May 2018

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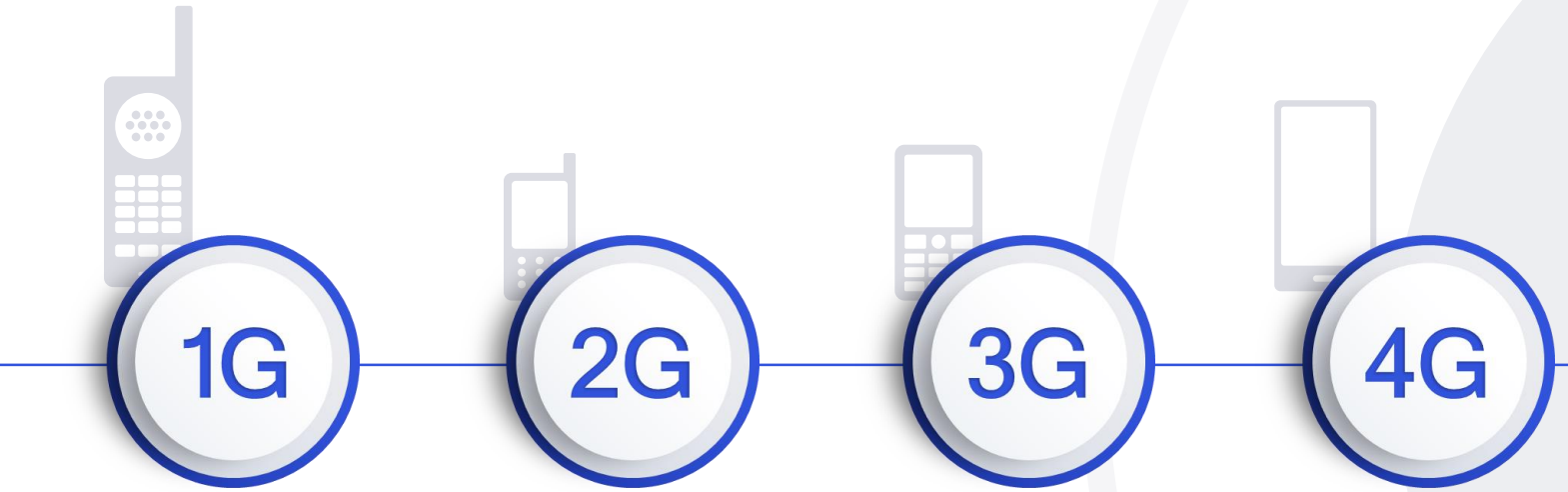
Qualcomm

Accelerating the mobile ecosystem expansion in the 5G Era with LTE Advanced Pro

Qualcomm Technologies, Inc.

Mobile is the largest technology platform in human history

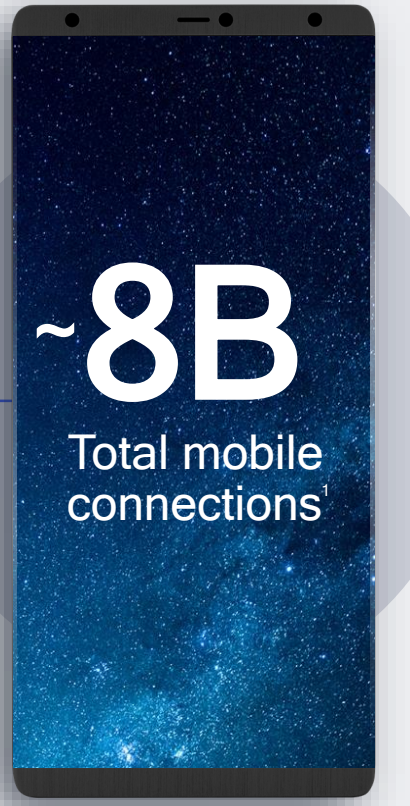


1980s
Analog voice
AMPS, NMT, TACS

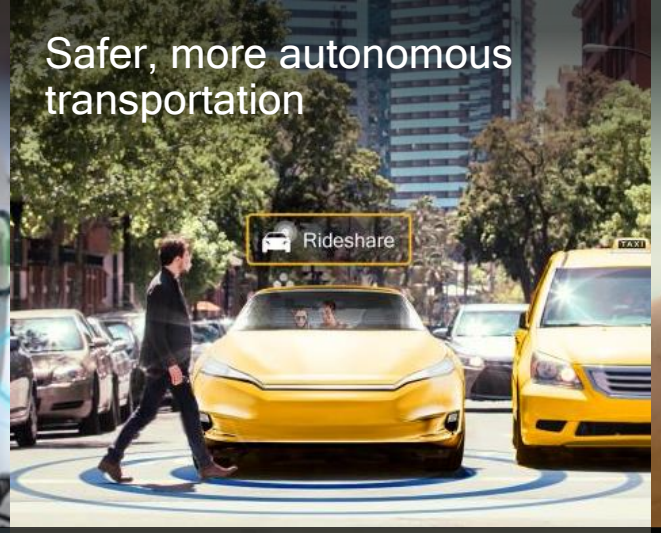
1990s
Digital voice
D-AMPS, GSM, IS-95 (CDMA)

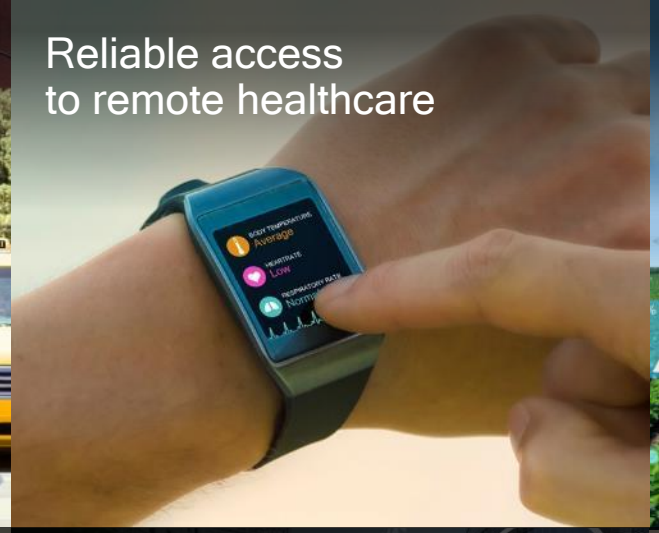
2000s
Mobile data
WCDMA/HSPA+, CDMA2000/EV-DO

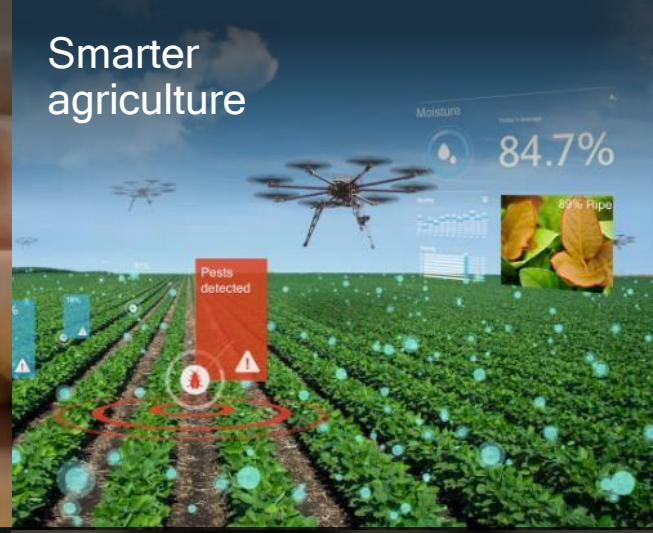
2010s
Mobile broadband
LTE, LTE Advanced, Gigabit LTE

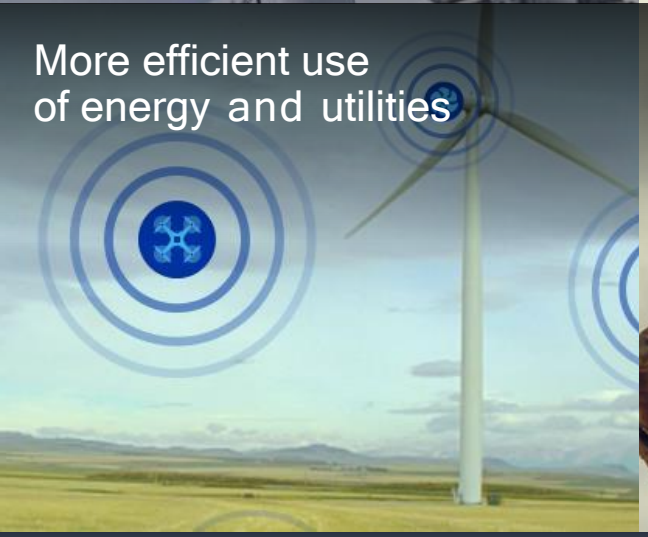


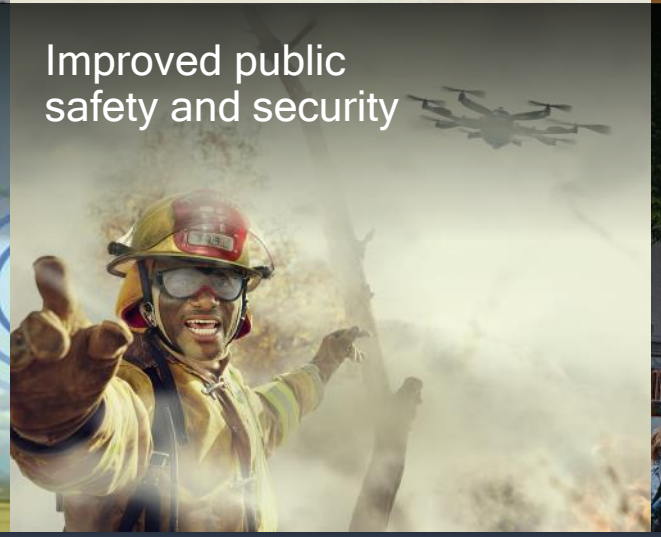
1. Source: GSMA Intelligence, January 2018











5G

5G will expand the mobile ecosystem to new industries

*The 5G Economy, an independent study from IHS Markit, Penn Schoen Berland and Berkeley Research Group, commissioned by Qualcomm

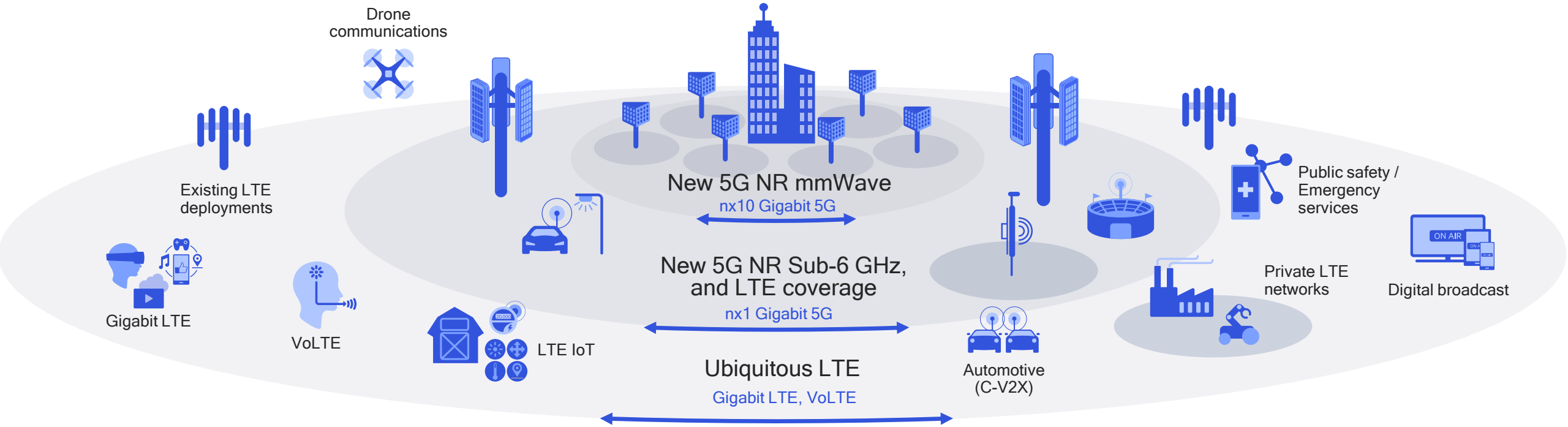
Powering the digital economy

>$12 Trillion

In goods and services by 2035*

LTE Advanced Pro accelerates the 5G mobile expansion

Providing ubiquitous coverage and essential services that complement 5G NR



Gigabit LTE is here now and delivers a seamless 5G mobile experience

LTE IoT, private LTE network, C-V2X are enabling new mobile use cases today

LTE Advanced Pro leadership is essential to success in the 5G Era

Providing essential services to 5G from Day 1

Also digital TV, public safety, drone communication, and more…

5G NR mmWave

5G NR sub-6 GHz

LTE Advanced Pro

Gigabit LTE with LAA

Enables ubiquitous Gigabit-class mobile experiences globally; LAA co-siting benefits 5G NR mmWave coverage

Voice (VoLTE)

Delivers essential voice services for a wide variety of 5G use cases leveraging ubiquitous LTE networks

LTE IoT (eMTC + NB-IoT)

Starts to connect the massive IoT today; deployable in-band with 5G NR to enable new 5G NR IoT deployments

Cellular V2X (C-V2X)

Establishes the foundation for safety use cases; continued 5G NR C-V2X evolution for future autonomous cars

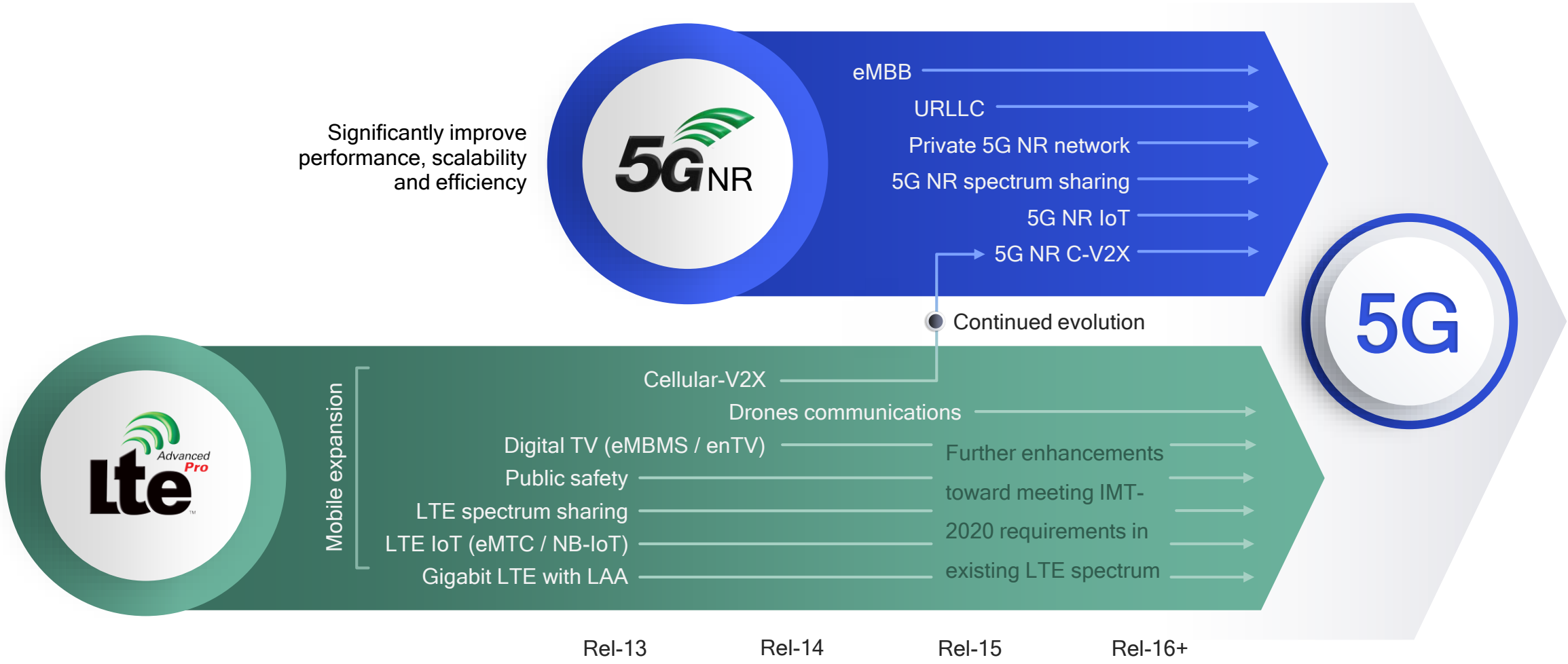
Private LTE Network

Deploys optimized, dedicated, on-premise network for industrial IoT use cases; paving the path to private 5G NR networks

