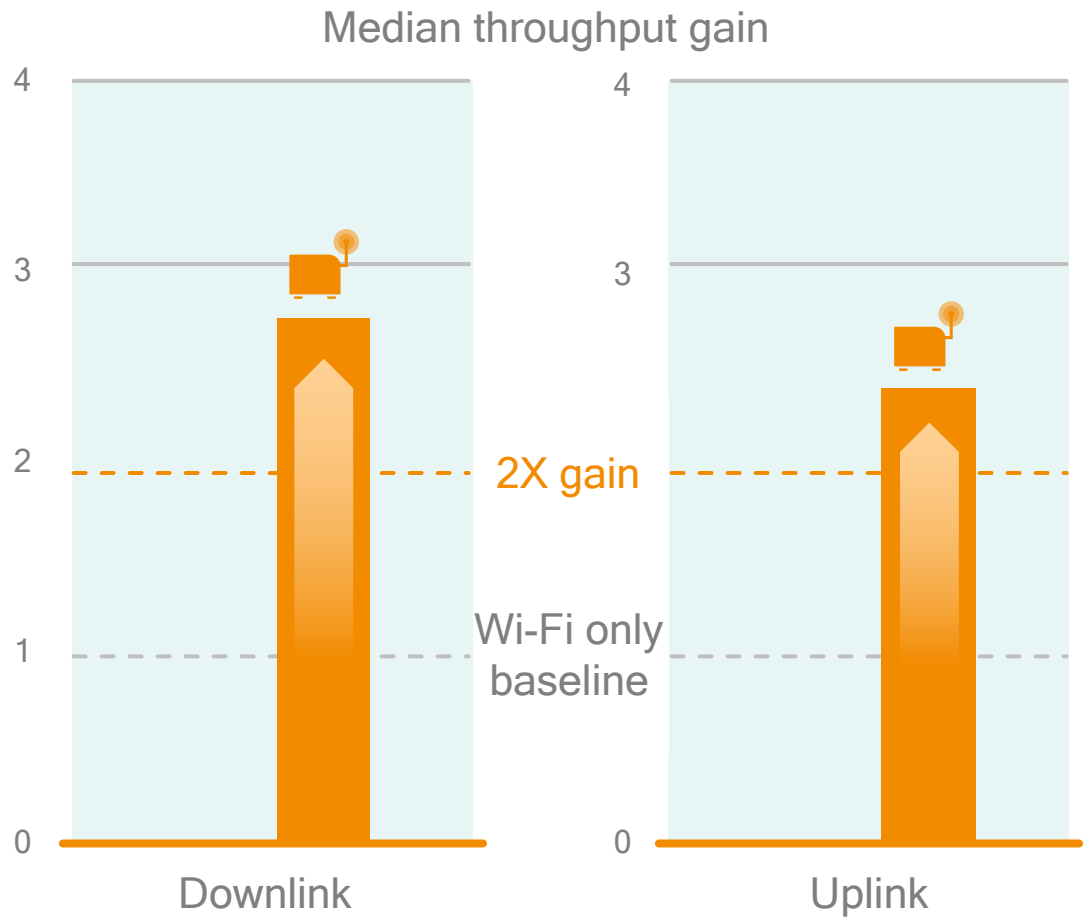


1) Indoor, single 20 MHz channel in 5 GHz, 80%-20% traffic split between down- and uplink, bursty traffic generated with 4 Mb files arriving with exponential inter arrival times, high traffic load with buffer occupancy at 50% in downlink and 20% in uplink for Wi-Fi only baseline, 4 APs per operator, 2 operators, office building size 120m x 50m, propagation model 3GPP indoor hotspot (InH), Wi-Fi is 802.11ac, MIMO 2x2, no MU-MIMO

MulteFire by itself offers >2X capacity gain over Wi-Fi[1]

