July 2018

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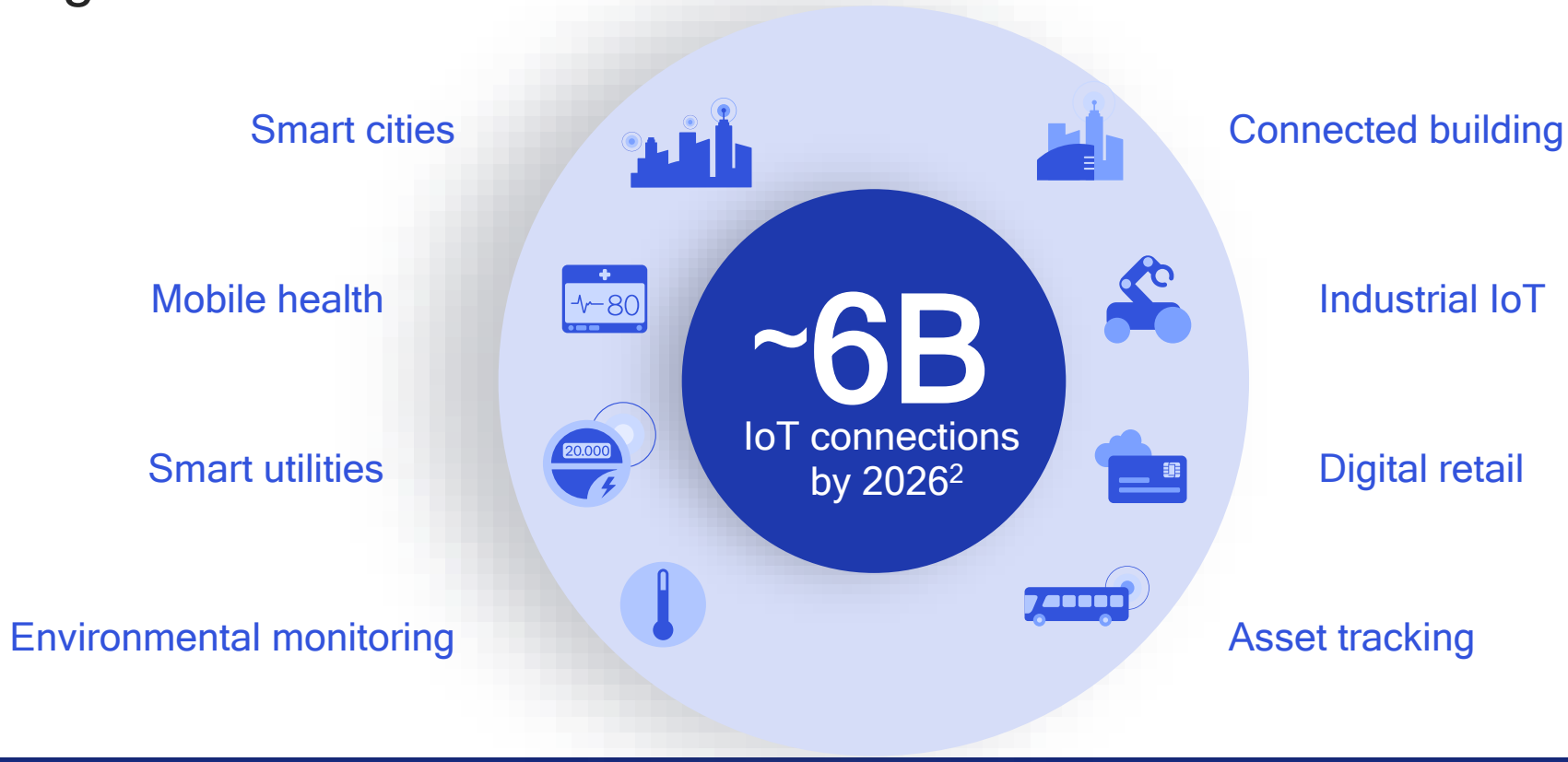
Qualcomm

Leading the LTE IoT evolution to connect the massive Internet of Things


5G NR
4G LTE
Wi-Fi
Bluetooth
NFC
15.4
GNSS
Powerline
At the heart of the IoT ecosystem
Qualcomm
Delivering heterogeneous connectivity powered by global standards
Trillions of connected things
Massive amount of data

Cellular technologies enable a wide range of IoT services

Bringing significant value for LPWA[1] use cases over non-3GPP solutions



Always-available, ubiquitous connectivity

Mature, interoperable global ecosystem

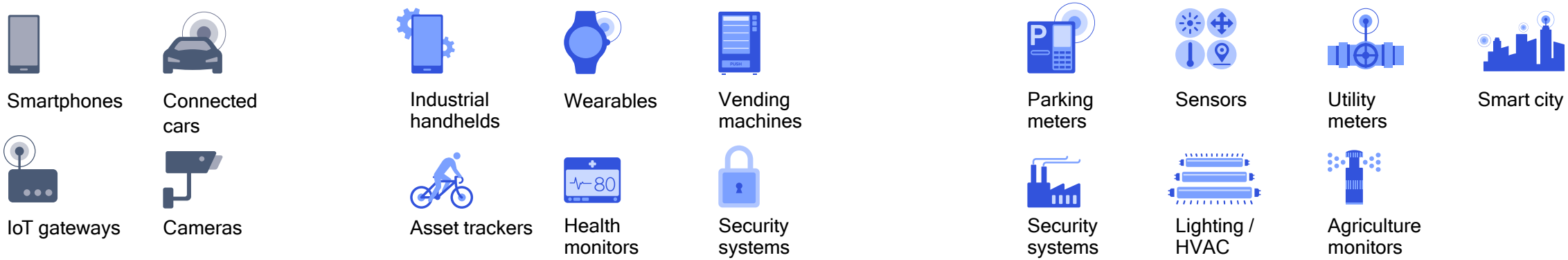
Scalable performance

Seamless coexistence of different services

High reliability and proven security

1. Low-power, wide-area; 2. Including cellular and LPWA M2M connections, Machina Research, June, 2018

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

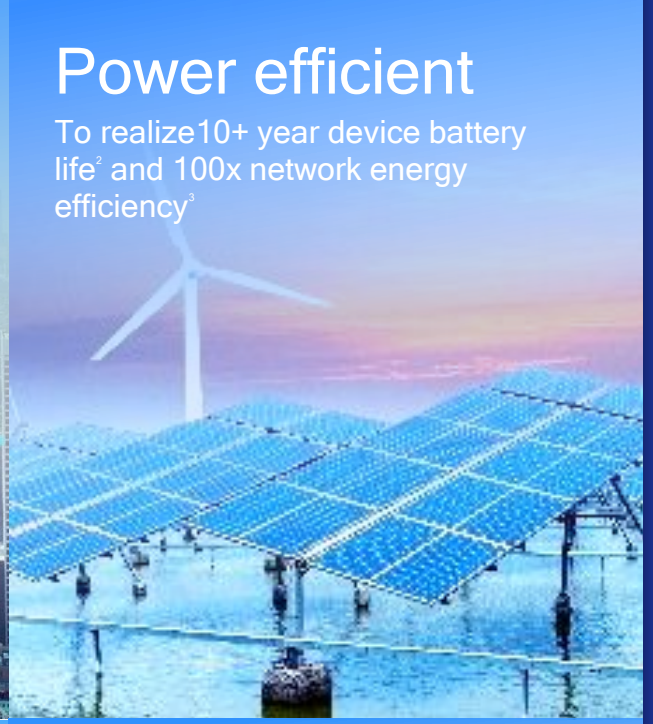
1. Based on Release-13, Release 14 provides additional enhancements; 2. Full duplex mode, ~300 kbps in half-duplex mode; 3. Integrated PA possible