1. ITU Recommandation ITU-R M.2083-0, September 2015

LTE-A Pro will be submitted with 5G NR to meet IMT-2020[1] requirements

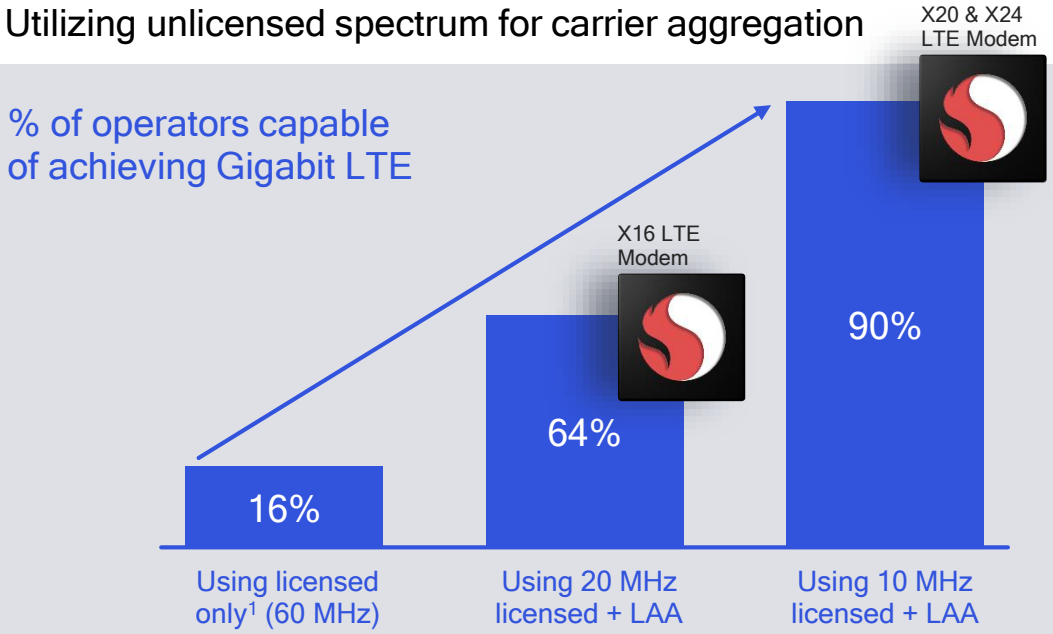
A rich and continued roadmap of LTE Advanced Pro advancements is foundational to the 5G evolution



Gigabit LTE delivers 2 Gbps now and is essential to 5G

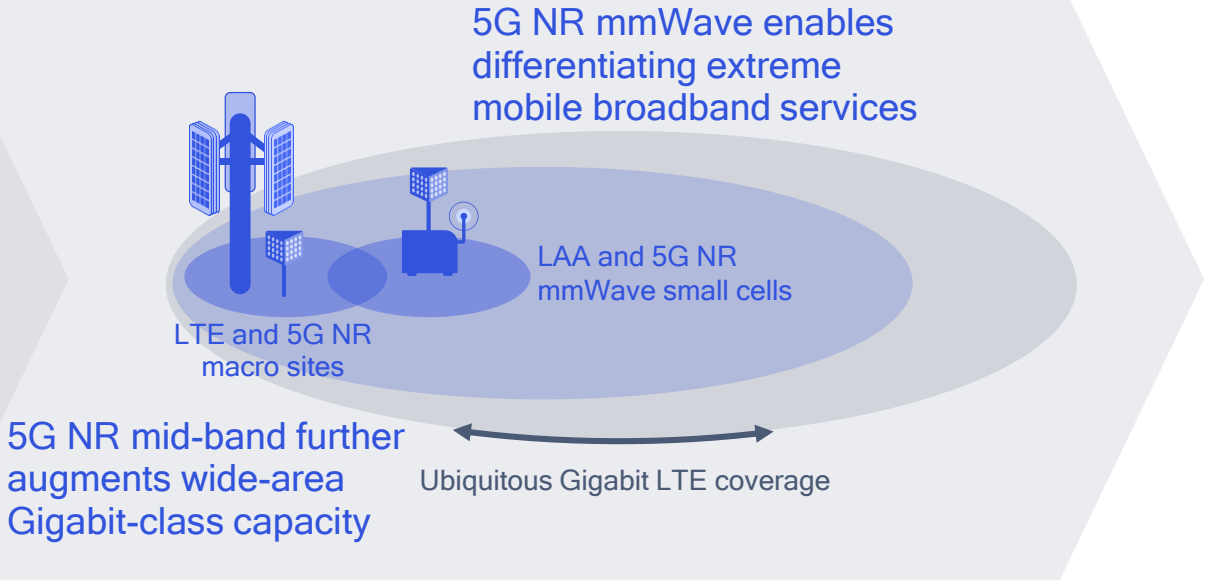
LAA enables global deployments

Utilizing unlicensed spectrum for carrier aggregation



LTE infrastructure benefits 5G NR deployment

Co-siting with LAA small cells to achieve significant mmWave coverage[2]



Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. and/or its subsidiaries 1. Based on the use of 4x4 MIMO and 256-QAM; 2. Based on mmWave coverage study, more details at https://www.qualcomm.com/documents/white-paper-5g-nr-millimeter-wave-network-coverage-simulation

Qualcomm snapdragon

Over 20 commercial devices, including smartphones, always connected PCs, and more…

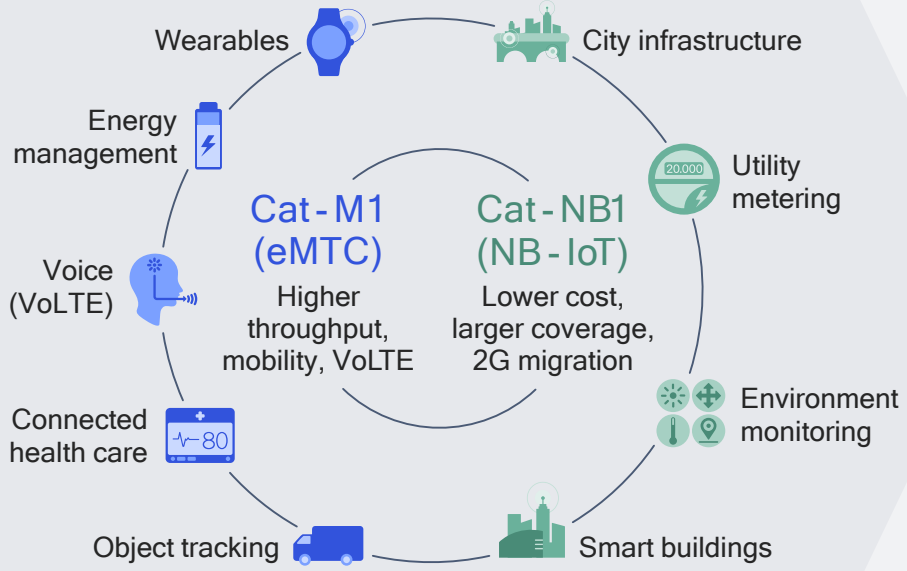
Learn more at: https://www.qualcomm.com/gigabit-lte

45 Operators in 26 countries with Gigabit LTE planned or trialed

LTE IoT will be the massive IoT solution in the 5G Era

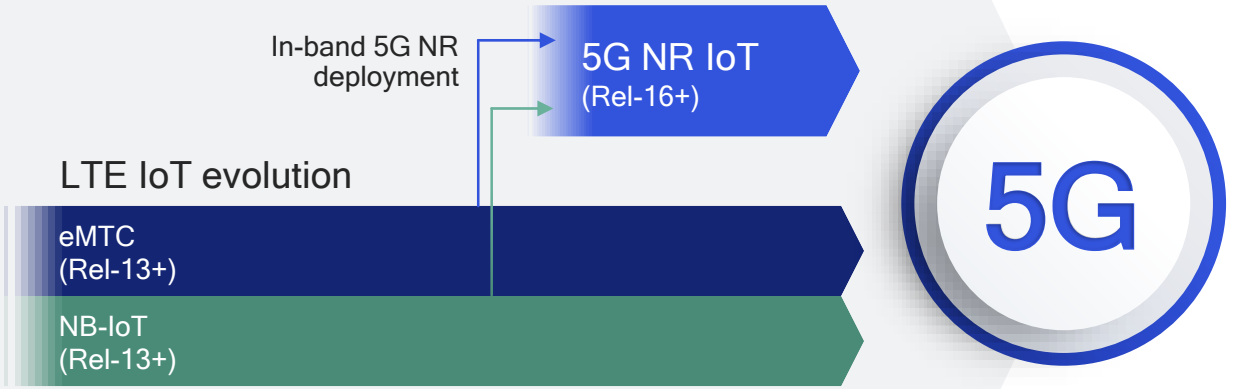
Starting to connect the massive IoT today

With global commercial Cat-M1/NB1 network deployments



5G NR IoT fully leverages LTE IoT

Deploying eMTC and NB-IoT in-band with 5G NR



LTE IoT will be submitted along with 5G NR to meet 5G requirements defined by IMT-2020[1]

MDM9206 is a product of Qualcomm Technologies, Inc and/or its subsidiaries

Qualcomm MDM9206

Flexible LTE IoT chipset platform for Cat-M1 / Cat-NB1 / E-GPRS

Learn more at: https://www.qualcomm.com/lte-iot

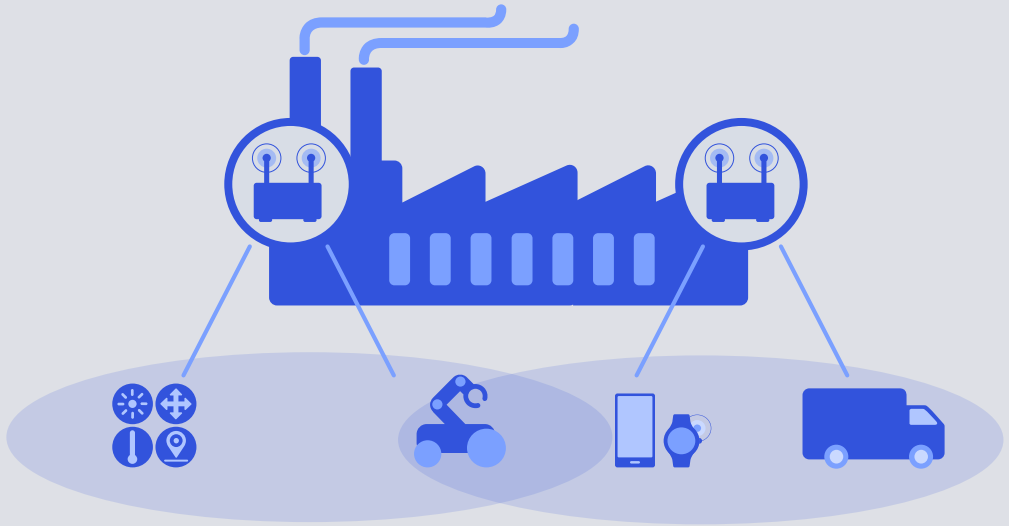
- Global dual-mode solution – single SKU
- Pre-certified modules commercially available today
- Multiple design wins across industry-leading OEMs

1. Defined in ITU Recommendation ITU-R M.2083-0, September, 2015

Private LTE network addresses industrial IoT needs today

Optimizing LTE for the industrial IoT

Scalable from Gigabit LTE to LTE IoT



Paving the path to private 5G NR networks

Advanced capabilities in 3GPP Release 15 Study Items[1]

- Ultra-reliable low-latency
- Time-sensitive networking
- mmWave for extreme eMBB
- Wireless industrial ethernet

1. TR 22.821 Feasibility Study on LAN Support in 5G and TR 22.804 Study on Communication for Automation in Vertical Domain

Optimized

Tailored for industrial applications, e.g., QoS, latency, security

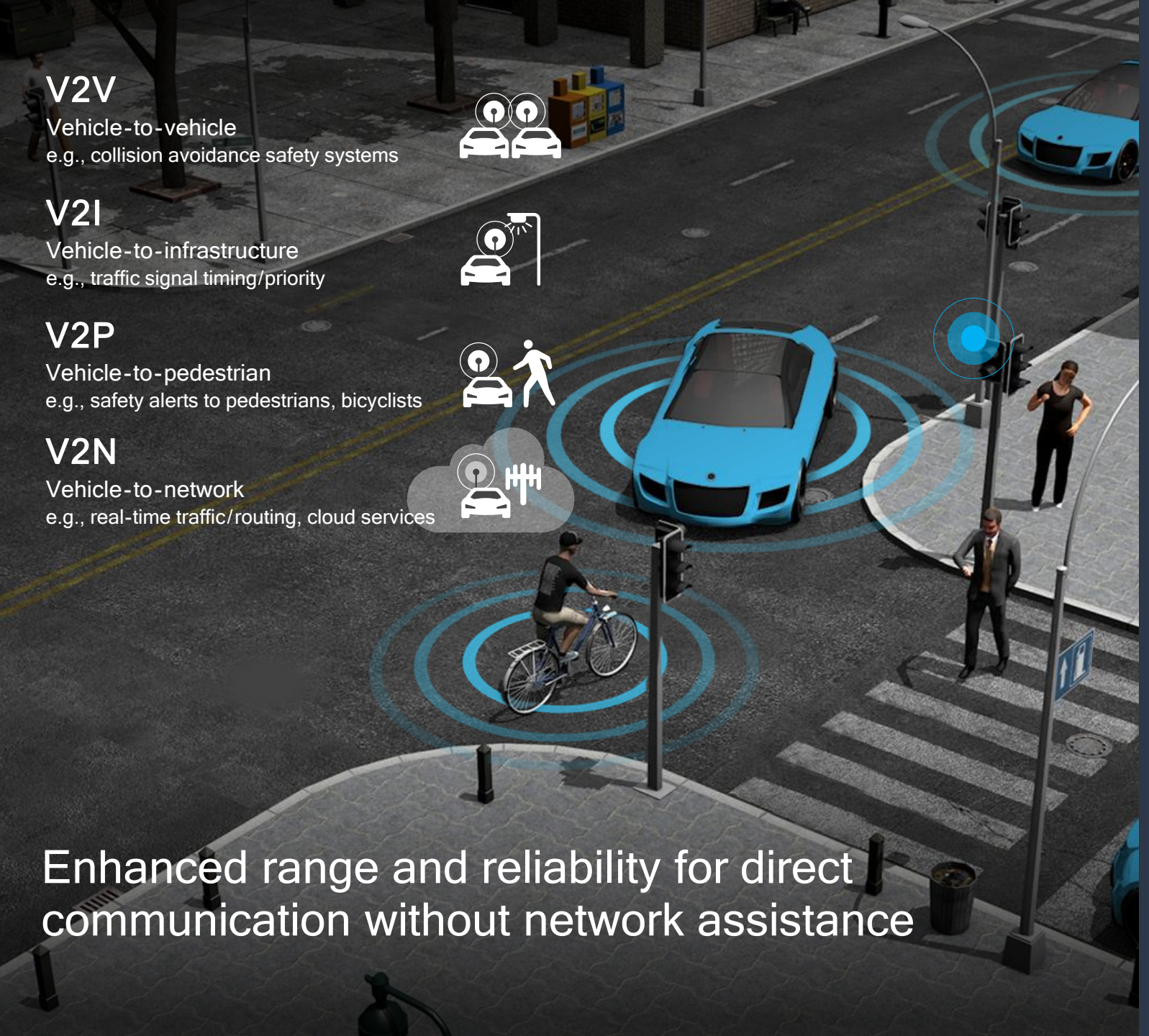
Dedicated

Easy to deploy small-cells, hosted or self-contained core network

On-premise

Locally managed, sensitive data stays local

Learn more at: https://www.qualcomm.com/private-lte



C-V2X

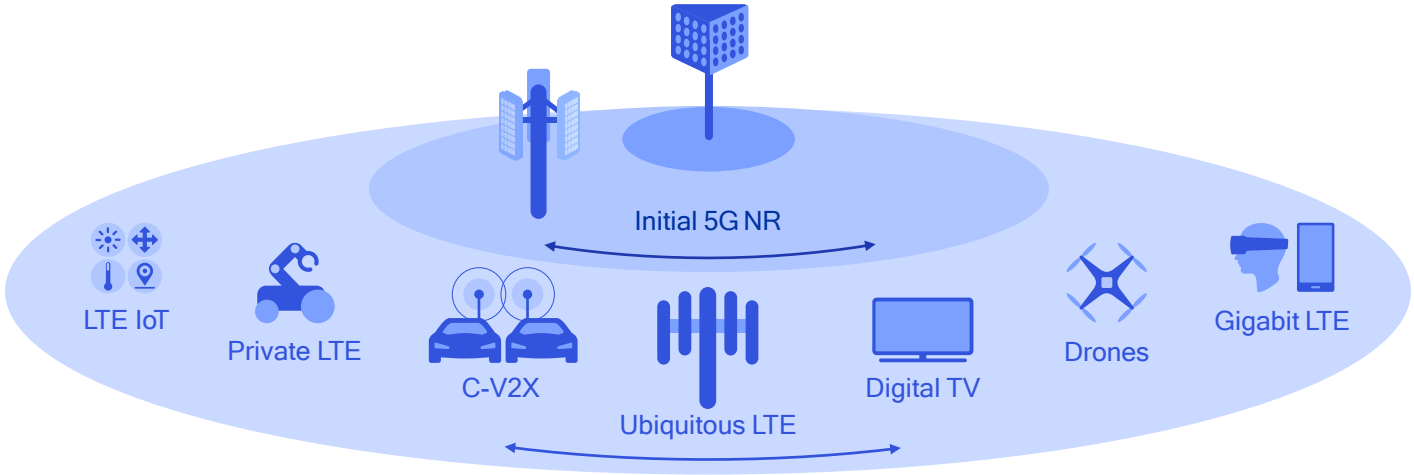
Establishes the foundation for safety use cases and a continued 5G NR C-V2X evolution for future autonomous vehicles