Higher gains in MulteFire only deployments, especially in dense scenarios





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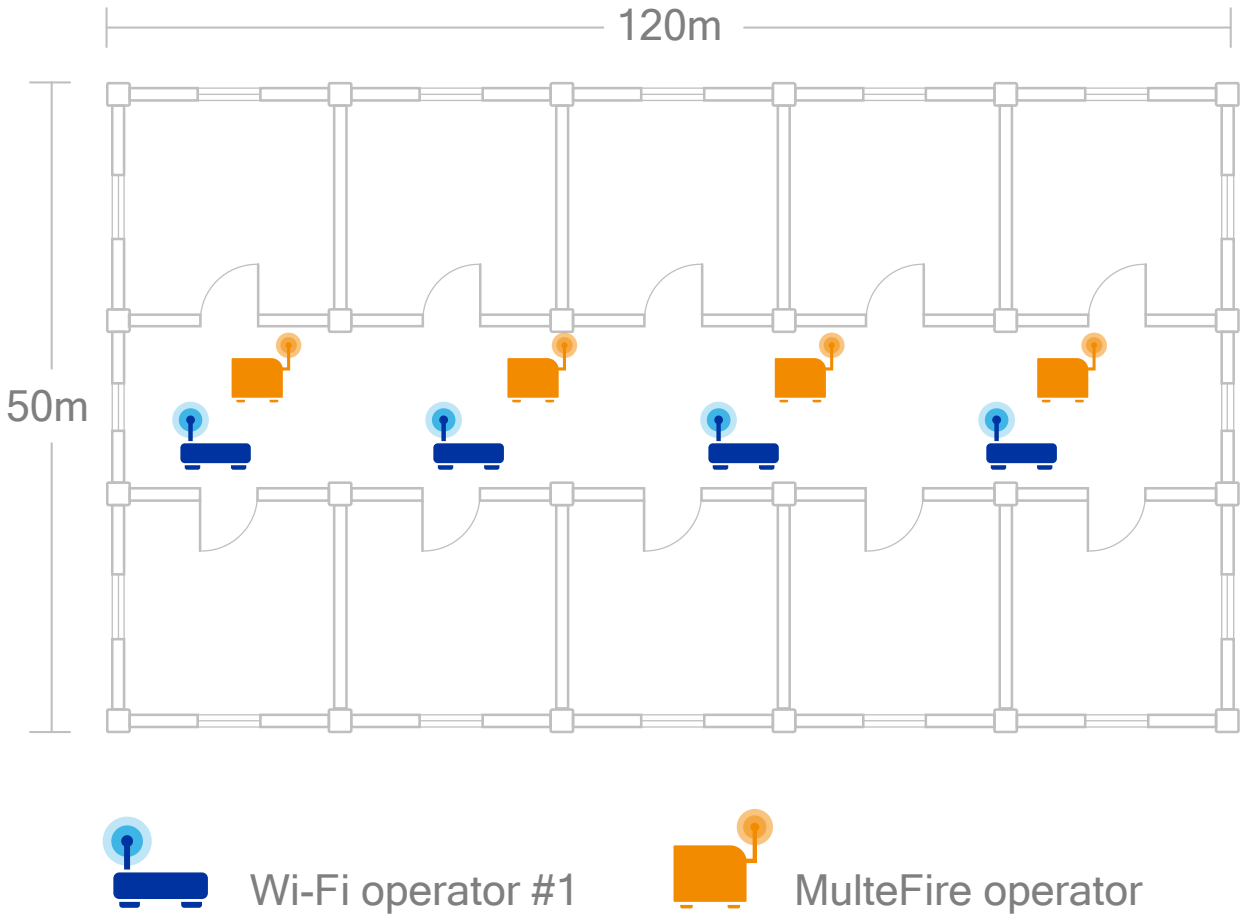
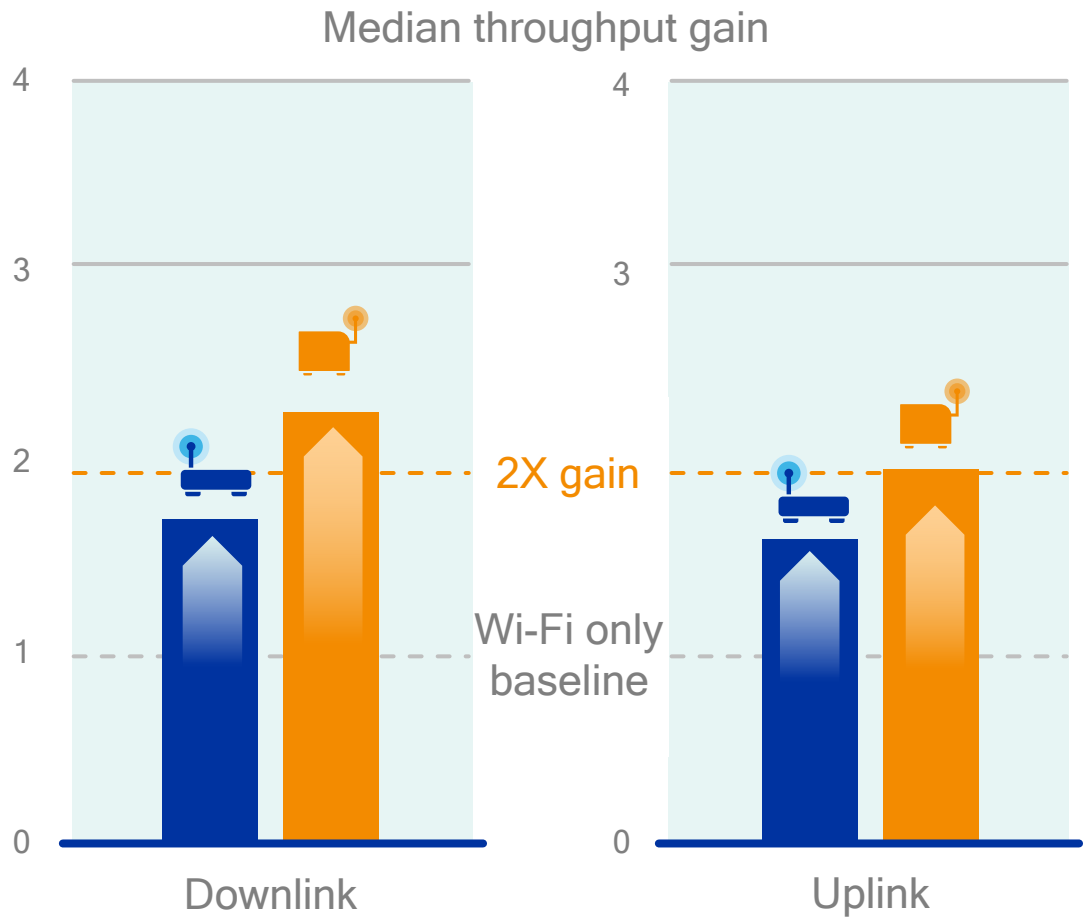
MulteFire offers ~2X capacity gain over Wi-Fi baseline[1]