Massive scale

To efficiently support dense connections of 1+ million devices/km^2

Power efficient

To realize10+ year device battery life[2] and 100x network energy efficiency[3]

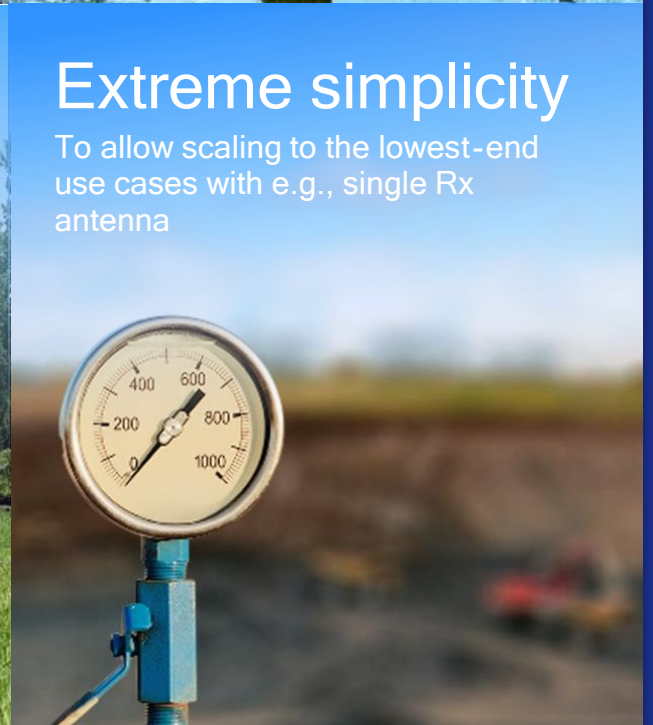


Long range

To reach challenging locations by achieving device link budget of 164 dB[1]

Extreme simplicity

To allow scaling to the lowest-end use cases with e.g., single Rx antenna



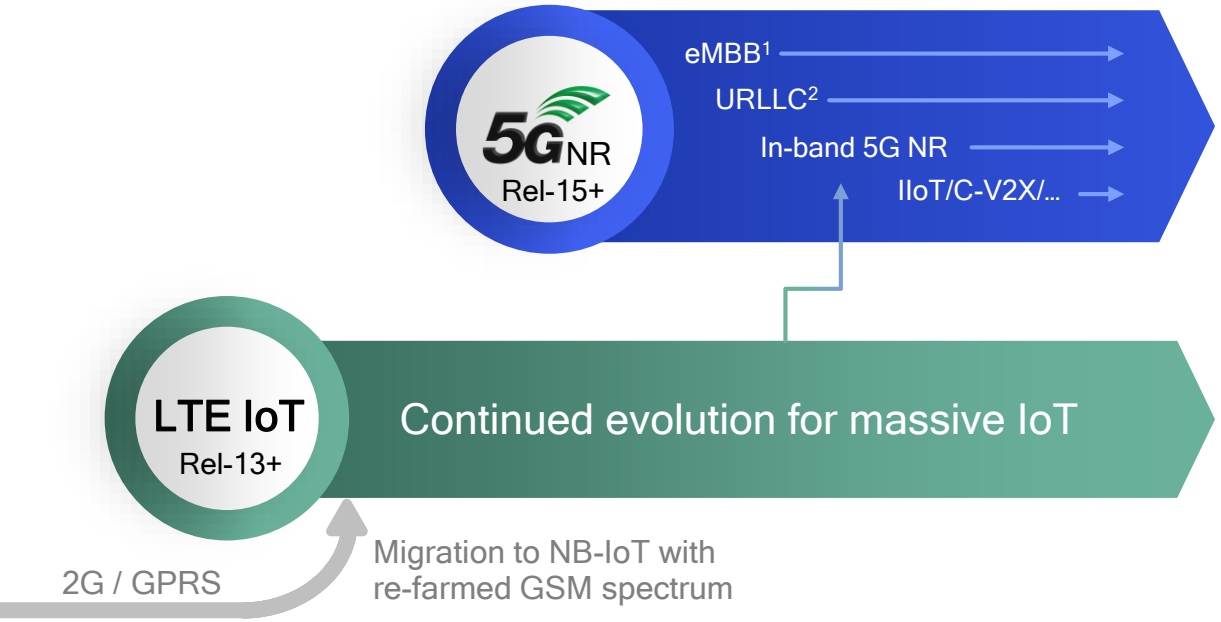
Scaling for the massive Internet of Things

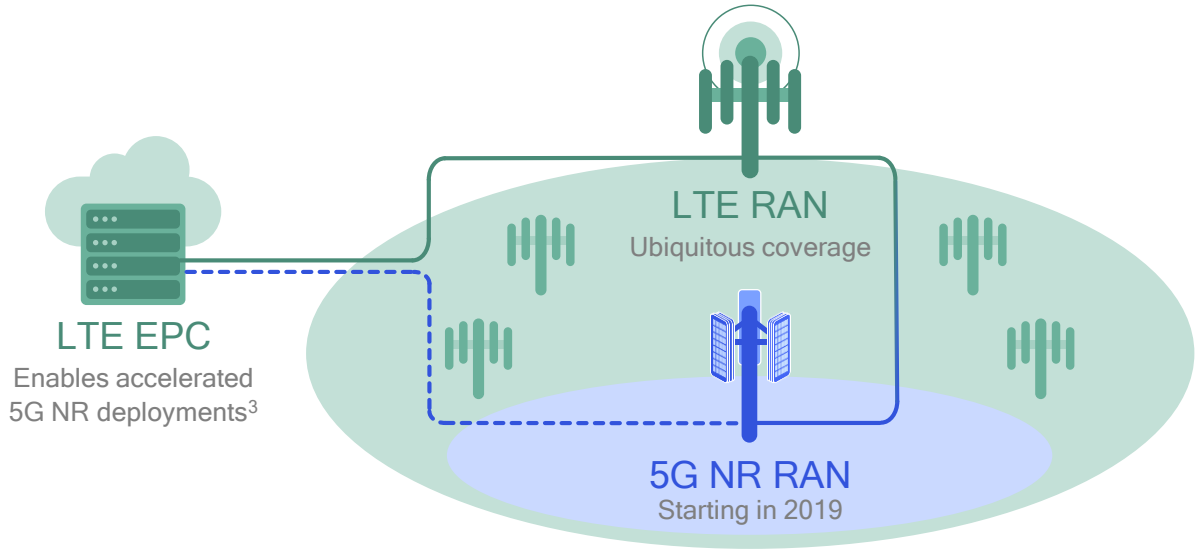
Addressing growing needs of low-power, wide-area IoT use cases