- C-V2X Release 14 completed in 2017
- Broad industry support – 5GAA
- Global trials started in 2017
- Our 1st announced C-V2X product in September, 2017

Learn more at: https://www.qualcomm.com/c-v2x

LTE Advanced Pro accelerates the 5G mobile expansion

Providing ubiquitous coverage and essential services that complement 5G NR



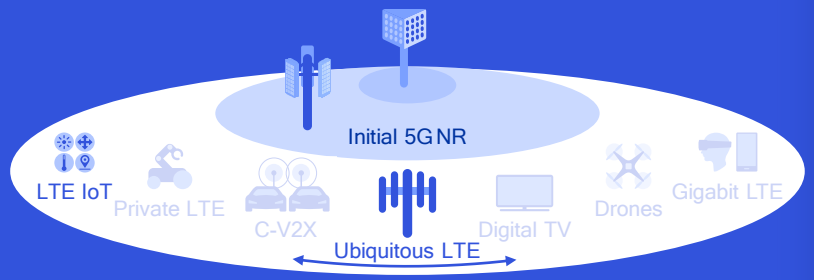
LTE IoT starts to connect the massive IoT and will be the 5G NR IoT solution

Low complexity and power

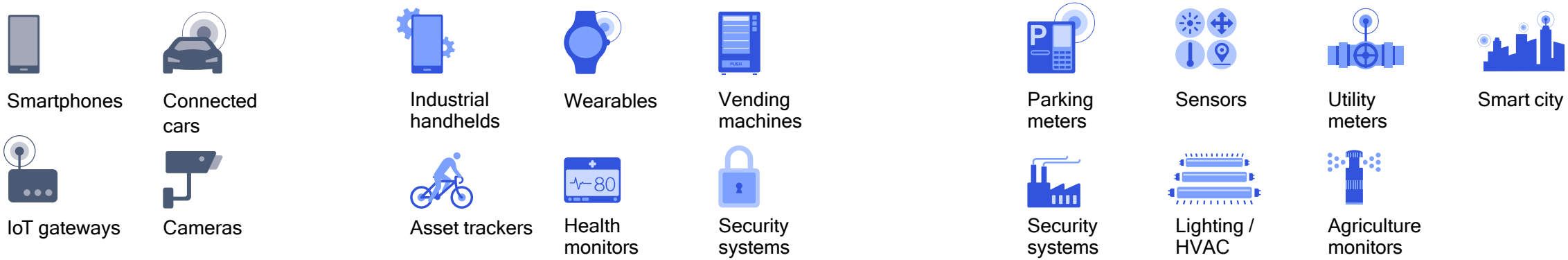
Long range

Large scale

In-band 5G NR deployment



LTE today provides a scalable IoT connectivity platform



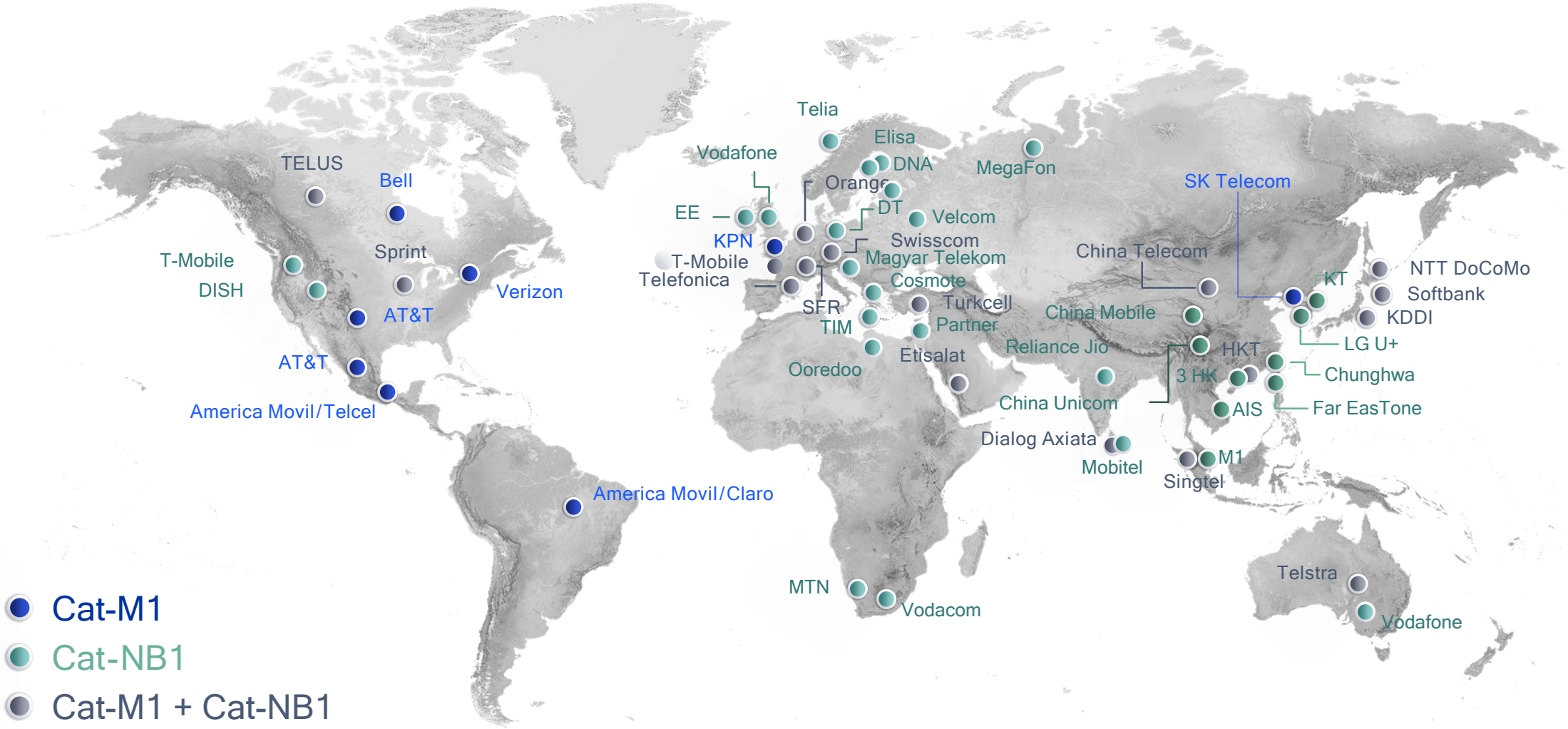
LTE IoT: complementary narrowband technologies scaling down in complexity/power

	LTE Cat-1 and above For high-performance IoT and eMBB – scalable to Gigabit LTE	eMTC Cat-M1[1] For the broadest range of low-complexity IoT use cases	NB-IoT Cat-NB1[1] For delay-tolerant, ultra-low complexity IoT use cases
Peak data rate		Up to 1 Mbps[2]	<100 kbps
Bandwidth		1.4 MHz	200 kHz
Rx antenna		Single Rx	Single Rx
Duplex mode		Full or half duplex FDD/TDD	Half duplex FDD
Mobility		Limited-to-full mobility	Cell reselection only
Voice		VoLTE	No voice support
Transmit power		23, 20 dBm[3]	23, 20 dBm[3]
Deployment		In-band	Standalone, in-band, guard band

1. Based on Release-13, Release 14 provides additional enhancements; 2. Full duplex mode, ~300 kbps in half-duplex mode; 3. Integrated PA possible

Strong global momentum for LTE IoT—May 2018 status

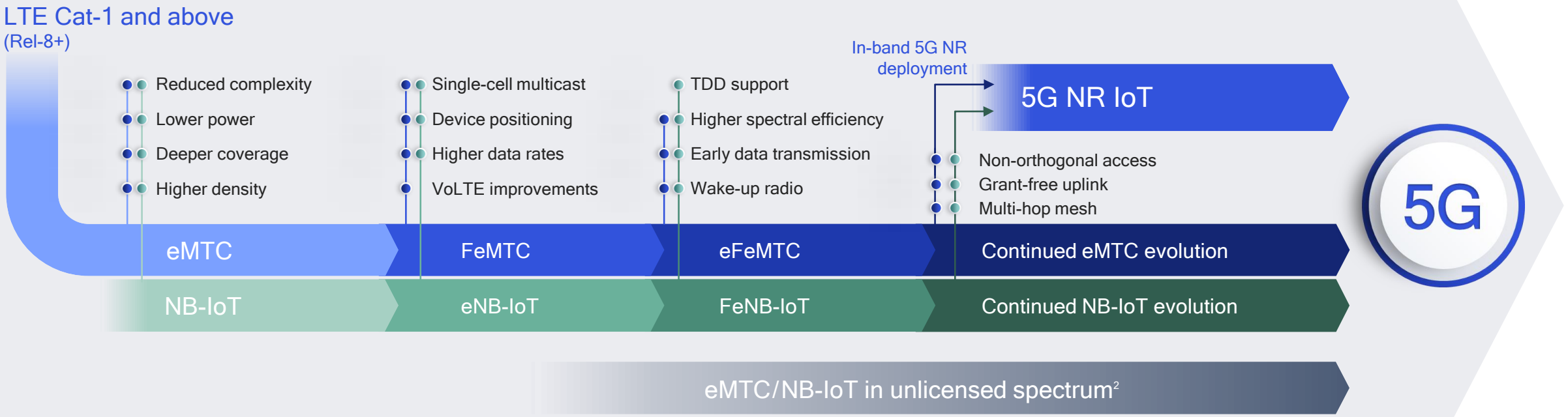
50+ commercial Cat-M1 and/or Cat-NB1 networks in over 30 countries



Sources: GSA NB-IoT/LTE-M: Global Market Status, Mar'18; AT&T, NTT DoCoMo, KDDI, KPN, Orange, TELUS, Telstra, Telefonica, Verizon, Feb.'17, Sprint May '17, Bell June '17; SKT, Softbank, SFR from GSA 4G Market & Technology Update, Jan. '17

Continued evolution to meet tomorrow's massive IoT needs

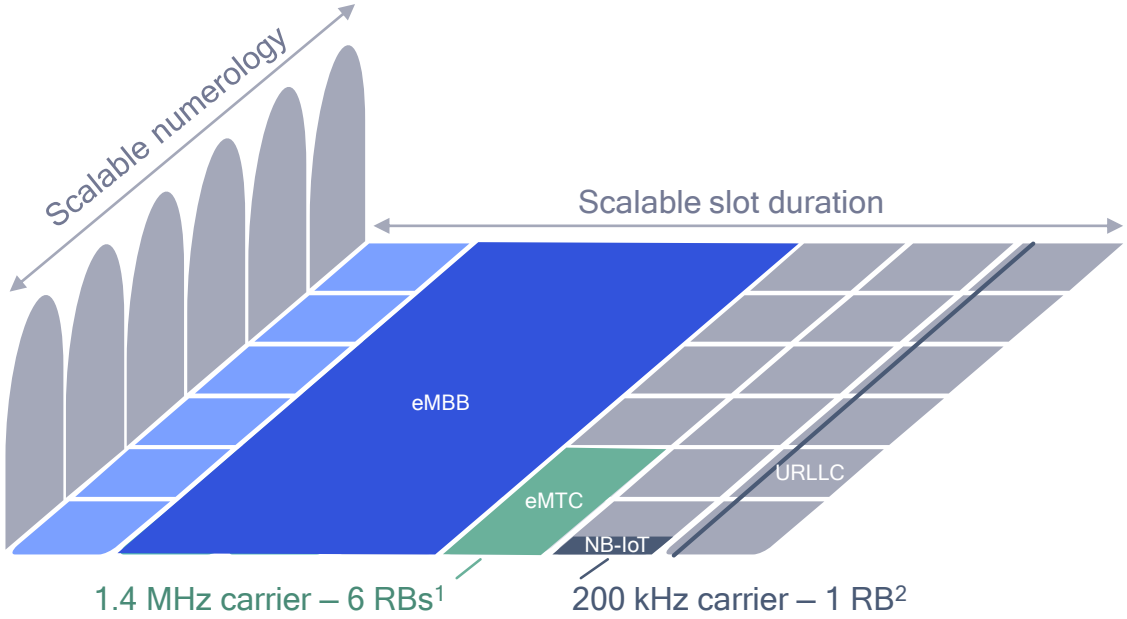
Essential to 5G – LTE IoT to be submitted to meet IMT-2020[1] requirements



1. Defined in ITU Recommendation ITU-R M.2083-0, September, 2015; 2. Standardization in MulteFire Alliance

5G NR IoT to fully leverage the LTE IoT evolution

Enabled by in-band deployment of LTE IoT in 5G NR spectrum



In-band eMTC / NB-IoT support in Rel-16

5G NR 2^n scaling of 15 kHz subcarrier spacing is natively compatible with eMTC and NB-IoT numerologies

Agnostic to core networks

Both 5G NR deployment options – NSA with LTE EPC and SA with 5G core – support eMTC and NB-IoT evolution

Advanced features coming in Rel-16+

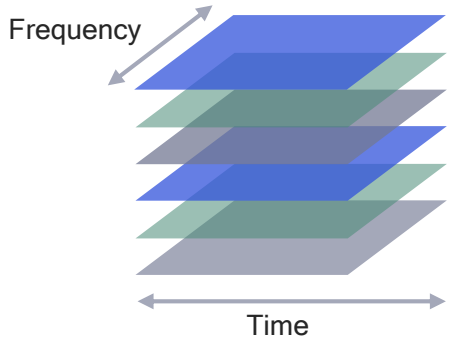
Non-orthogonal access, grant-free uplink, and multi-hop mesh will deliver even better performance and efficiency

1. Cat-M1 uses 6 Resource Blocks (RBs) with 12 tones per RB at 15 kHZ SCS; 2. Cat-NB1 uses 1 Resource Block (RB) with 12 tones with 12 tones per RB at 15 kHz SCS, single-tone option also available

5G NR Flexible framework designed to support future evolution addressing even broader IoT use cases such as latency sensitive applications

Pioneering tomorrow's massive IoT technologies

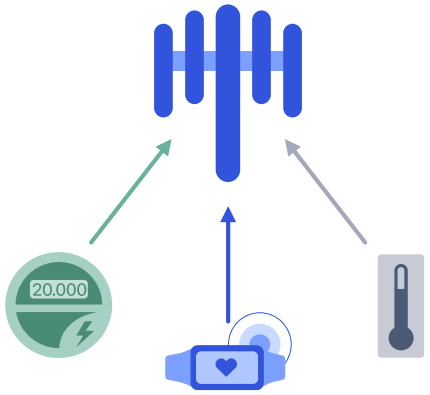
Applies to LTE IoT and 5G NR IoT evolution – potential for 3GPP Rel-16+



Non-orthogonal multiple access

Even higher connection density

- NOMA is part of 5G NR Rel-15 Study Item
- Can be either scheduled or grant-free
- Increases device density and network efficiency

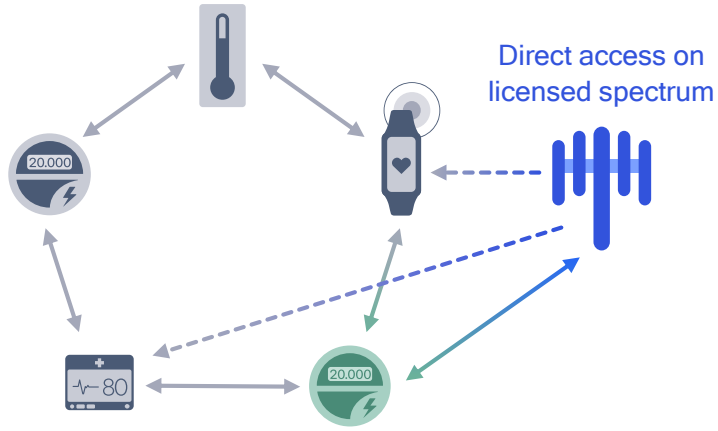


Grant-free uplink

Autonomous mode transmission

- Contention-based access for IoT devices
- For sporadic uplink of small data bursts
- Also key enabler of mission-critical communication