Wi-Fi performance preserved, sometimes better, when neighbor switch to MulteFire





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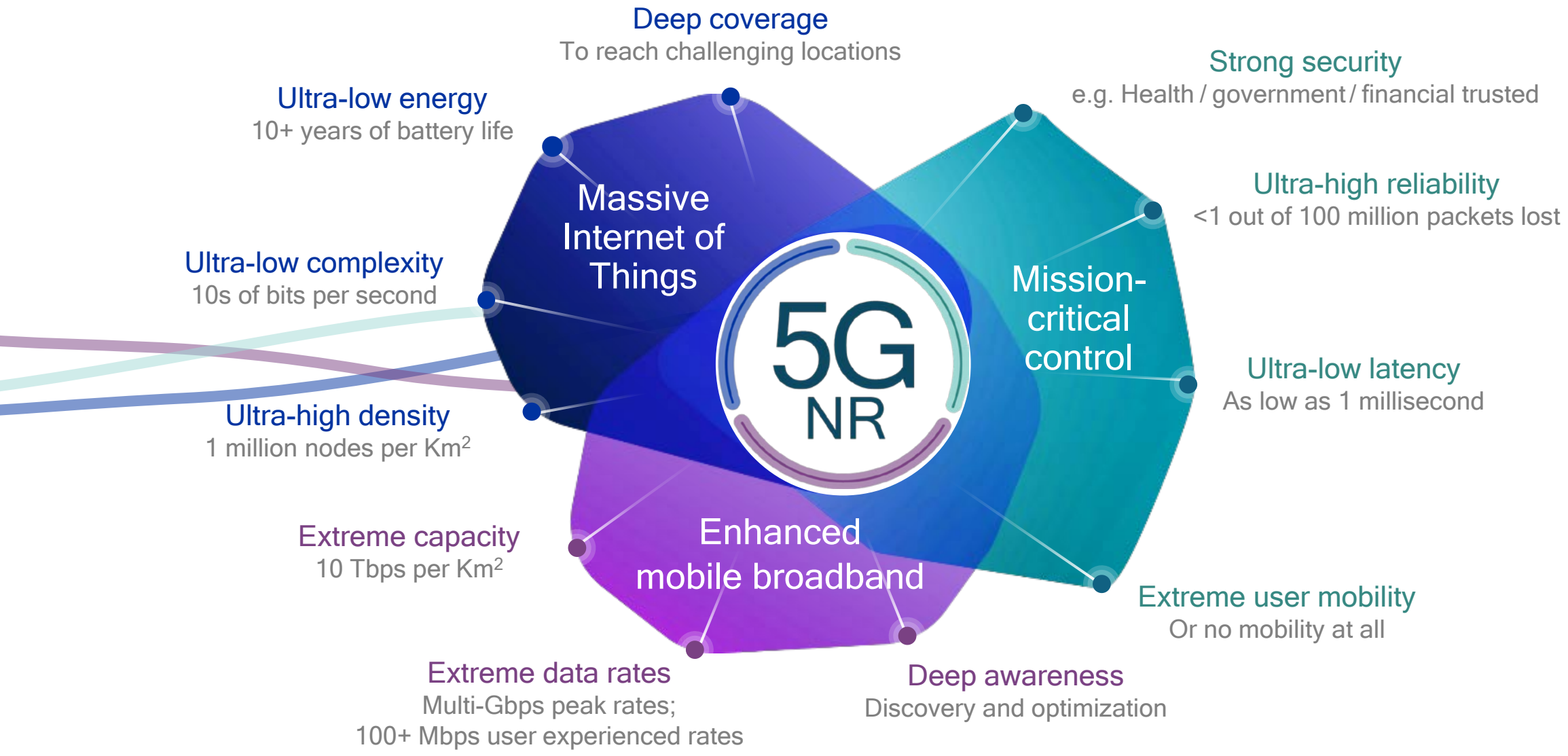
Scalability to address diverse service and devices



Based on target requirements for the envisioned 5G use cases

Getting the most out of every bit of diverse spectrum

Low bands below 1 GHz: longer range for e.g. mobile broadband and massive IoT
e.g. 600 MHz, 700 MHz, 850/900 MHz

Mid bands 1 GHz to 6 GHz: wider bandwidths for e.g. eMBB and mission-critical
e.g. 3.4-3.8 GHz, 3.8-4.2 GHz, 4.4-4.9 GHz

High bands above 24 GHz (mmWave): extreme bandwidths
e.g. 24.25-27.5 GHz, 27.5-29.5, 37-40, 64-71 GHz