1. Maximum Coupling Loss, assuming data rate of 160bps
2. Assuming 200B UL + 20B DL per day at 164 MCL with 5Wh battery
3. Compared to IMT-Advanced

LTE IoT starts to connect the massive IoT today

Complemented with early 5G NR eMBB deployments starting in 2019





Complementary use cases

5G NR Rel-15 focuses on eMBB and high-performance IoT; LTE IoT addresses the massive IoT with in-band 5G NR deployment in Rel-16

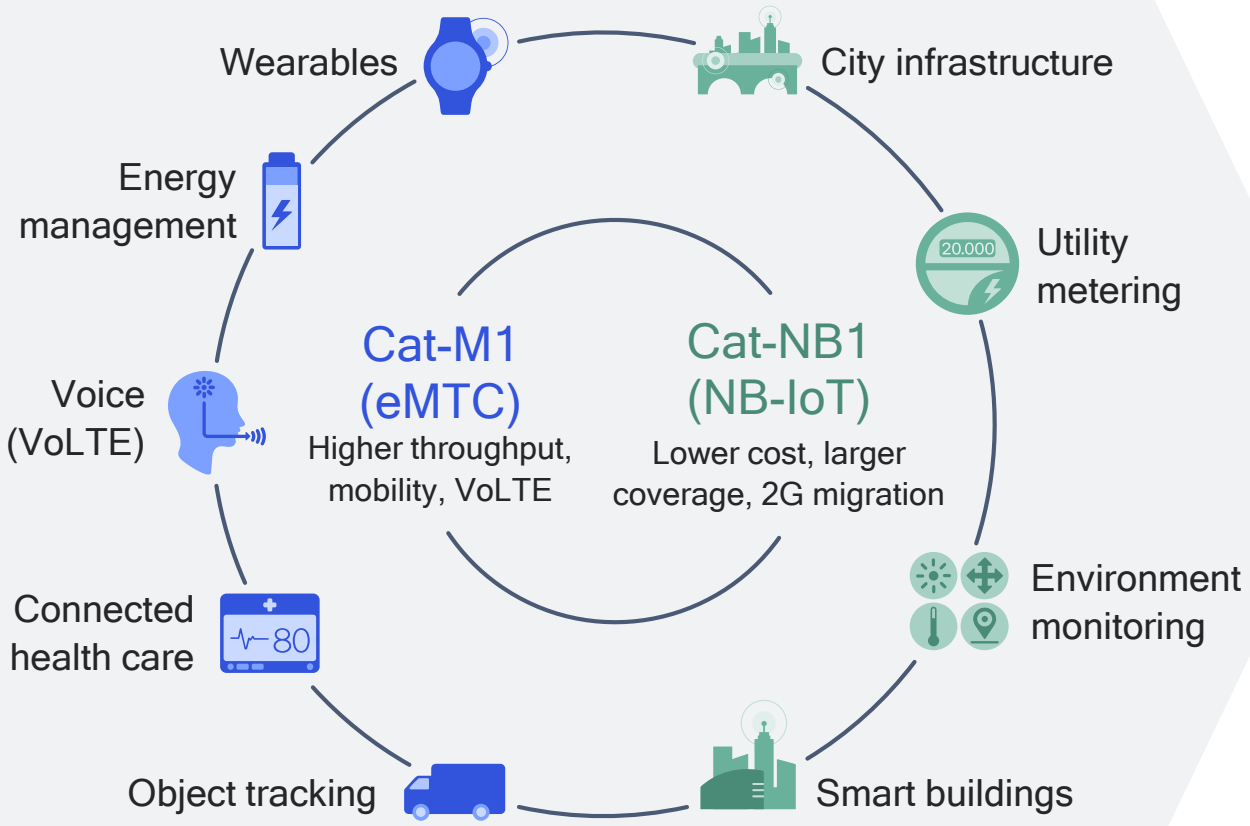
Leveraging LTE's global footprint

LTE IoT leverages existing LTE infrastructure & coexist with other services such as Gigabit LTE – the anchor to the 5G experience

1. Enhanced Mobile Broadband; 2. Ultra-reliable, low-latency communications; 3. 3GPP also defining new 5G core network that will support continued eMTC and NB-IoT evolution

LTE IoT starts to connect the massive IoT today

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



MDM9206

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

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

QUECTEL Wireless Module Expert · ZTE Welink · Telit · LONGSUNG 龙尚科技 · Neoway 有方 · SIMCom A company of SIM Tech · MobileTek · u-blox · WNC · mobike