Mesh on unlicensed or partitioned with uplink licensed spectrum[1]



Mesh networking

Multi-hop mesh with WAN management

- For low-power devices with challenging placements
- Especially uplink data relayed via nearby devices
- Expands on LTE Device-to-Device (D2D)

1. Greater range and efficiency when using licensed spectrum, e.g. protected reference signals. Network time synchronization improves peer-to-peer efficiency

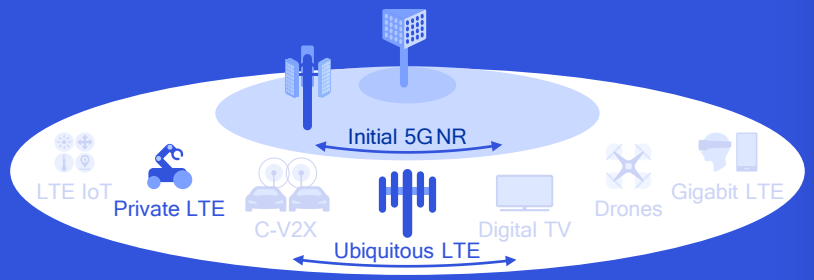
Private LTE network enables optimized industrial IoT use cases

Dedicated local network

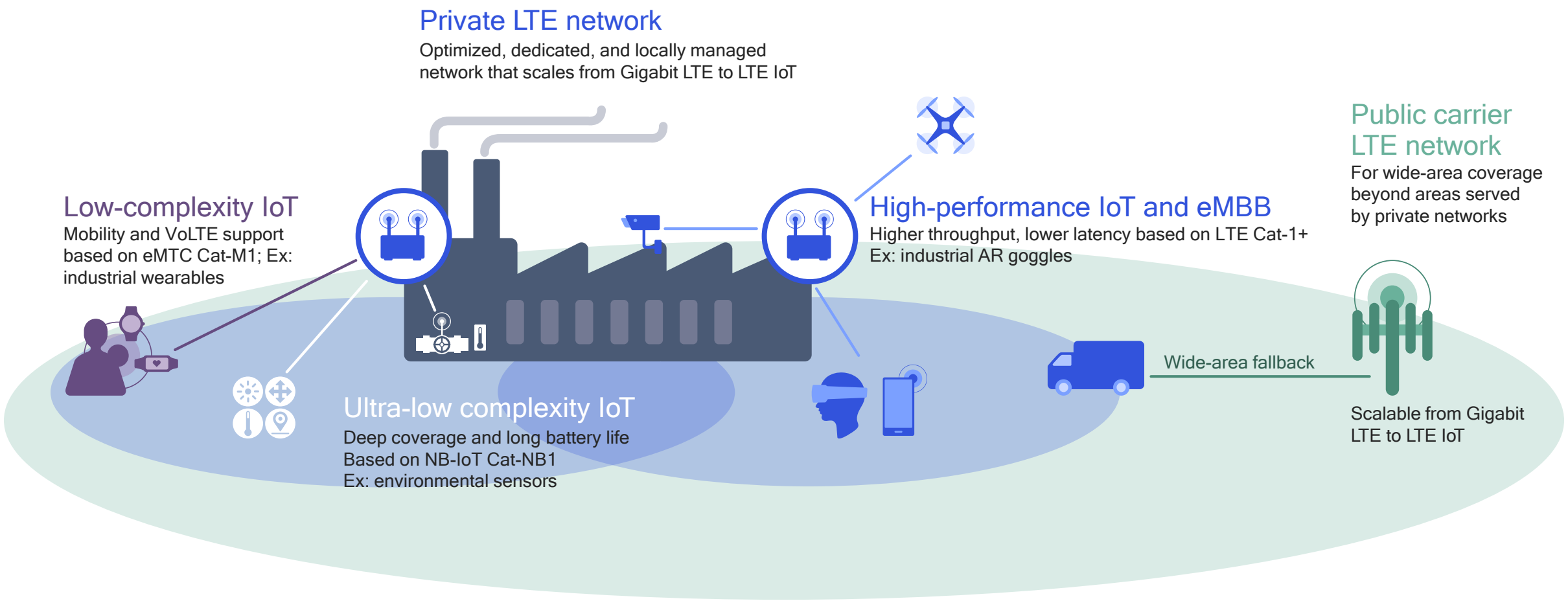
Customized services

Ready for deployment

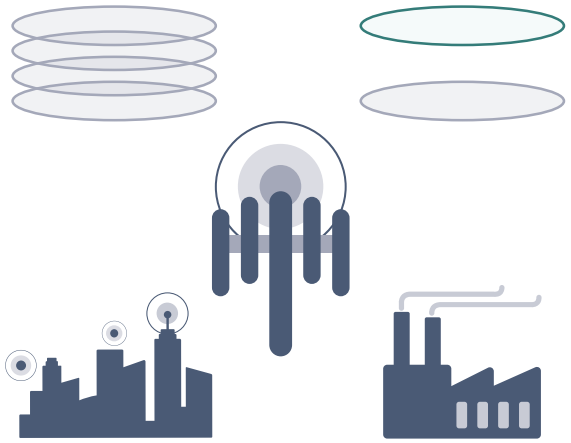
Path to private 5G NR network



Providing a scalable platform for diverse IIoT use cases



Private LTE Networks—an opportunity for mobile operators

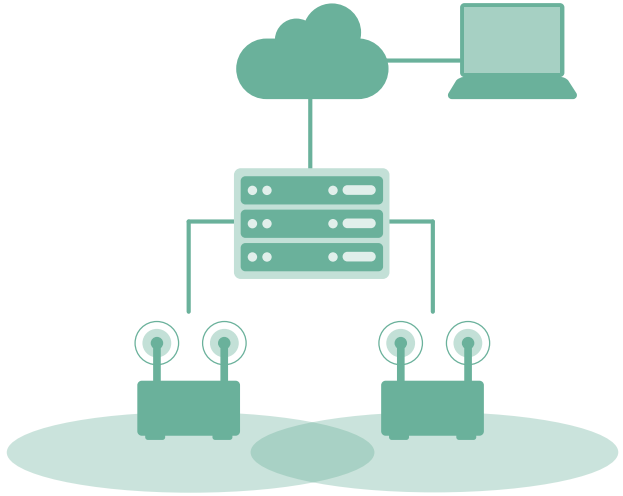


Licensed spectrum assets

Dedicate a portion for private LTE networks

Provides predictable performance

Spectrum often under-utilized in industrial areas



Expertise in mobile networks

Expertise in deploying and operating mobile networks

Existing relationships with vendors

Leverage existing mobile network assets

Existing sales channels

Already provide services to many industrial customers

Extend with private LTE network

Multiple options, including selling private LTE network as a service

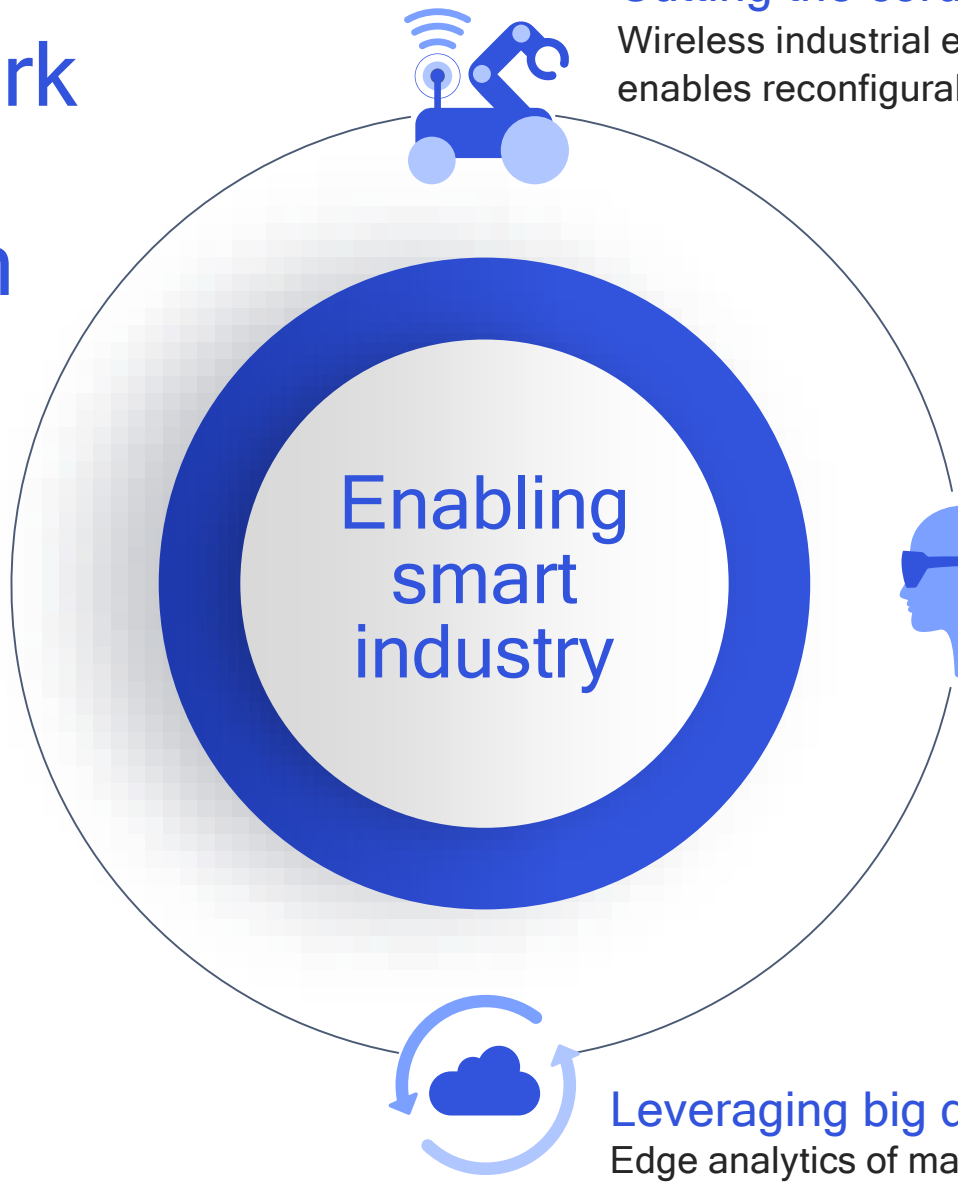
Private 5G NR network enables the next Industrial Revolution

New capabilities
- URLLC – ultra-reliable, low-latency
- Time sensitive networking

Large cellular ecosystem
- Global solutions
- Certified interoperability

More spectrum
- Licensed, shared, unlicensed
- Low, mid, mmWave spectrum

Single network for the entire factory
- Multimode network supporting LTE & 5G NR
- Scalable to all connectivity needs



Cutting the cord
Wireless industrial ethernet enables reconfigurable factories

Enabling new use cases
Such as operators using Augmented Reality (AR) glasses

Leveraging big data analytics
Edge analytics of massive real-time data collection increases productivity

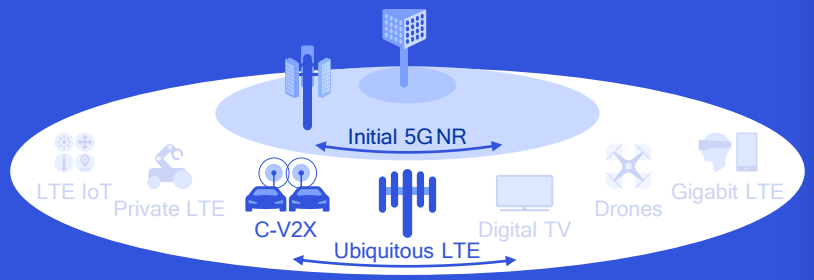
C-V2X establishes the safety foundation for future autonomous vehicles

Enhanced safety

Low-latency and high-reliability

Network-independent

Forward compatible to 5G NR C-V2X



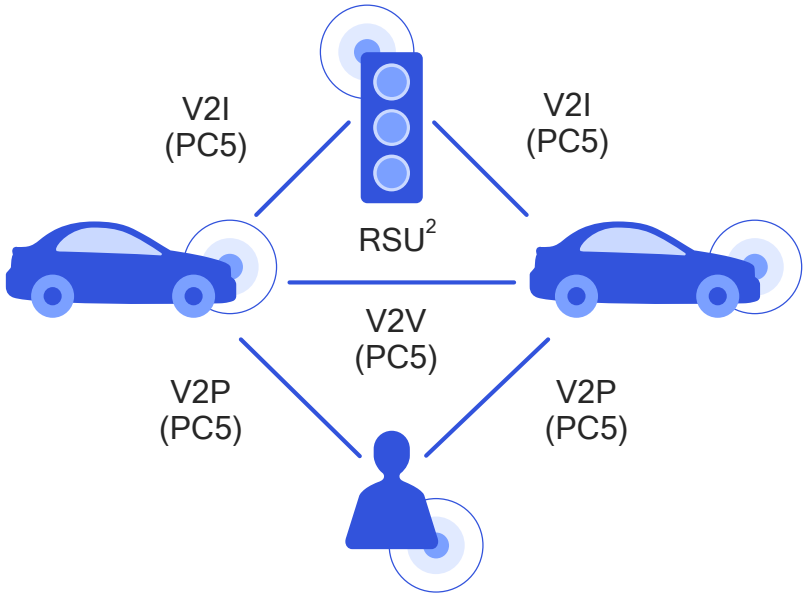
C-V2X enables network independent communication

Direct safety communication independent of cellular network

Low latency Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), and Vehicle to Person (V2P) operating in ITS bands (e.g. 5.9 GHz)

Direct PC5 interface

e.g. location, speed, local hazards

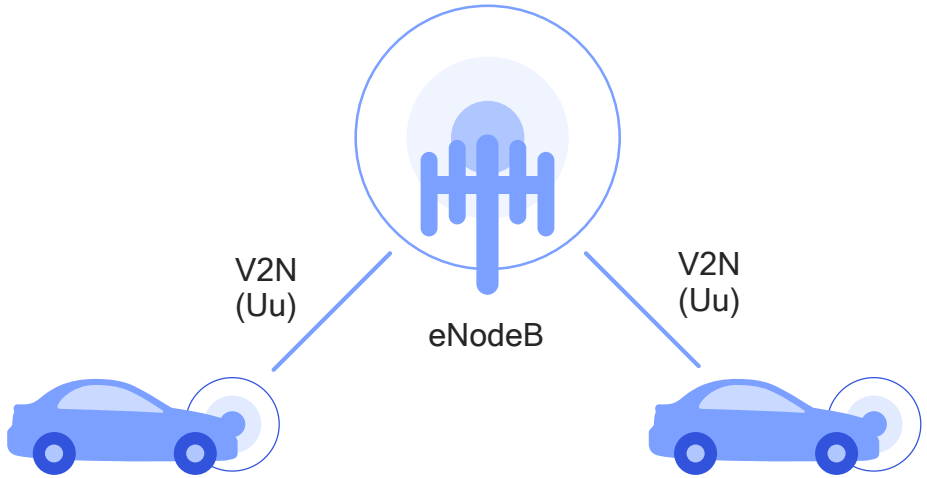


Network communications for complementary services

Vehicle to Network (V2N) operates in a mobile operator's licensed spectrum

Network Uu interface

e.g. accident 2 kilometer ahead



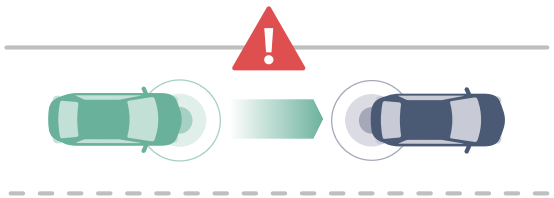
1. PC5 operates on 5.9GHz; whereas, Uu operates on commercial cellular licensed spectrum 2. RSU stands for roadside unit.1. 3GPP also defines a mode, where eNodeB helps coordinate C-V2X Direct Communication; 2. GNSS is required for V2X technologies, including 802.11p, for positioning. Timing is calculated as part of the position calculations and it requires smaller number of satellites than those needed for positioning

C-V2X has a strong evolution path towards 5G NR

While maintaining backward capabilities

Evolution to 5G NR, while being backward compatible
C-V2X Rel-14 is necessary and operates with Rel-16