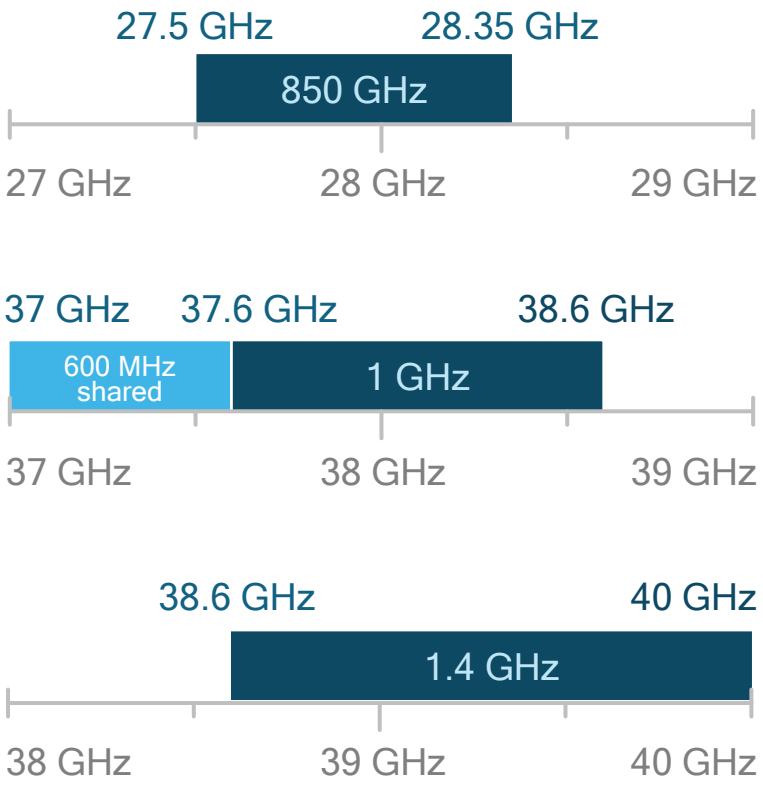
Licensed spectrum
Exclusive use

Shared spectrum
New shared spectrum paradigms

Unlicensed spectrum
Shared use

mmWave as a 5G component

US FCC proposed allocations

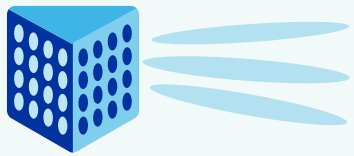


mmWave challenge

Robustness due to high path loss and susceptibility to blockage

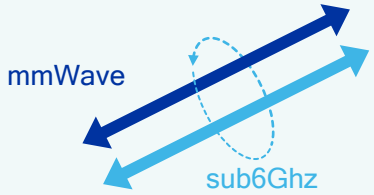
Device cost/power and RF challenges at mmWave frequencies