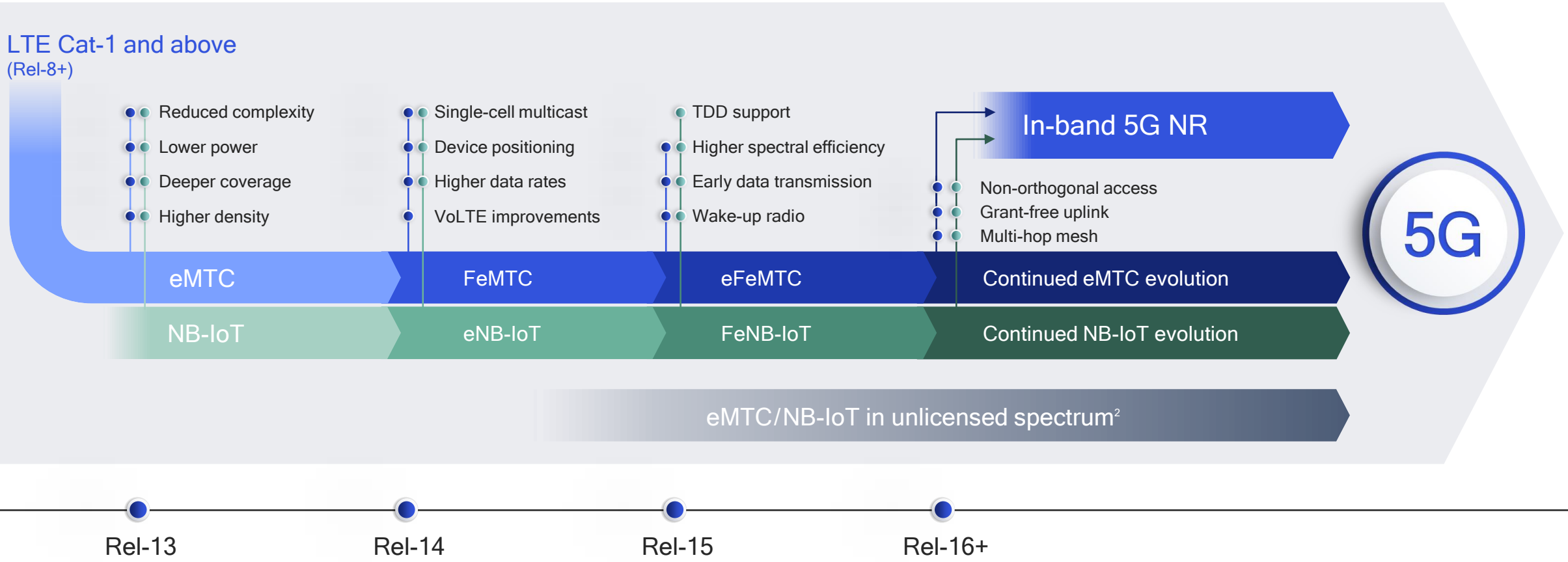
...and many more

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

Sources: GSA NB-IoT and LTE-M: Global Market Status, March, 2018

Continued evolution to meet tomorrow's massive IoT needs

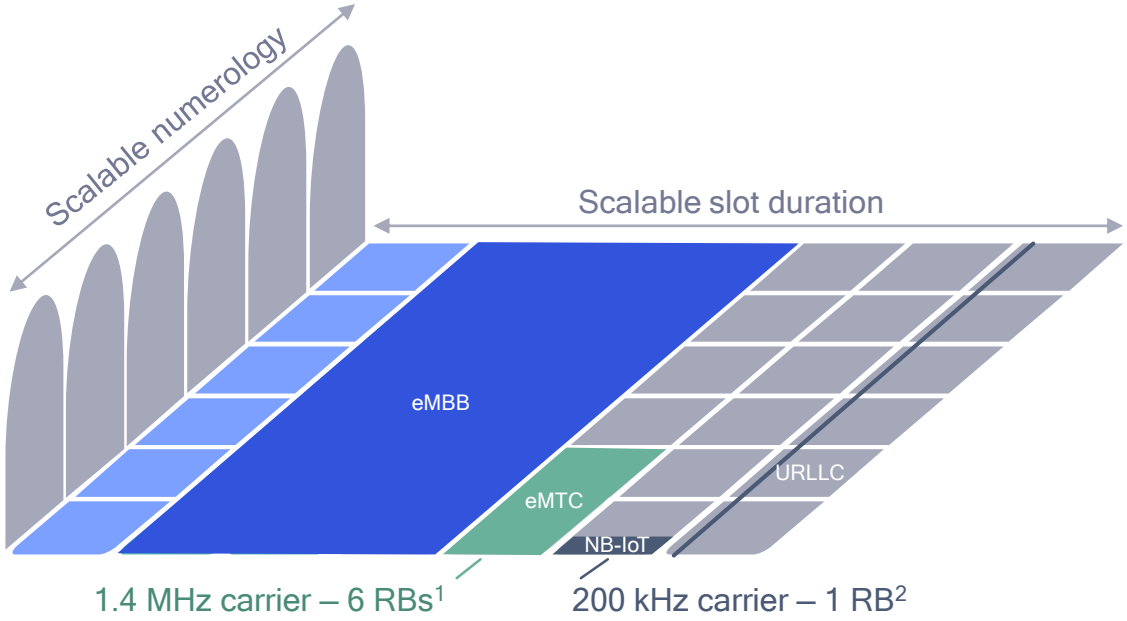
Essential to 5G – LTE IoT to be submitted to meet IMT-2020[1] requirements



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+

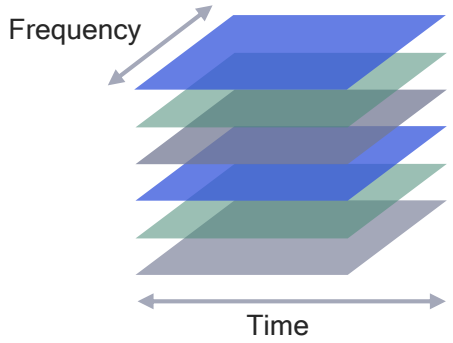
Non-orthogonal access, grant-free uplink, and multi-hop mesh will deliver even better performance and efficiency

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

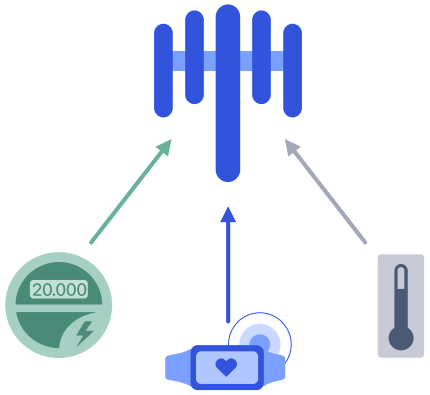
Applies to LTE IoT and 5G massive IoT evolution – potential for 3GPP Rel-16+