Basic safety
IEEE 802.11p

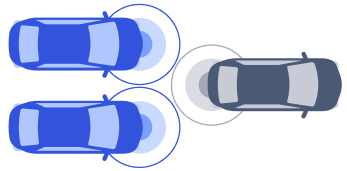


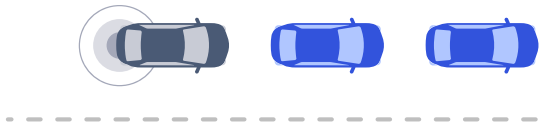
Basic and enhanced safety
C-V2X Rel-14/Rel-15 with enhanced range and reliability

Autonomous driving use cases
5G NR C-V2X Rel-16

Backward compatible with Rel-14/Rel-15 enabled vehicles

Higher throughput
Higher reliability
Wideband ranging/positioning
Lower latency





5G NR C-V2X complements Rel-14 with new capabilities

Targeting new use cases for autonomous driving

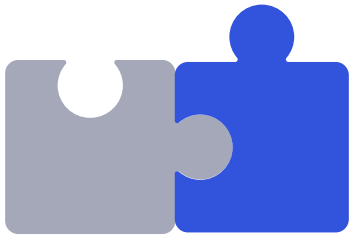
Rel-14 C-V2X

Automotive safety

Do not pass warning (DNPW)

Intersection movement assist (IMA) at a blind intersection

Blind curve / Local hazard warning



Rel-16 5G NR C-V2X

Autonomous driving

Local high definition maps / “Bird’s eye view”

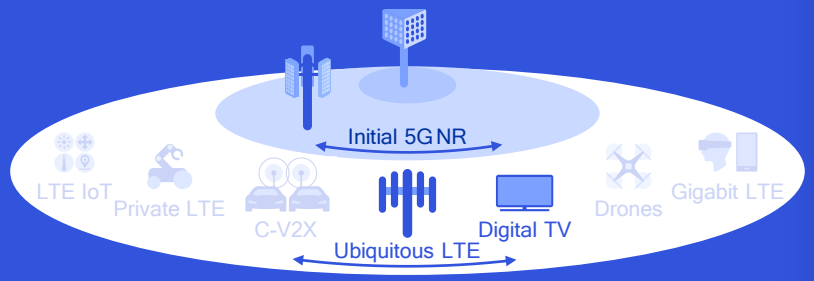
Intention / Trajectory sharing

High throughput sensor sharing

Wideband ranging and positioning

LTE eMBMS/enTV is the 5G Broadcast solution

- High spectrum efficiency
- Scalable capacity
- For next-gen digital TV delivery
- Meets 5G broadcast requirements



LTE broadcast addresses a wide range of services

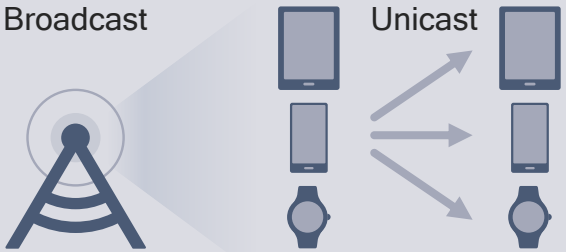
Two paths—mixed and standalone broadcasting

LTE Broadcast evolution

(Rel-14+)

Mixed-mode broadcast

Dynamic mode switching between unicast and broadcast to more efficiently deliver identical content (e.g., OTA firmware update) over the network



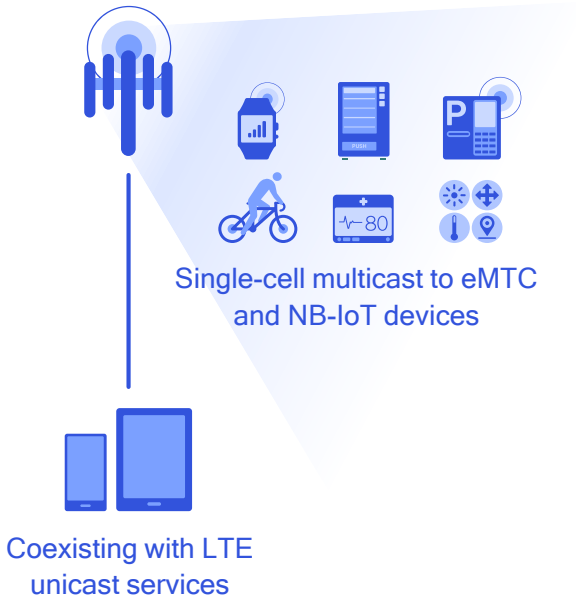
Terrestrial broadcast

Dedicated broadcasting network that provides a common delivery platform for different contents and services (e.g., for next-gen digital TV)

Mixed-mode broadcast is essential to new mobile services

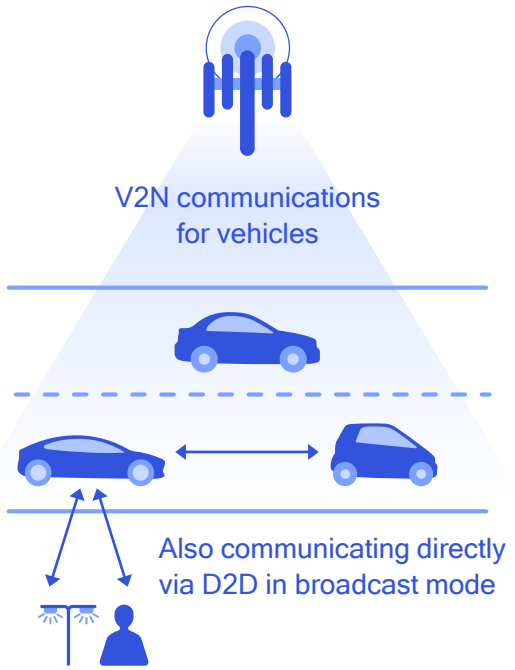
Enabling new capabilities and efficiencies for a wide variety of use cases

LTE IoT
3GPP Rel-14+



Enhancing SC-PTM[1] to enable efficient firmware upgrade and group messaging

C-V2X
3GPP Rel-14+

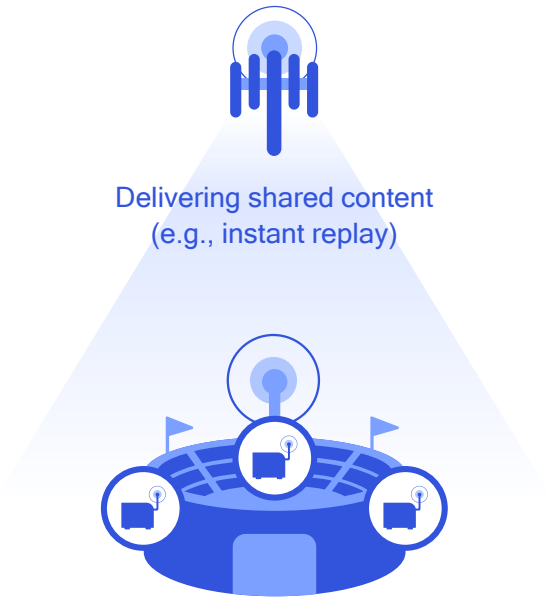


V2N builds upon eMBMS to deliver real-time information (e.g., traffic) to vehicles

Public safety
3GPP Rel-12+

Leveraging eMBMS to efficiently deliver real-time emergency notifications

Venue broadcast
3GPP Rel-9+



Dynamic broadcast can offload mass media traffic in high-density deployments

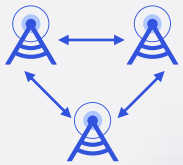
1. Single cell point to multipoint defined in 3GPP Rel-13

Terrestrial broadcast for next-gen digital TV delivery

enTV[1] – part of 3GPP Rel-14 – meets terrestrial TV broadcast requirements

Radio access enhancements

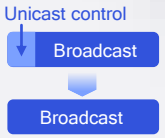
Longer range
New 1-symbol numerology with longer 200us CP[2] to support 15 km ISD[3]



More broadcast capacity
Supports dedicated broadcast network with 100% eMBMS carrier allocation

More deployment flexibility
Single network for mobile and fixed devices with enhanced support for rooftop reception

Better efficiency
New subframe design reduces overhead in dedicated broadcast transmissions



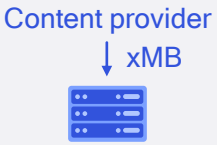
Rel-14 enTV

System layer enhancements

Receive only mode
Delivery of free-to-air content to devices without SIM/service subscription

Transport only service
TV broadcasters can deliver content in native format without transcoding

Standardized interface
Content providers can deliver media over LTE with a unified framework

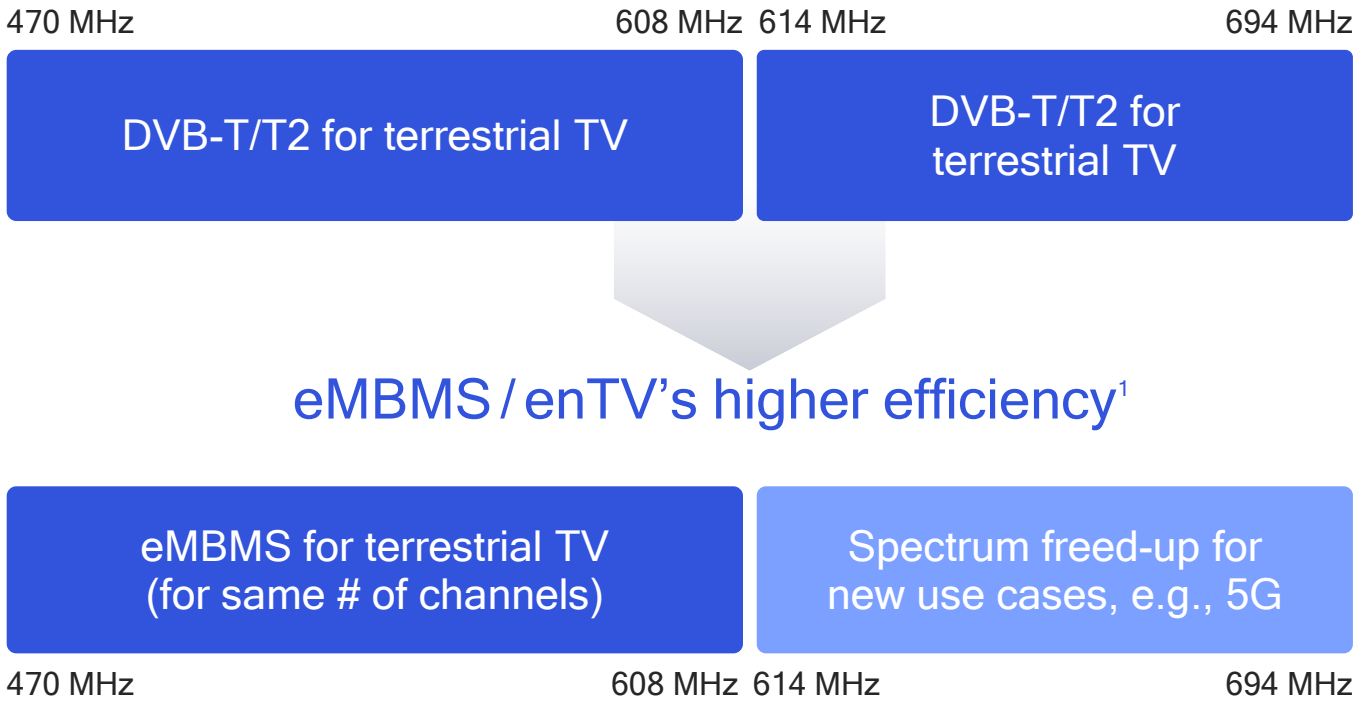


Shared broadcast
Multiple operators can serve users on a common broadcast carrier

1. Enhanced TV; 2. Cyclic Prefix; 3. Inter-site distance

enTV—a strong candidate for next-gen digital TV in Europe

Targeting deployments in re-farmed 700 MHz



Meeting all EU digital TV broadcast requirements

Regulation compliant

Allows frequency reuse and adheres to ITU-GE-06 to protect existing DTT[2] services

Wide-area coverage

Provides at least 50% edge coverage[3] for fixed TV and 95% area coverage for mobile TV

Diverse services

Supports free-to-air content delivery, paid media[4] streaming, as well as applications

Diverse deployments

Supports fixed (e.g., rooftop) and mobile (e.g., smartphone) receptions in a common spectrum allocation

1. ~2x more efficient than DVB-T/ATSC and provides longer range up to 15km (with further extended CP of 200 us and features such as 2x2 MIMO, 256 QAM, increased subframe limit); Assumptions: current broadcast technology operates in MFN mode with a frequency reuse of at least four with a spectrum efficiency of up to 4 bps/Hz inside each cell. This corresponds to an overall spectrum efficiency of approx. 1bps/Hz. Whereas eMBMS operates in SFN over the entire coverage area with a spectrum efficiency of up to 2bps/Hz; 2. Digital Terrestrial TV; 3. With margin for 1% time co-channel interference; 4. Can be video, audio, text, etc.

LTE eMBMS/enTV is the 5G broadcast solution

Building upon a strong 3GPP technology foundation

eMBMS defined for LTE starting in Rel-8[1], improving coverage and efficiency

eMBMS enhancements in Rel-12 include MOOD[2] and expansion to MCPTT[3]

Enabling terrestrial broadcast and expanding to new services; Meeting 7/10 5G Broadcast requirements[4] in Rel-14

1. 3GPP Rel-8 defined physical layer aspects, Rel-9 defined higher layer and network related aspects; 2. Multicast operation on Demand in Rel-12, evolving for per cell basis in Rel-13;
3. Mission-critical Push to Talk is part of Rel-12; 4. 5G broadcast requirements defined in 3GPP TS 38.913; 5. Such as wider area coverage up to 100 km cell radius, more efficient multiplexing with unicast, and utilizing MIMO

Accelerating cellular drone communications technology

Completed OTA testing over commercial LTE networks and 3GPP Study Item in 2017

Optimize LTE for drones in Rel-15

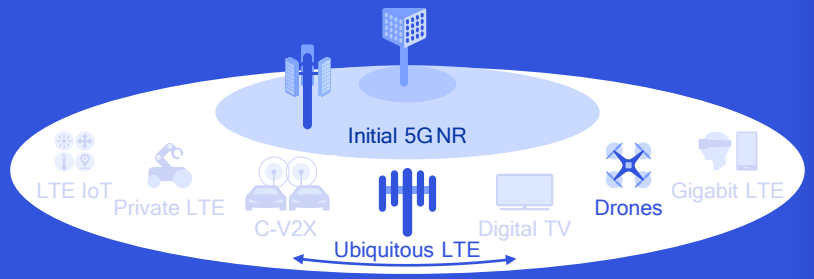
Better mobility and interference management for high-altitude operation

Guide cellular drone regulations development

For command and control, subscription verification, certification, and more

Accelerate 5G development

Specifically for massive deployments of mission-critical drone use cases



Learn more at: http://www.qualcomm.com/cellular-drones

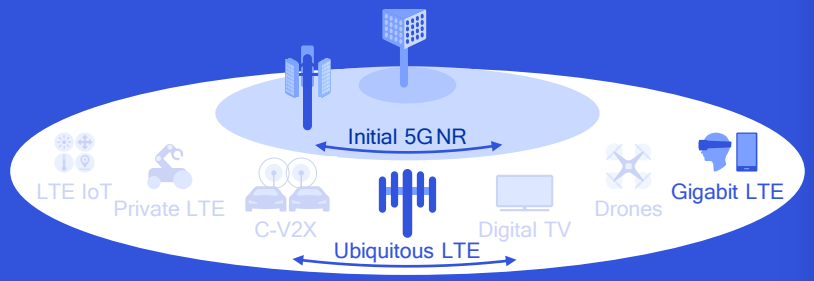
Gigabit LTE is here now and delivers a seamless 5G mobile experience

Global deployments today

Enabling next-gen mobile broadband

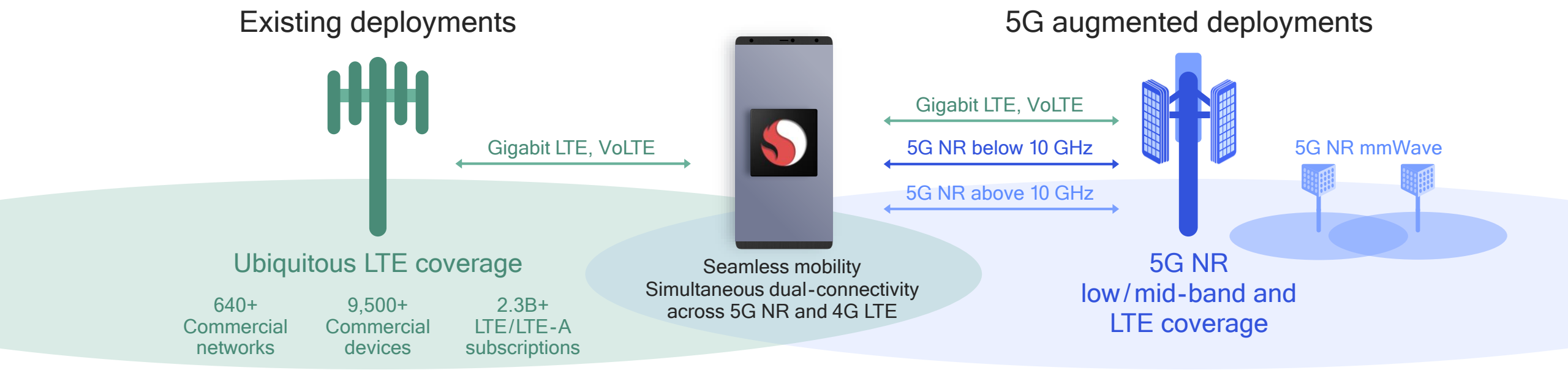
Evolving to 2 Gbps

Essential to 5G NR eMBB



Gigabit LTE provides the coverage foundation for 5G

Spectrum aggregation with 5G NR to fully leverage LTE investments



Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. Source: GSA (www.gsacom.com)—Oct 2017 on network launches, Oct 2017 on subscriptions, Nov 2017 on commercial devices