mmWave approaches



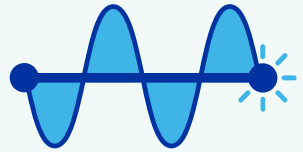
Smart beamforming and beam tracking

Increase coverage and minimize interference



Tight interworking with sub 6 GHz

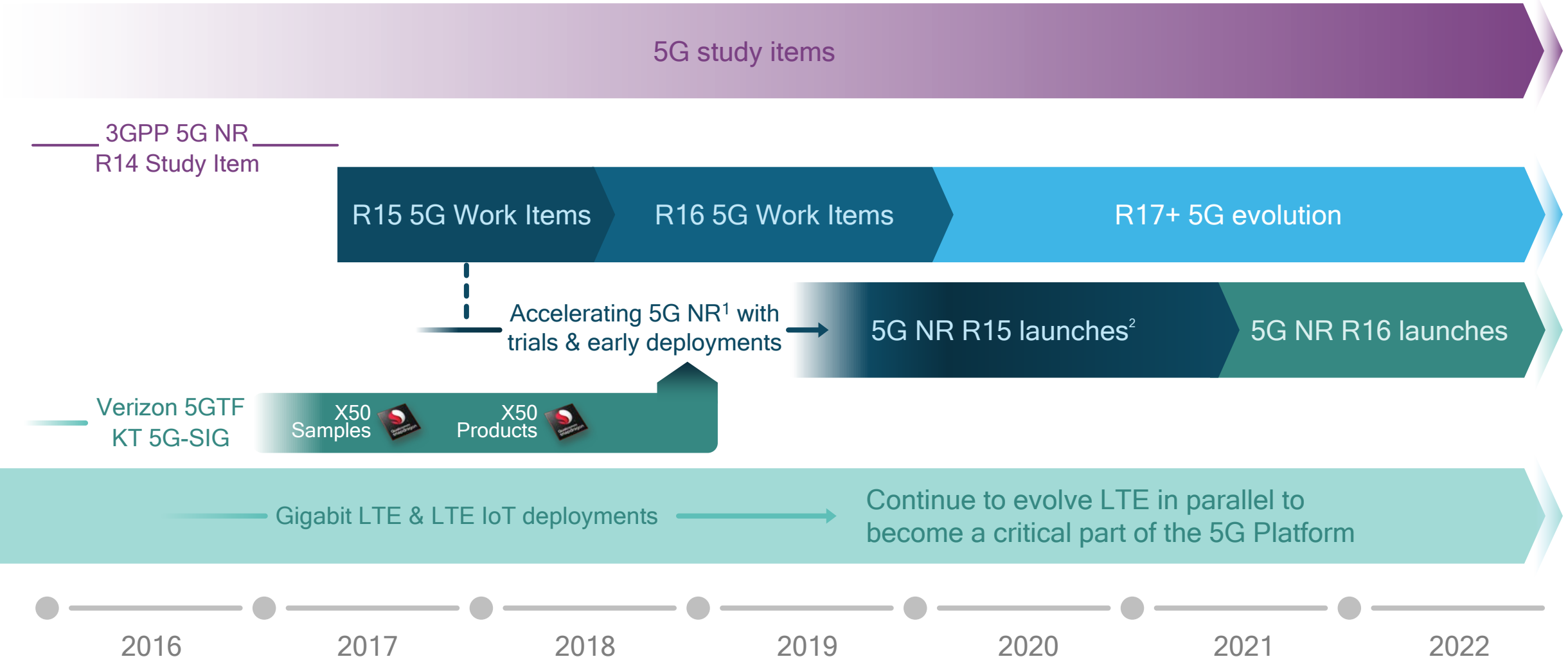
Increase robustness, faster system acquisition



Optimized mmWave design for mobile

To meet cost, power and thermal constraints

Accelerating 5G NR, the global standard for 5G

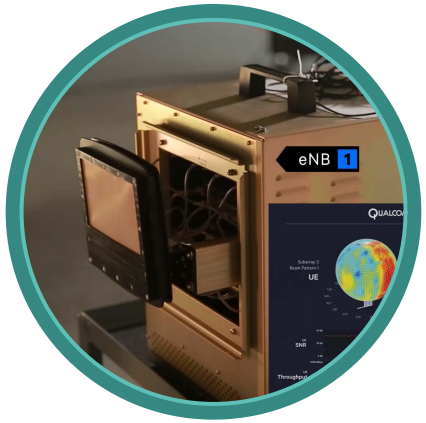


Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. X50 sampling expected 2H 2017 Commercial devices expected in 1H 2018

Note: Estimated commercial dates. 1 The latest plenary meeting of the 3GPP Technical Specifications Groups (TSG#72) has agreed on a detailed workplan for Release-15; 2 Forward compatibility with R16 and beyond

Qualcomm Research 5G NR prototype systems

Testbed for 5G designs to drive standardization and timely commercialization



Sub-6 GHz for flexible deployments across a wide range of use cases

End-to-end system operating at 3.5 GHz showcasing multi-Gbps rates at low latency

Spectrum sharing to expand 5G ecosystem and drive new deployments

Common HW platform supporting LBT[1], low-latency wideband waveforms, and protocol enhancements[2]

Robust mmWave for extreme mobile broadband

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

Qualcomm Research is a division of Qualcomm Technologies, Inc.

1 Listen-Before-Talk; 2 Radio and network layers enhancements for shared spectrum deployments

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