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

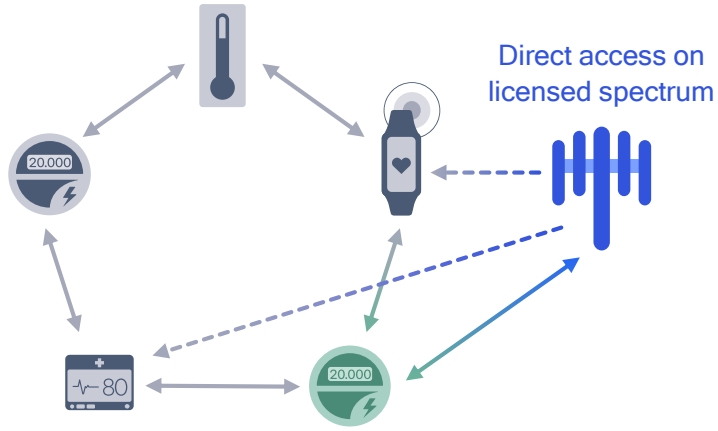


Grant-free uplink

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

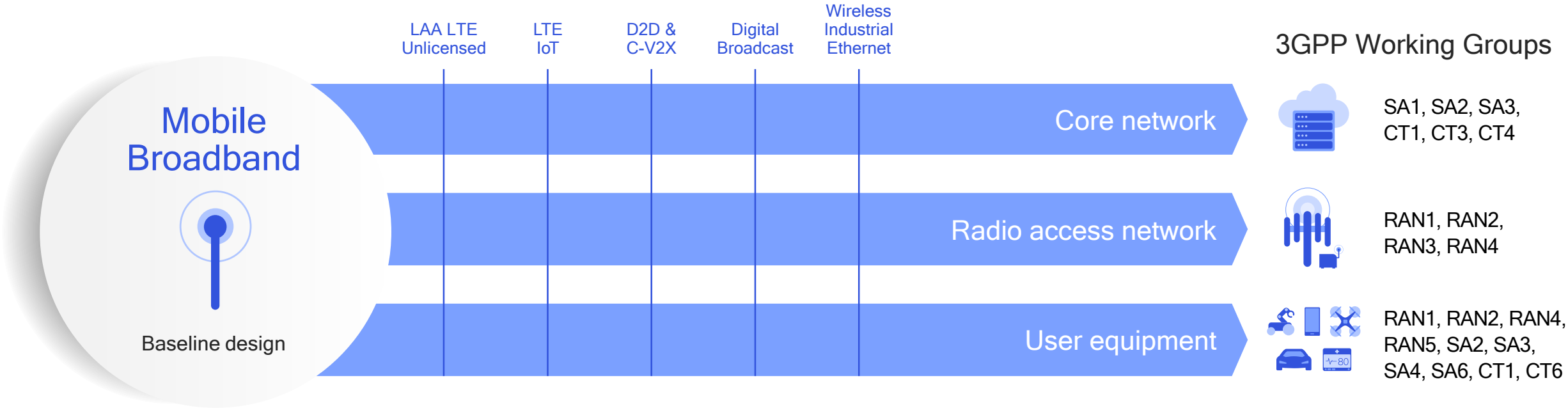
Multi-hop mesh with WAN management

- 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

Expanding into new areas requires system leadership

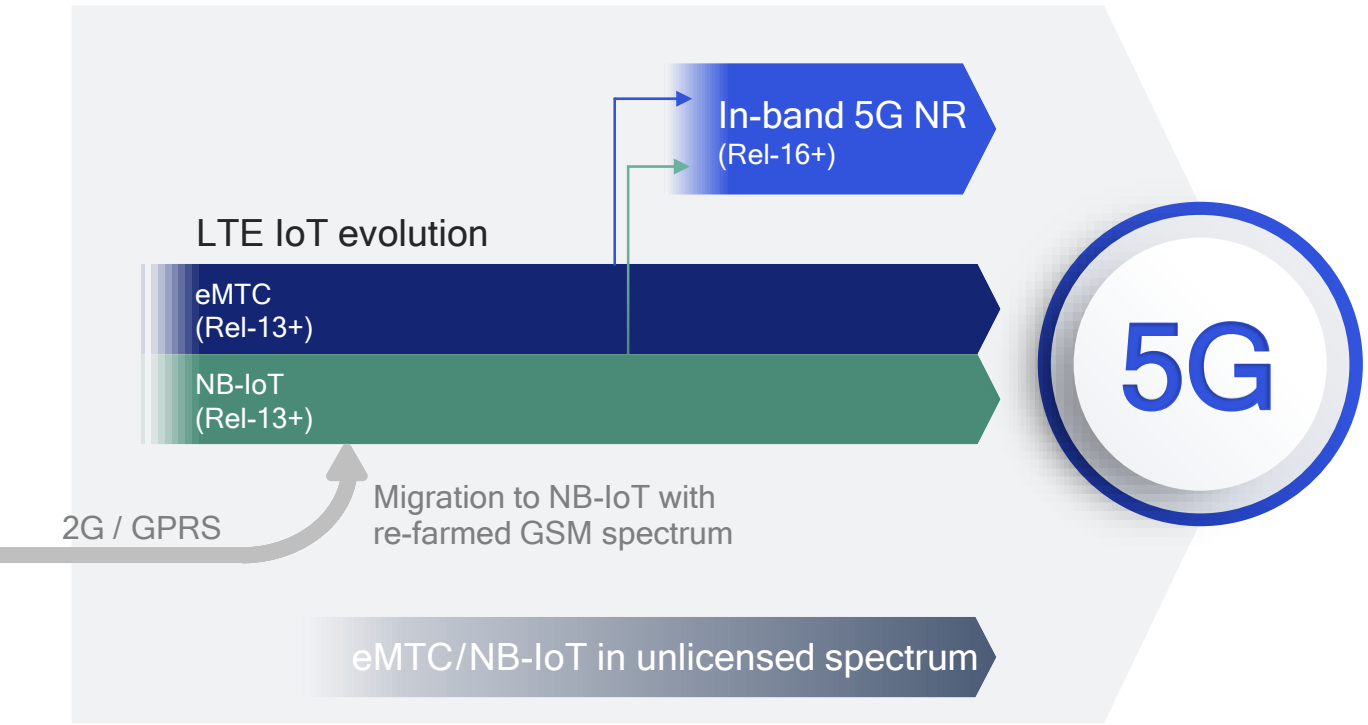
The ability to drive an end-to-end design across multiple 3GPP Working Groups



Each new area requires creating a new sub-system built on top of “baseline”

Adjusting, optimizing, and redesigning procedures across all layers to address the new requirements

Leading the LTE IoT evolution to connect the massive IoT



LTE IoT starts to connect the massive IoT today

Complemented with initial 5G NR eMBB deployments

Continued LTE IoT evolution is broadening use cases

A rich technology roadmap for tomorrow's massive IoT and expansion into unlicensed spectrum

We are driving broad ecosystem adoption of LTE IoT

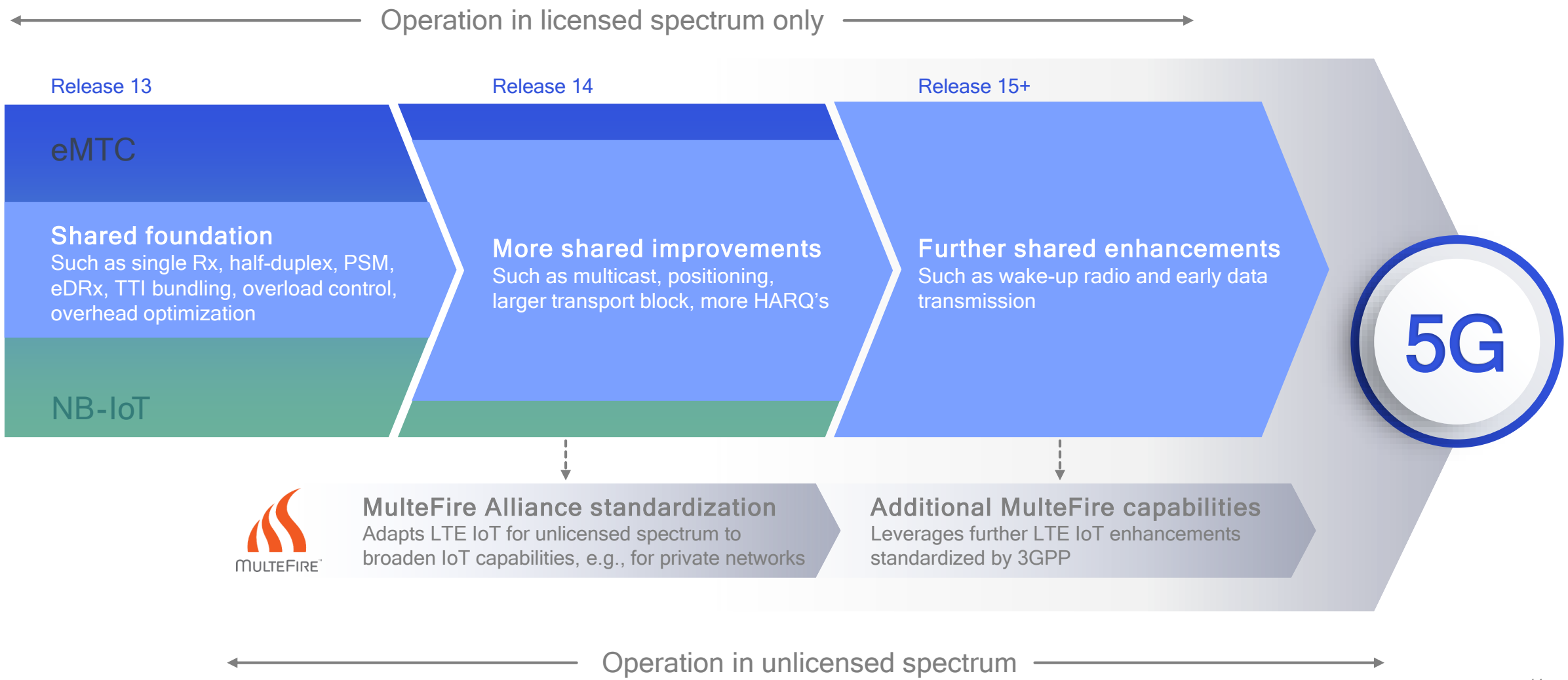
Strong global momentum with our multi-mode commercial solution