Enabling gigabit experiences everywhere

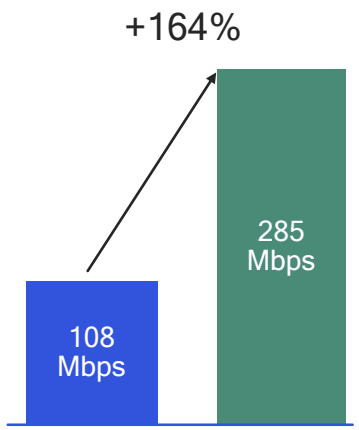
Providing VoLTE leveraging LTE's ubiquitous coverage

Supplementing 5G NR mid-band and mmWave

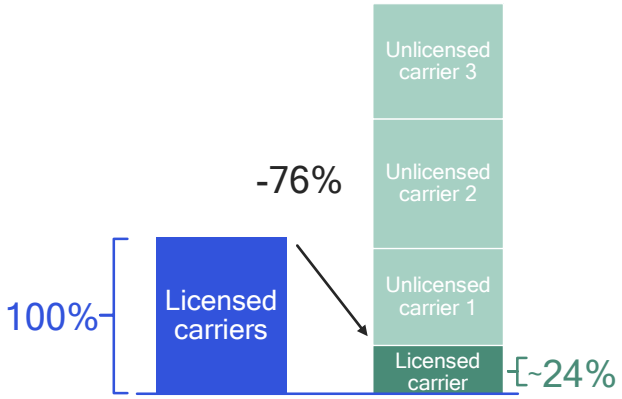
Gigabit LTE enables a more consistent 5G experience

Optimizing existing LTE networks to deliver faster throughput and more capacity

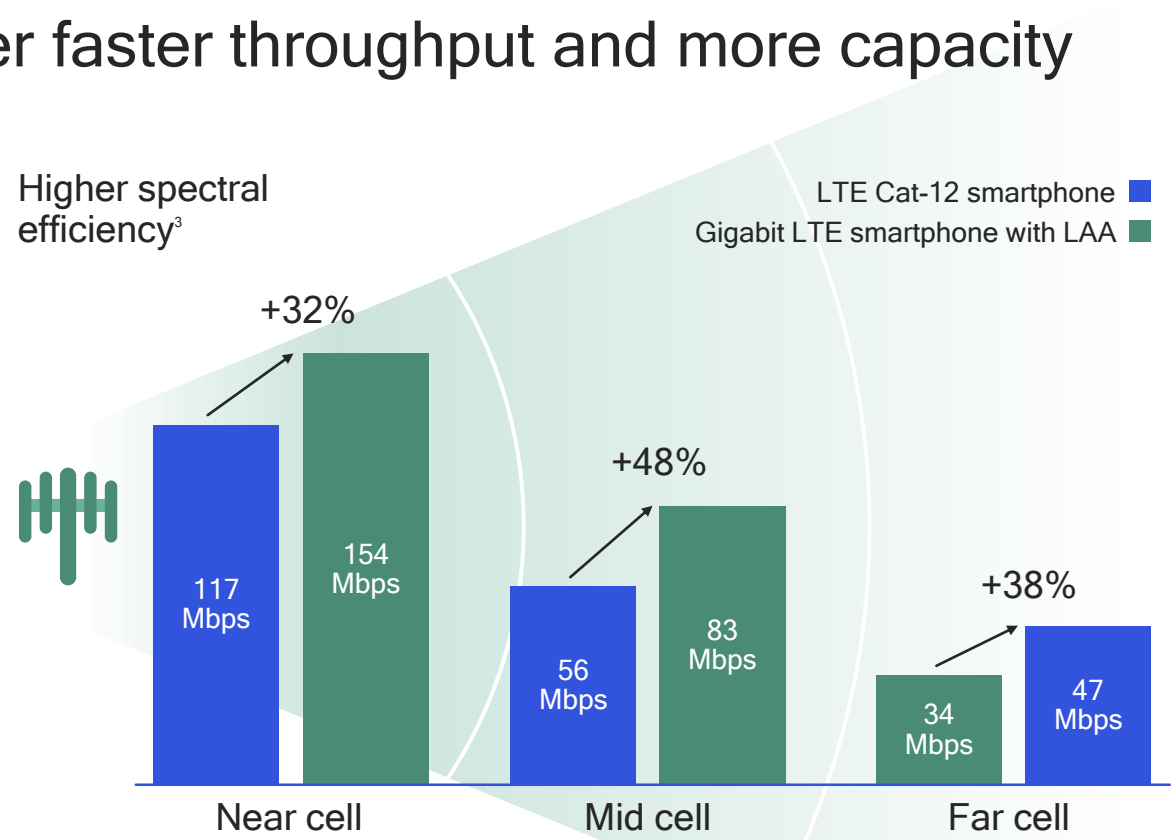
Faster experienced user throughput[1]



More capacity with fewer licensed resources[2]



Higher spectral efficiency[3]

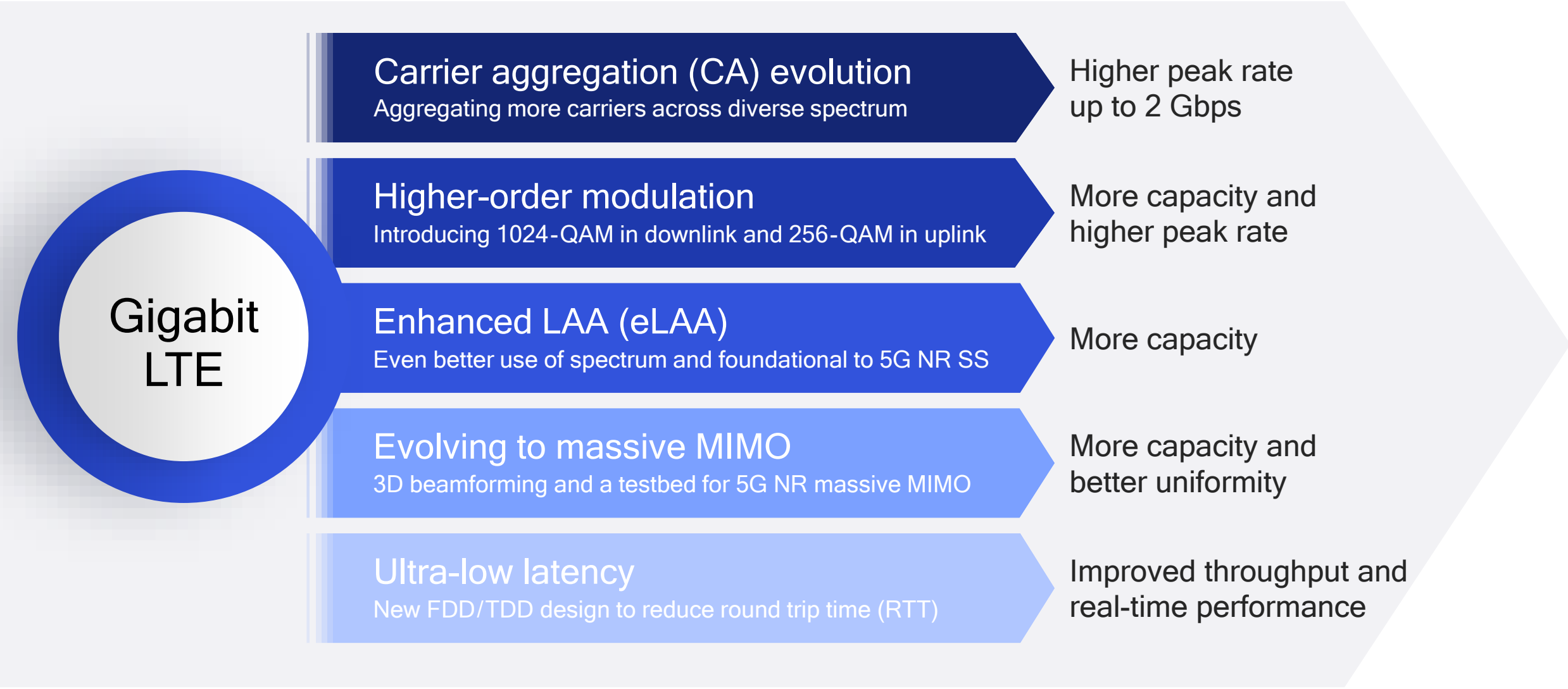


1. Based on Google Play download; 2. Using 20 MHz licensed carrier and 60 MHz unlicensed carriers, 4x4 MIMO, 256-QAM; 3. RB normalized data rates, RSRP assumptions: far cell - > -85dBm; mid cell - < -85 dBM & > -100 dBM; far cell - < -100 dBm

Based on real-world Gigabit LTE network testing by Signals Research Group

Download the full report – https://www.qualcomm.com/media/documents/impact-gigabit-lte-technologies-user-experience

Gigabit LTE continues to evolve in multiple dimensions

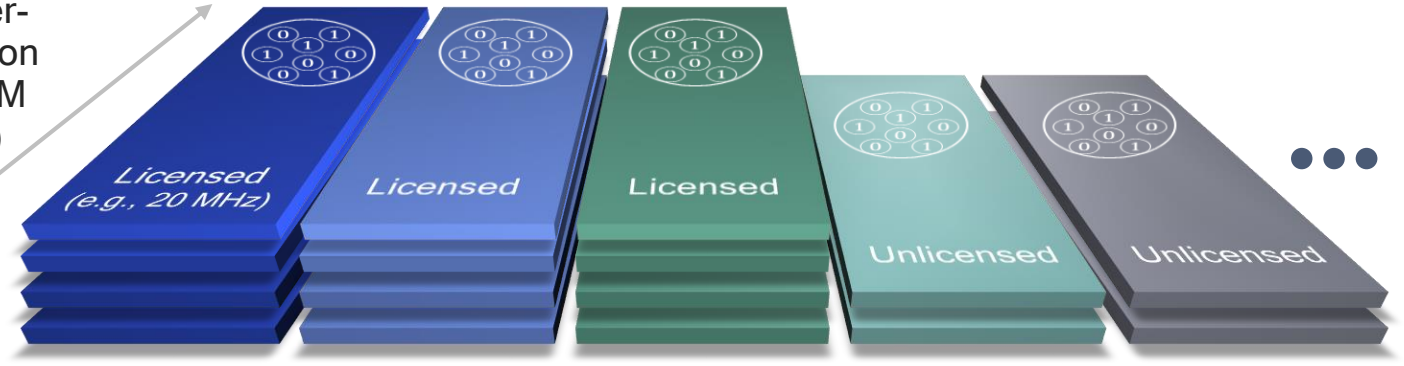


Achieving peak throughputs up to 2 Gbps

Higher peak rates by adding more, higher-efficiency ~100 Mbps streams[1,2]

Utilizing higher-order modulation (e.g., 256-QAM and beyond)

Adding up to 4 MIMO layers



1st LTE Carrier 2nd LTE Carrier 3rd LTE Carrier 4th LTE Carrier 5th ...

Aggregating more carriers across licensed and unlicensed with LAA[3]

New Gigabit LTE device categories

Qualcomm snapdragon X24 LTE Modem — Category 20 (2.0 Gbps)

Category 19 (1.6 Gbps)

Qualcomm snapdragon X20 LTE Modem — Category 18 (1.2 Gbps)

Qualcomm snapdragon X16 LTE Modem — Category 16 (1 Gbps)

1. Example configuration per 3GPP specification; 2. Each data stream ~100 Mbps per 20 MHz stream with 256-QAM; 3. Licensed Assisted Access

Which Chipsets support Gigabit LTE?

Portfolio of Gigabit LTE Products

1st Gigabit LTE Generation

Qualcomm snapdragon X16 LTE modem

4xCA | 1.0 Gbps | 10 streams

2nd Gigabit LTE Generation

Qualcomm snapdragon X20 LTE modem

5xCA | 1.2 Gbps | 12 streams

3rd Gigabit LTE Generation

Qualcomm snapdragon X24 LTE modem

7xCA | 2.0 Gbps | 20 streams

Qualcomm snapdragon X24 LTE modem

Our best LTE modem yet – unprecedented user throughput enabling breakthrough mobile performance

World's first announced

2 Gbps LTE modem

Breakthrough mobile user experience

World's first announced

7nm Chip

Lower power, smaller footprint*

World's first announced

14nm RF Chip

Better power efficiency*

World's first announced

7x Carrier Aggregation

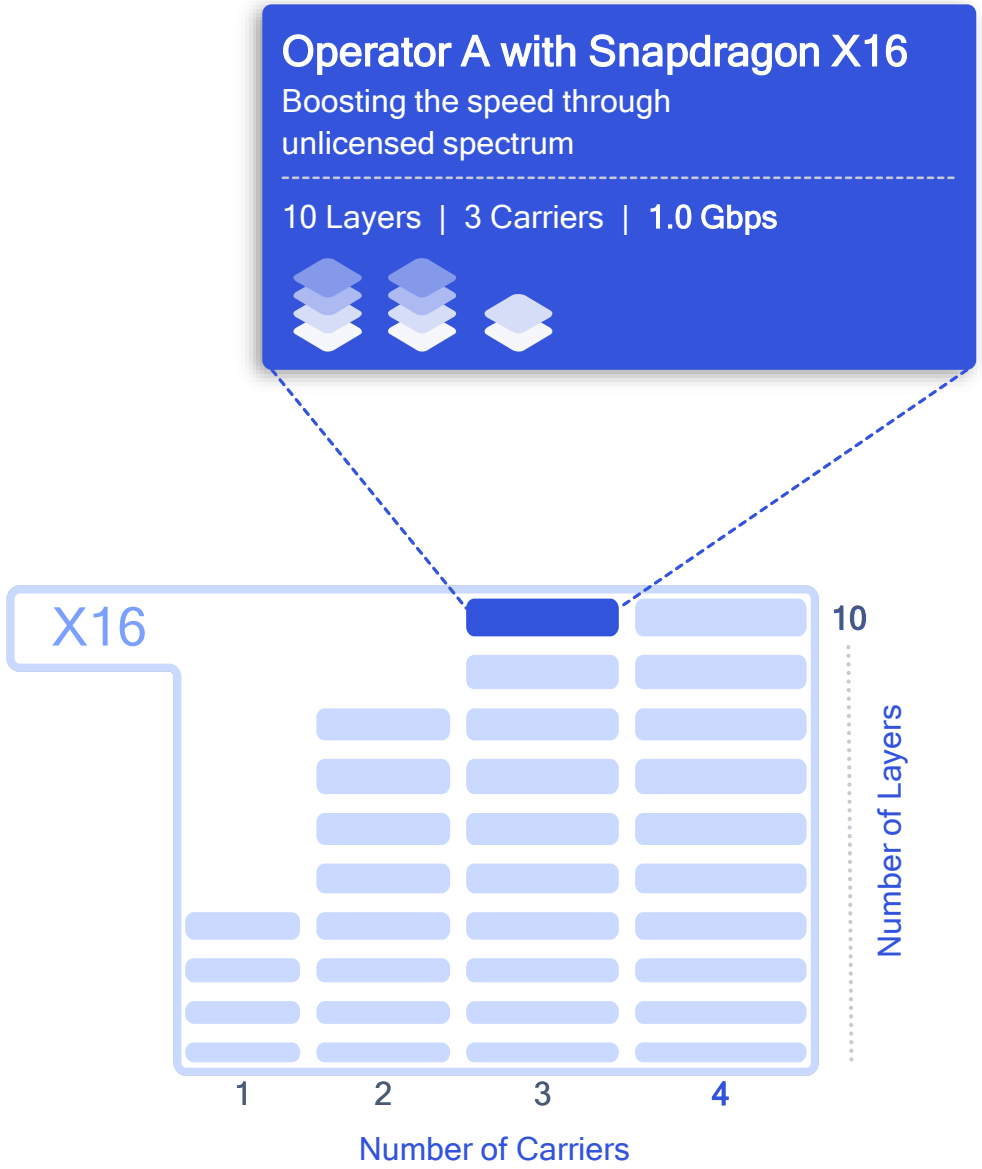
Expanded Gigabit footprint

*Compared to larger feature size fabrication processes.

Snapdragon X24: Full utilization of operator spectrum

7xCA and 20 spatial streams allow wider variety of ways to deploy Gigabit LTE

More advanced modem allows operator to tap into all existing spectrum resources, and add more capacity via LAA.



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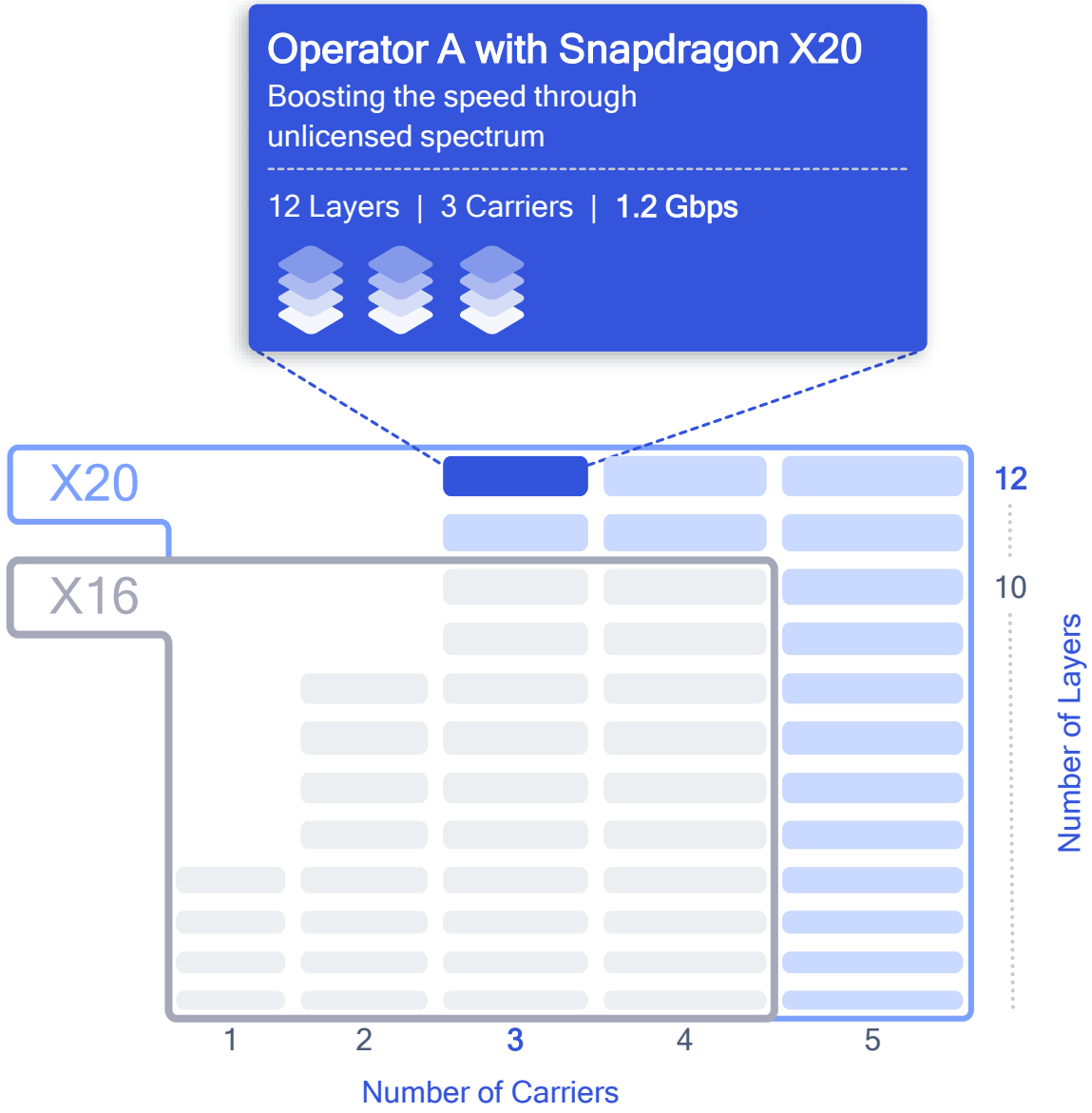

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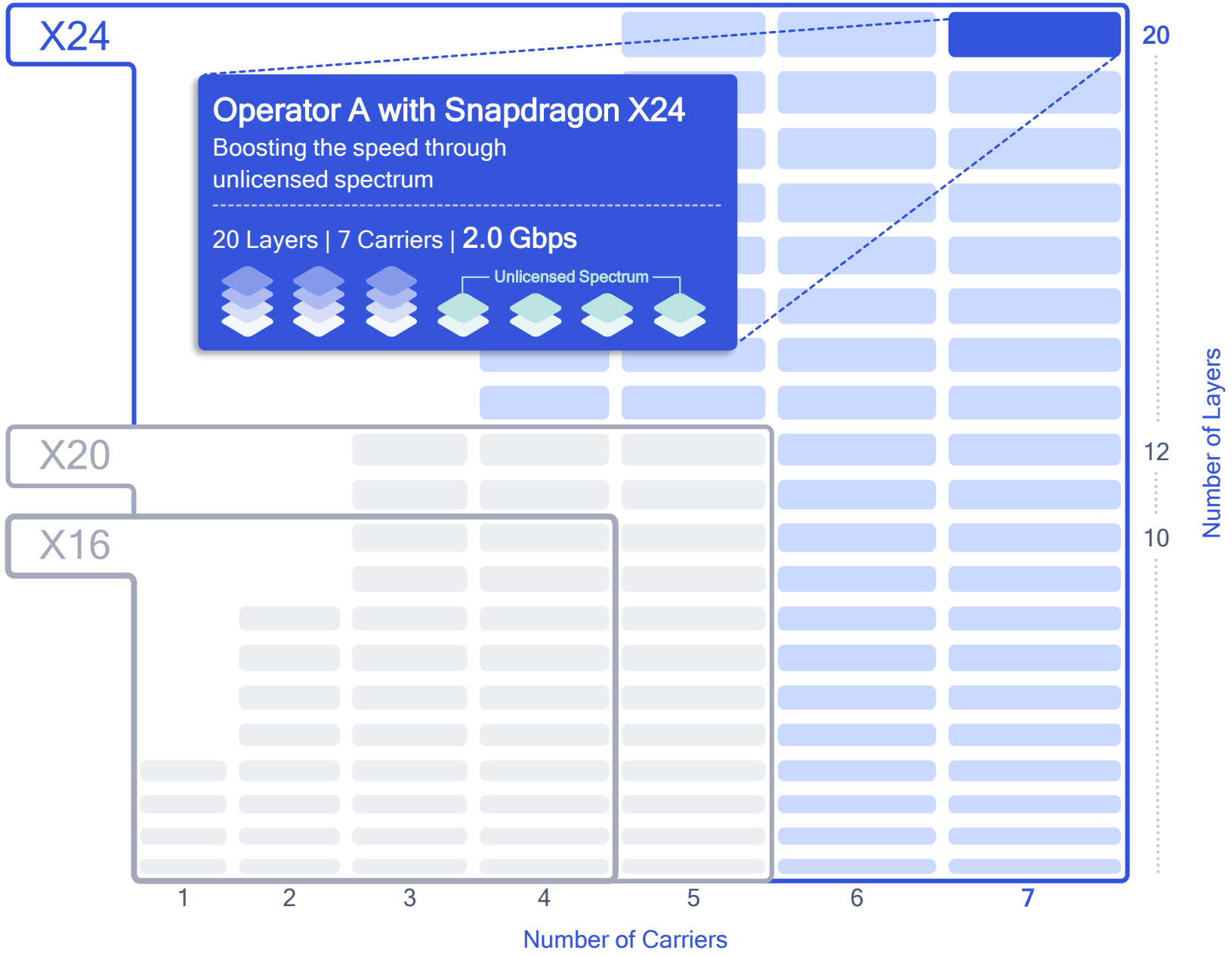


Delivering new levels of performance and efficiency

Also enabling a more consistent 5G experience when 5G NR rolls out

Frankfurt
Gigabit LTE vs. Cat-12
Macro + small cells

~3x increase in burst rate

~2.8x faster responsiveness

~2x higher spectral efficiency

San Francisco
Gigabit LTE vs. Cat-12
Macro + small cells

~3.2x increase in burst rate

~4x faster responsiveness

~2.2x higher spectral efficiency

Source: Company data and internal analysis
Frankfurt: B3 (4x4), B7 (4x4), B20, B28, B32; San Fran: B2 (4x4), 2xB66 (4x4), B12, B71, 4xB46 LAA

5G NR Rel-15[1] eMBB expands to new spectrum bands

5G spectrum – low, mid, and high

Scalable numerology to support a wider range of spectrum bands

Low bands
Re-farmed for mobile, e.g., 600 GHz in US and 700 MHz in EU

Higher mid-bands
New bands opening for eMBB, e.g., 3.5 GHz in US/EU

Rel-15 mmWave bands
Enabling extreme mobile broadband, e.g., 28/39 GHz

Rel-16+ mmWave bands
Even more mmWave bandwidth up to ~100 GHz

1. 3GPP Rel-16+ will bring continued eMBB evolution, plus new features for massive IoT and mission-critical

New mid-band spectrum
Expanding to new frequency bands leveraging existing cell sites

mmWave spectrum
LTE/5G NR in existing low/mid bands provides the anchor

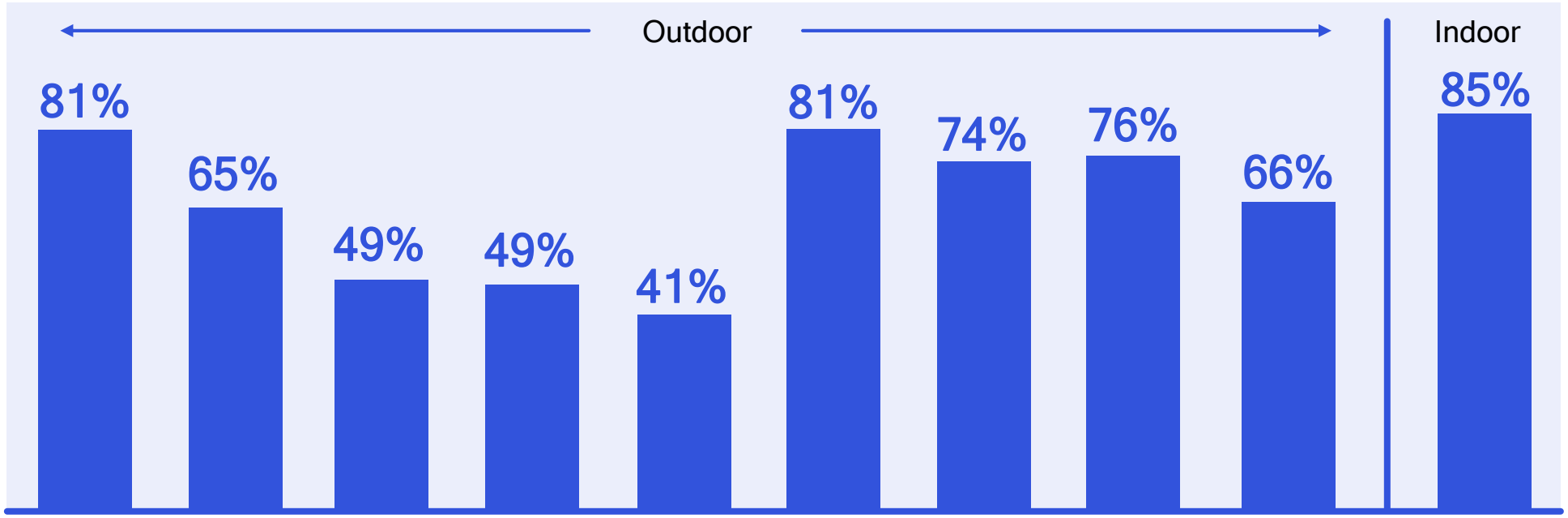
Excels in wider bandwidths
Improved performance, efficiency, and ability to leverage even more antennas

Significant 5G NR mmWave coverage via co-siting

Simulations based on extensive over-the-air testing and channel measurments

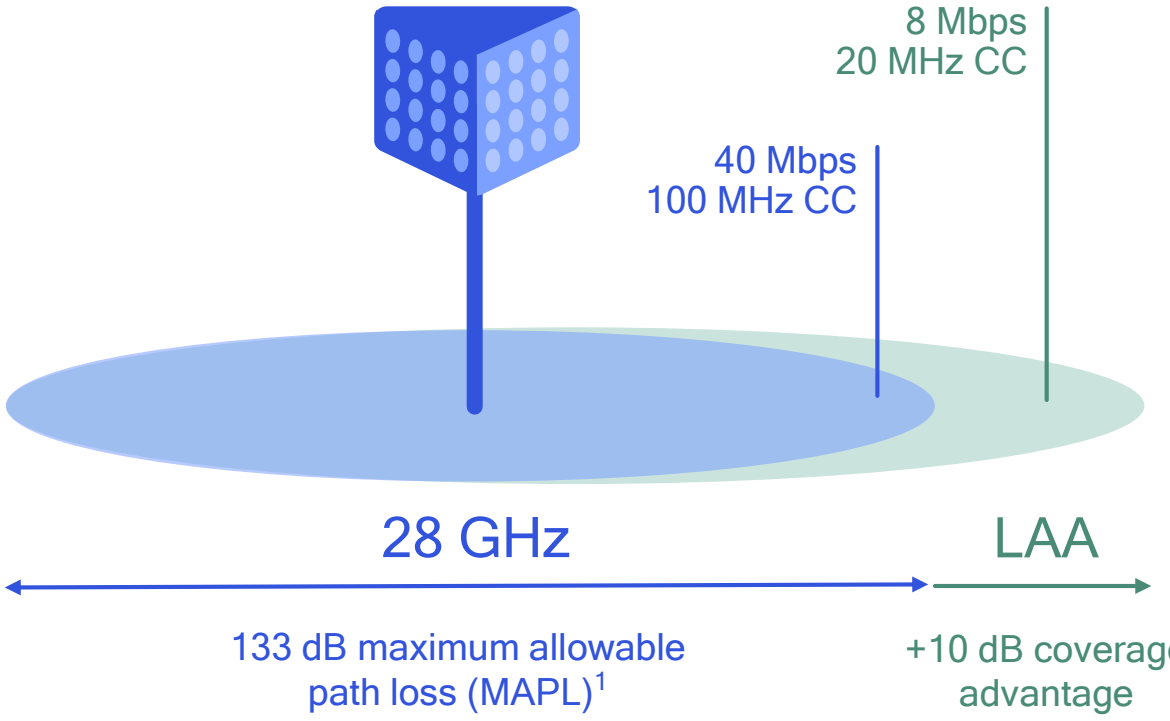
28 GHz downlink coverage %

Co-siting with LTE

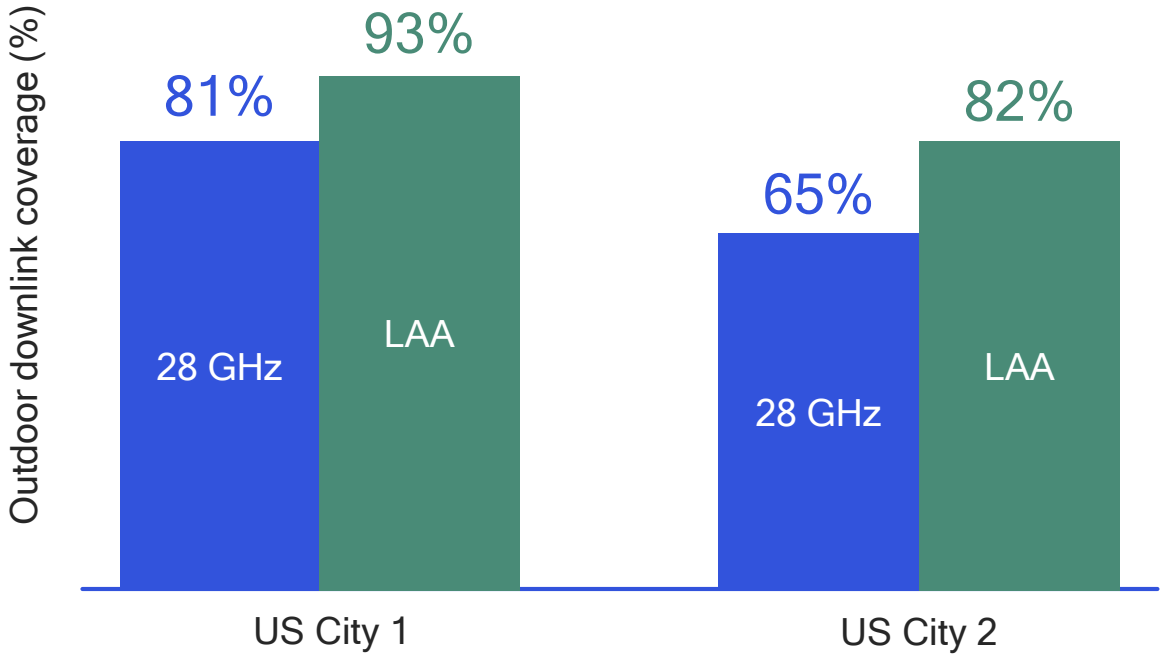


Site density (per km2)		US City 1	US City 2	US City 3	US City 4	EU City 1	Korea City 1	Korea City 2	Hong Kong	Japan City 1	LVCC Venue
	Total	**48**	**36**	**32**	**31**	**28**	**41**	**31**	**39**	**37**	**134** antenna locations
	Macro	0	8	15	14	7	33	31	39	37	
	Small	48	28	17	17	21	8	0	0	0	