Continued LTE IoT evolution is broadening use cases

A rich technology roadmap for tomorrow's massive IoT and expansion into unlicensed spectrum

LTE IoT evolution builds on a shared foundation

Also expanding into unlicensed spectrum for new use cases



Delivering new efficiencies for the massive IoT

Extreme simplicity

Reducing complexity

Narrowband operation (down to 180 kHz) plus further device and core network complexity reductions

Ultra energy efficiency

Lowering power consumption

Enhanced power save modes (PSM) and more efficient signaling, e.g., extended DRX (eDRx) sleep cycles

Ubiquitous coverage

Deepening coverage

Up to 20 dB link budget increase for hard-to-reach locations via redundant transmissions and more

Massive scale

Increasing device density

Signaling & network optimizations, e.g., overload control, to support a large number of devices per cell

Shared eMTC and NB-IoT foundation

Such as single Rx antenna, half-duplex, PSM, eDRx, TTI bundling, overload control, overhead optimizations, etc.

Reducing complexity: start supporting narrowband operation

To enable low-cost modules optimized for small, infrequent data transmissions

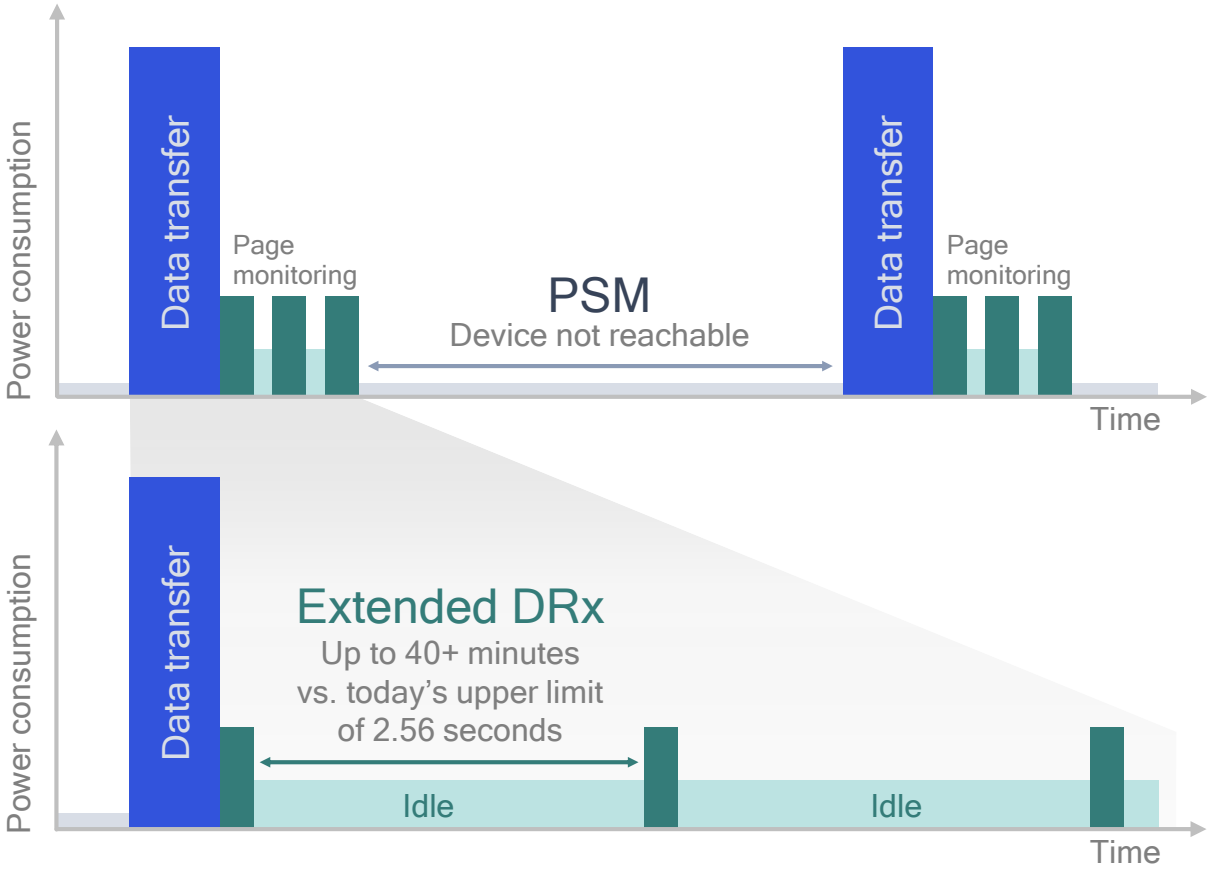
	LTE Cat-1 (Rel-8)	eMTC Cat-M1 (Rel-13)	NB-IoT Cat-NB1 (Rel-13)
Peak data rate	Up to 10 Mbps	Up to 1 Mbps[2]	<100 kbps
Bandwidth	Up to 20 MHz	1.4 MHz	200 kHz
Rx antenna	Dual Rx[1]	Single Rx	Single Rx
Duplex mode	Full duplex FDD/TDD	Full or Half duplex FDD/TDD	Half duplex FDD
Mobility	Full mobility	Limited-to-full mobility	Cell reselection only
Voice	VoLTE	VoLTE	No voice support
Transmit power	23 dBm	23, 20 dBm[3]	23, 20 dBm[3]

Reduces baseband/RF complexity and decreases memory

1. Single Rx added in Rel-14; 2. Full duplex mode, ~300 kbps in half-duplex mode; 3. Integrated PA possible

Lowering power: achieve 10+ year device battery life

For eMTC and NB-IoT, allowing devices wake up on a per-need basis



Power save mode (PSM)

Eliminates page monitoring between data transmissions for device-originated or scheduled applications, e.g., smart metering, environmental monitoring

Extended discontinuous receive (eDRx)