Leveraging LAA small cells used for Gigabit LTE to deliver significant 5G NR mmWave coverage



LAA vs. 28 GHz coverage[2]



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

Industry-first simulation of real world performance reveals immense 5G user experience gains over 4G

Frankfurt
5G NR multi-mode
3.5GHz (sub-6GHz)

5x
increase
in capacity

>490Mpbs
median
browsing speed

~7x
faster
responsiveness

San Francisco
5G NR multi-mode
28GHz mmWave

5x
increase
in capacity

1.4Gpbs
median
browsing speed

~23x
faster
responsiveness

Source: Company data and internal analysis
Frankfurt: 3.5 GHz 5G NR + Gigabit LTE multimode vs. Gigabit LTE San Fran: 28 GHz 5G NR + Gigabit LTE multimode vs. Gigabit LTE

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5G NR

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

Learn more at www.qualcomm.com / 5G

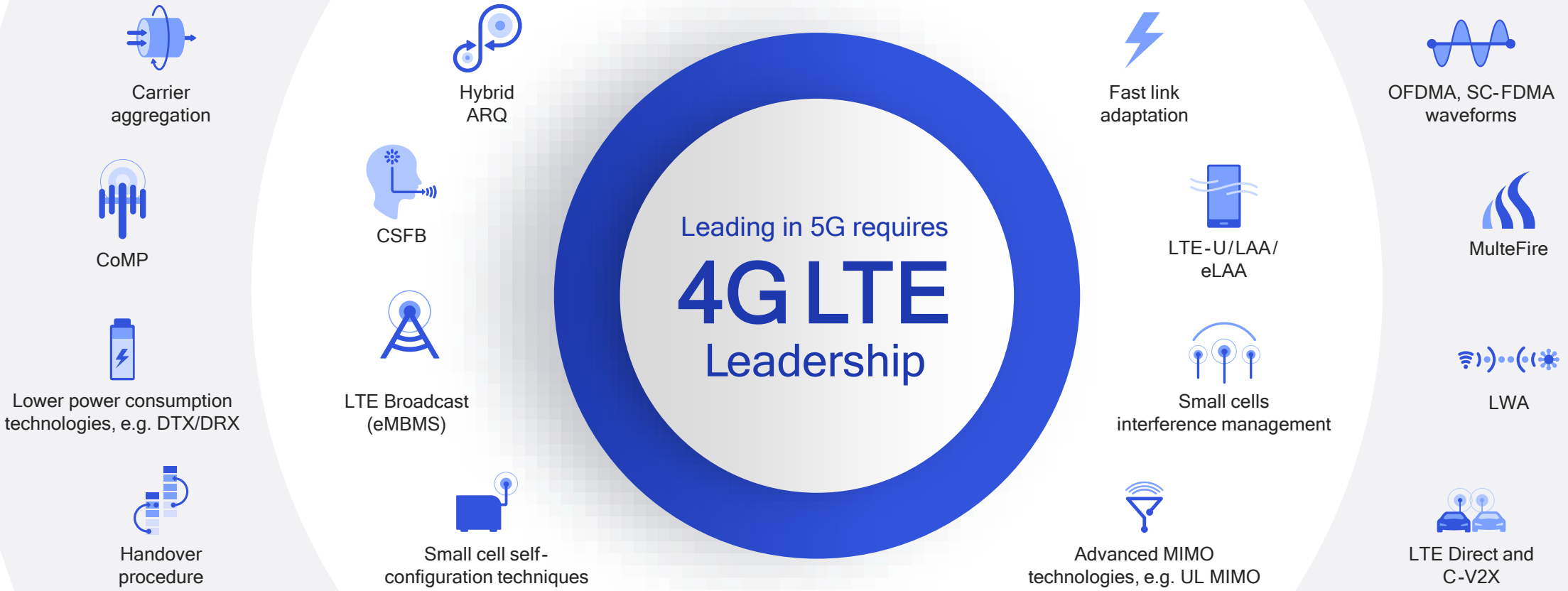
Enhanced Mobile Broadband

Mission-critical services

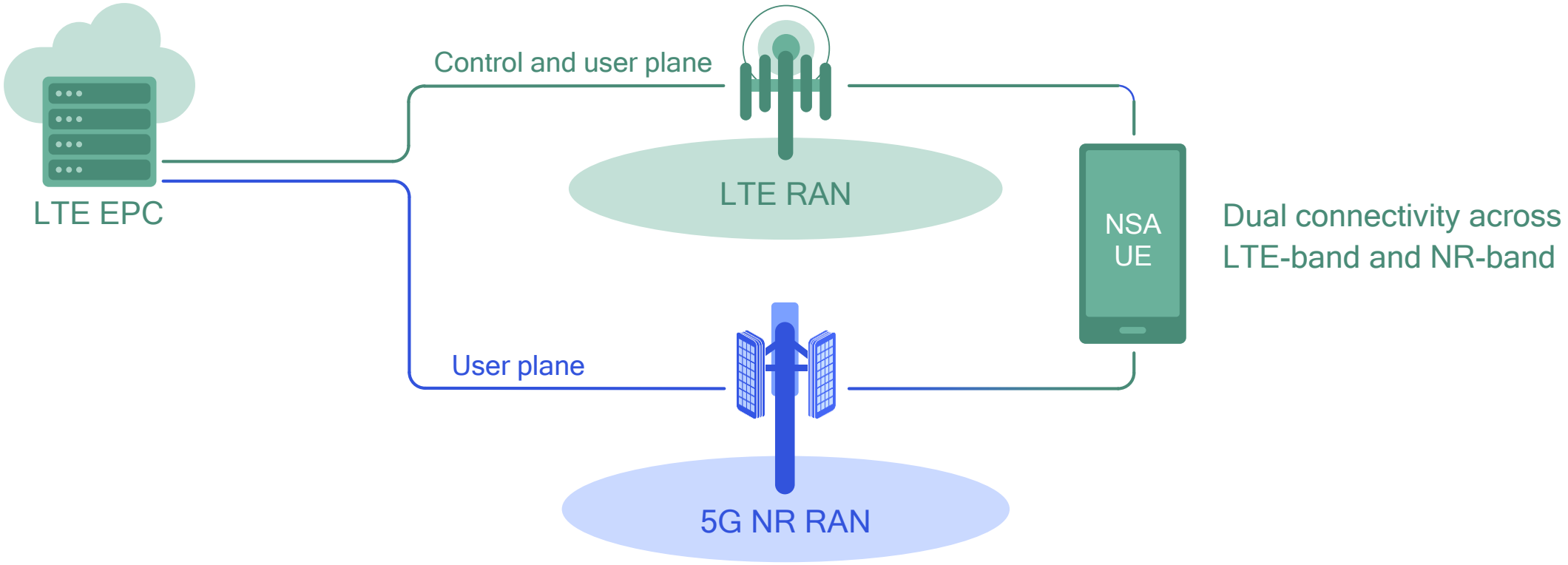
Massive Internet of Things

We have led the evolution and expansion of LTE

Our fundamental systems-level inventions are leading the world to 5G

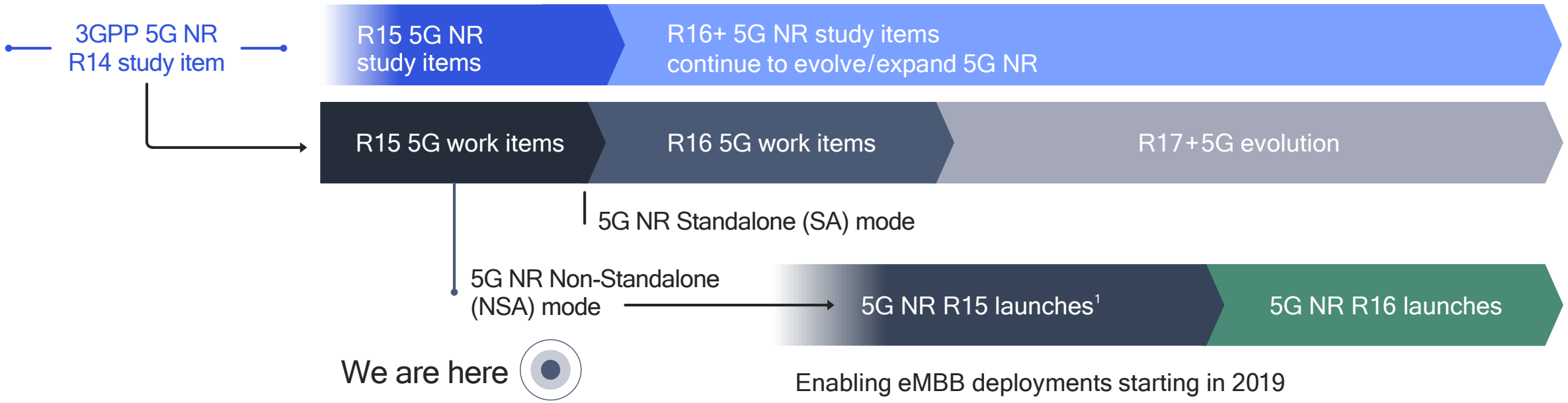


LTE is essential in enabling early NSA 5G NR deployments



Non-Standalone (NSA) leverages LTE RAN and EPC for coverage and mobility, while introducing 5G NR to enhance the user plane performance and efficiency

Accelerating 5G NR to meet the ever-increasing global demand for mobile broadband

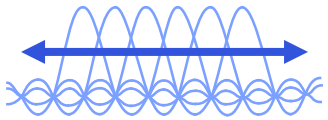


1. Forward compatibility with R16 and beyond

3GPP Rel-15 establishes a solid foundation for 5G NR

For enhanced mobile broadband and beyond

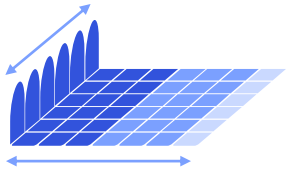
Scalable OFDM-based air interface



Scalable OFDM numerology

Efficiently address diverse spectrum, deployments and services

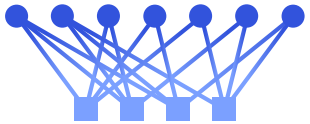
Flexible slot-based framework



Self-contained slot structure

Key enabler to low latency, URLLC and forward compatibility

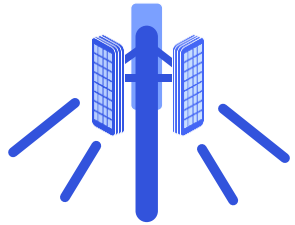
Advanced channel coding



ME-LDPC and CA-Polar[1]

Efficiently support large data blocks and a reliable control channel

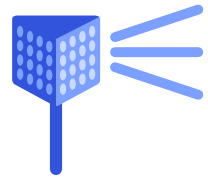
Massive MIMO



Reciprocity-based MU-MIMO

Efficiently utilize a large # of antennas to increase coverage / capacity

Mobile mmWave



Beamforming and beam-tracking

Enables wide mmWave bandwidths for extreme capacity and throughput

Qualcomm

Our technology inventions are driving Rel-15 specifications

Early R&D investments | Best-in-class prototypes | Fundamental contributions to 3GPP

Learn more at: https://www.qualcomm.com/5gnr

1. Multi-Edge Low-Density Parity-Check and CRC-Aided Polar

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

at&t · 中国移动 China Mobile · docomo · SK telecom · Sprint · T · verizon · vodafone · WIND · 3 · ERICSSON · NOKIA · ZTE中兴

5G NR interoperability testing and trials

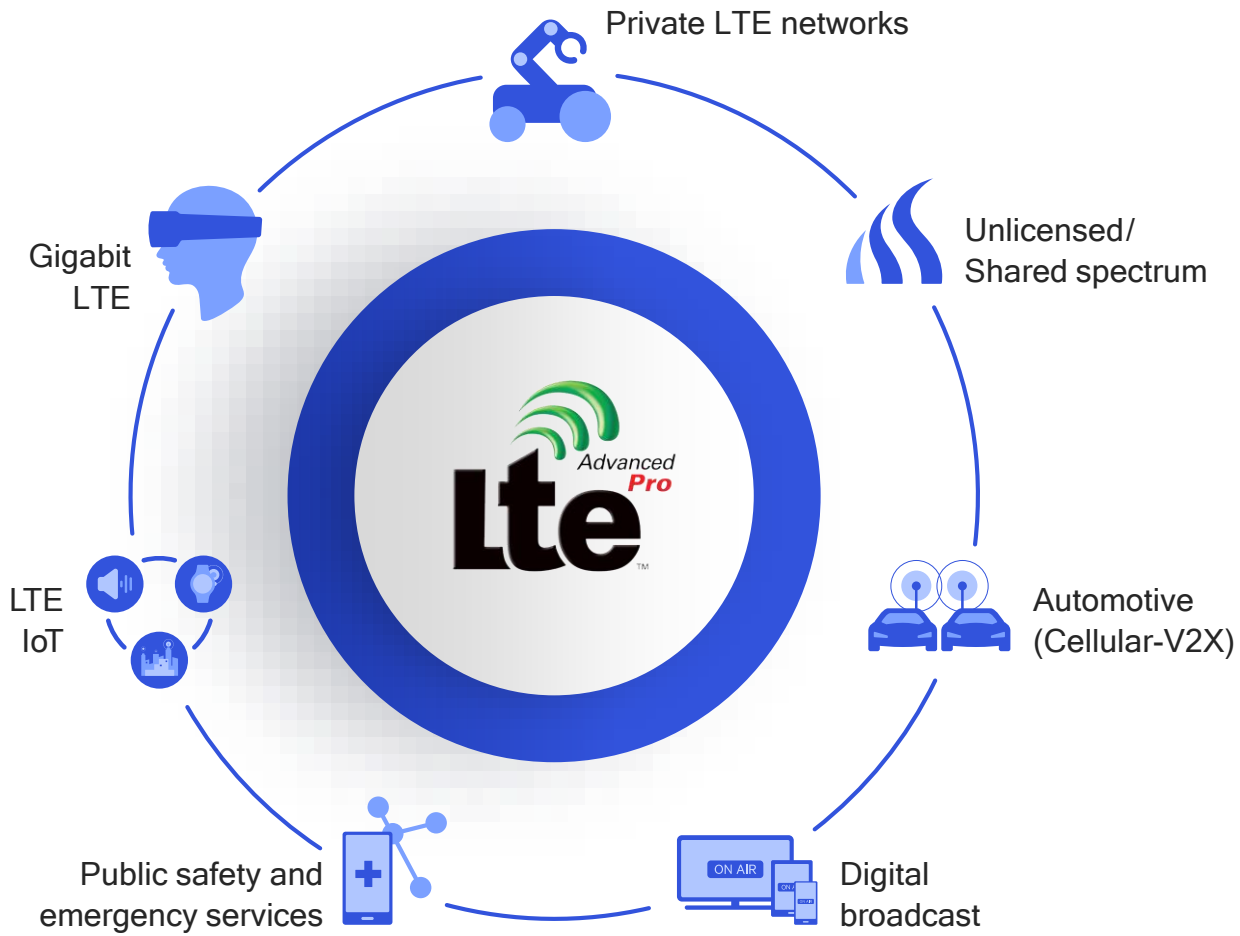
Leveraging prototype systems and our leading global network experience

Modem and RFFE leadership

Announced the Qualcomm Snapdragon X50 5G modem family

LTE foundational technologies

LTE Advanced Pro accelerates the 5G mobile expansion



LTE IoT, private LTE network, C-V2X are enabling new mobile use cases today

Gigabit LTE is here now and delivers a seamless 5G mobile experience

LTE will be submitted with 5G NR to meet IMT-2020 requirements

5G NR will fully leverage LTE investments and enable a phased roll-out

Qualcomm

Thank you!

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