Extends time between monitoring for network messages for device-terminated applications, e.g., object tracking, smart grid

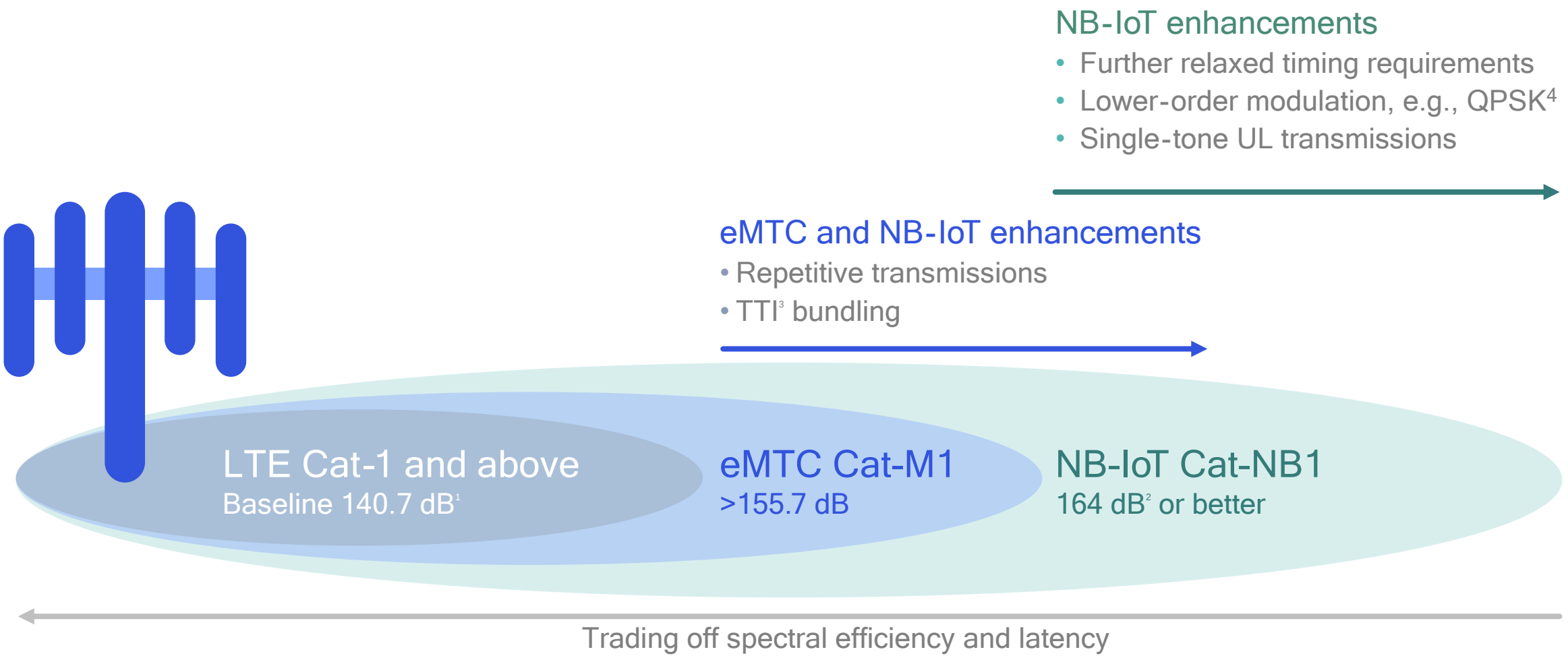
Also features such as reduced complexity and overhead optimizations[1] extend battery life

Note: PSM and eDRx applicable to both eMTC & NB-IoT; may also be applied to LTE Cat-1 and above

1. Rel-13 includes less channel measurements, Rel-15 includes semi-persistent scheduling, data transmission during random access, faster RRC release, relaxed monitoring for cell reselection, and more

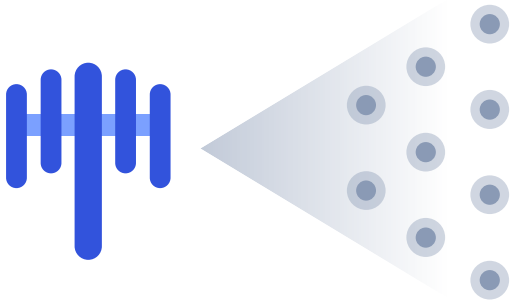
Deepening coverage: provide ubiquitous IoT connectivity

To reach the most challenging locations, e.g., penetrating more walls and floors



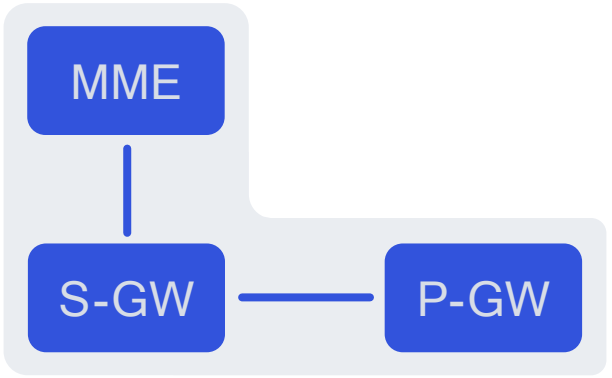
1. Link budget; 2. At least for standalone operation mode; 3. Transmission Time Interval; 4. Quadrature Phase Shift Keying

Increasing density: optimize for better network efficiency



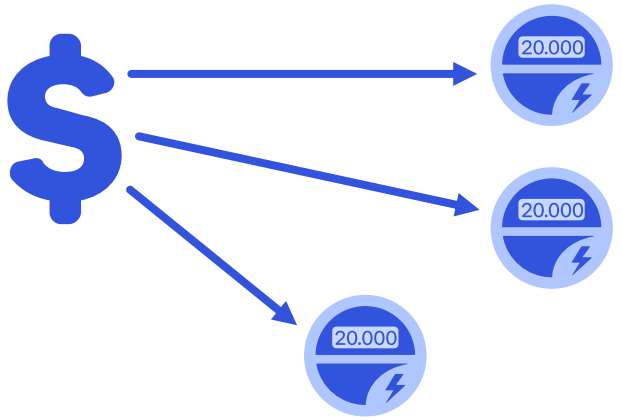
More efficient signaling

To support a larger number of devices per cell with new features such as group-based paging, messaging, and improved load management



Simplified core network (EPC-lite)

Reduced functionality, e.g., no/optional voice, limited mobility, optional optimizations that integrate network functions into a single entity



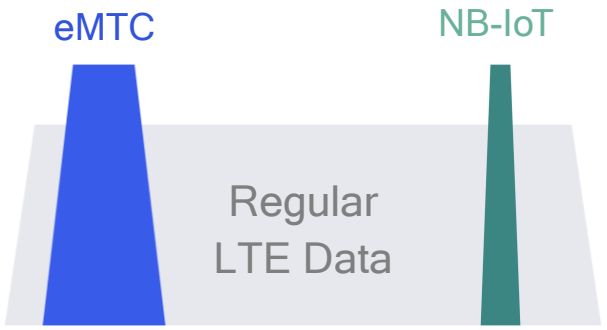
Enhanced resource management

Such as optimizations to allow a large set of devices to share the same subscription, e.g., all the water meters in a city

Coexist with today's mobile broadband services

Flexible deployments in FDD & TDD[1]; leveraging existing infrastructure & spectrum

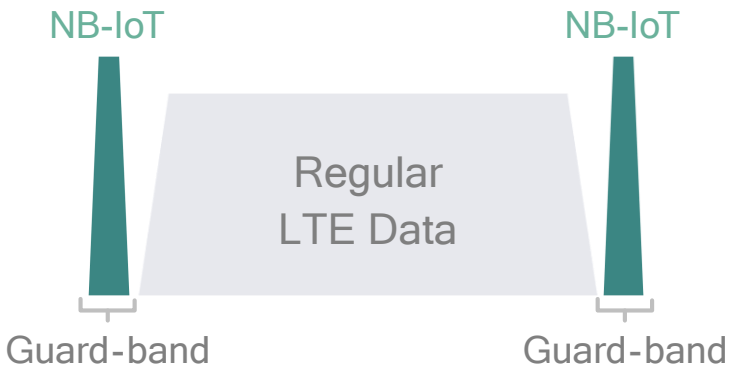
In-band



eMTC reuses LTE sync.[2] data channel operates across entire LTE band

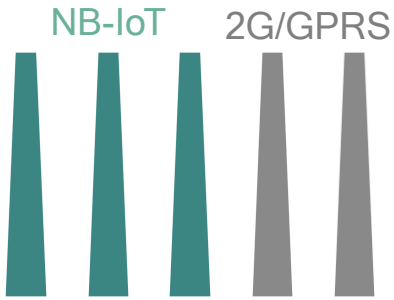
NB-IoT utilizes 1 RB[3] (180 kHz) within a normal LTE carrier

Guard-band



Utilizing unused resource blocks within a LTE carrier's guard-band

Standalone



Utilizing standalone 200 kHz carrier, e.g., re-farming spectrum currently used by 2G/GPRS

1. NB-IoT support in TDD proposed in Rel-15; 2. Center 6 Resource Blocks; 3. Resource Block

Easy migration to NB-IoT with re-farmed 2G/GPRS spectrum

A rich roadmap of enhancements in 3GPP Rel-14 & 15

eMTC

Enhancing VoLTE[1]
For wearables to more efficiently handle voice in half-duplex mode

Better mobility
Full support for inter-frequency measurements[1] and higher velocity in extended coverage[2]

eMTC and NB-IoT

Single-cell multicast[1]
Efficient OTA firmware update for large number of devices

Lower latency
More HARQ processes[1], faster system acquisition[2], early data transmission[2]

Device positioning[1]
Providing location services for e.g., asset tracking and eCall

Energy reduction
Wake-up radio for low-power channel monitoring[4] and lower transmit power classes[5]

Higher data rate[1]
Supporting wider bandwidth, e.g., 5 MHz, and more[3]

Higher density support[2]
Improved load control with level-based access class barring

NB-IoT

Cell size extension[2]
Additional cyclic prefixes to support cell radius of at least 100km

TDD support[2]
For deployment in higher TDD bands, also further optimizing for small cells

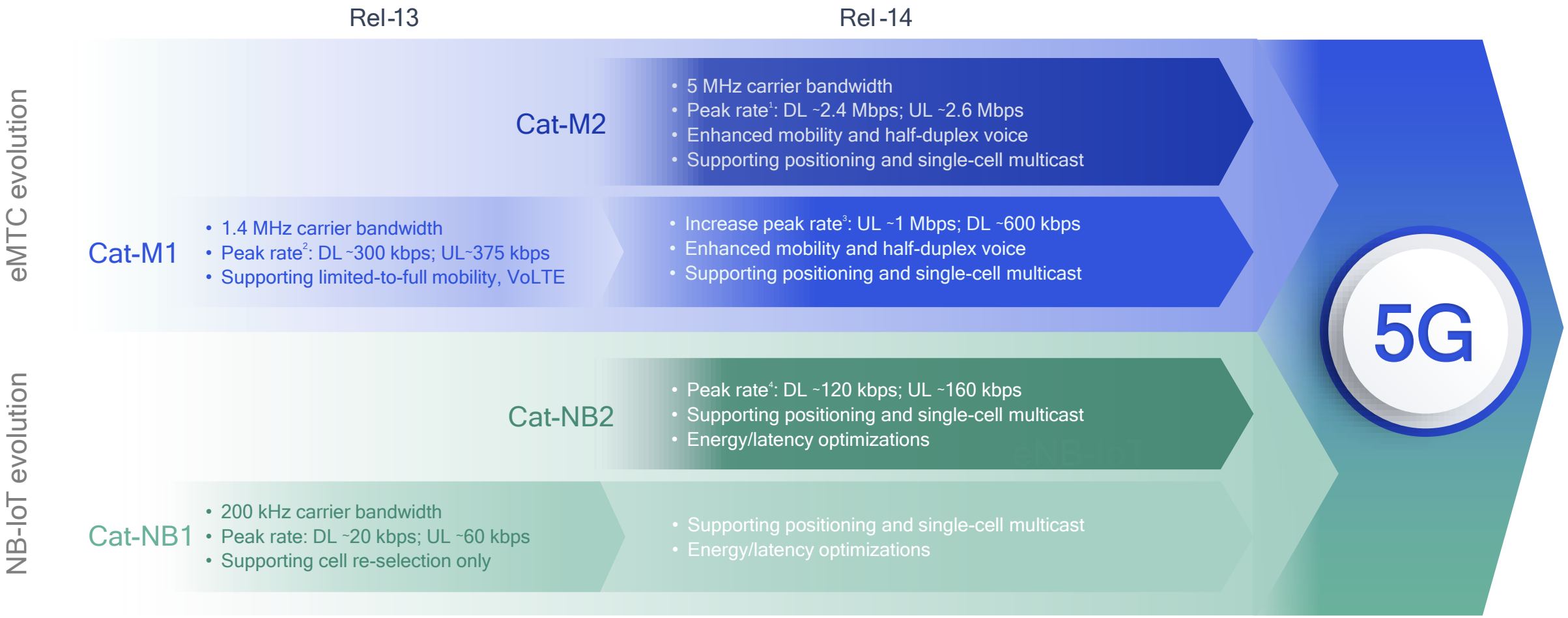
5G

Release 14 and 15 enhancements

1. Rel-14 feature; 2. Rel-15 feature; 3. FeMTC adds support for 5 MHz, larger TBS, more HARQ processes, eNB-IoT increases TBS and HARQ process; 4. Also relaxed monitoring for cell reselection, semi-persistent scheduling, quicker RRC release in Rel-15; 5. eNB-IoT adds 14 dBm in Rel-14, lower transmit power proposed for eFeMTC in Rel-15;

New device categories to address broader IoT use cases

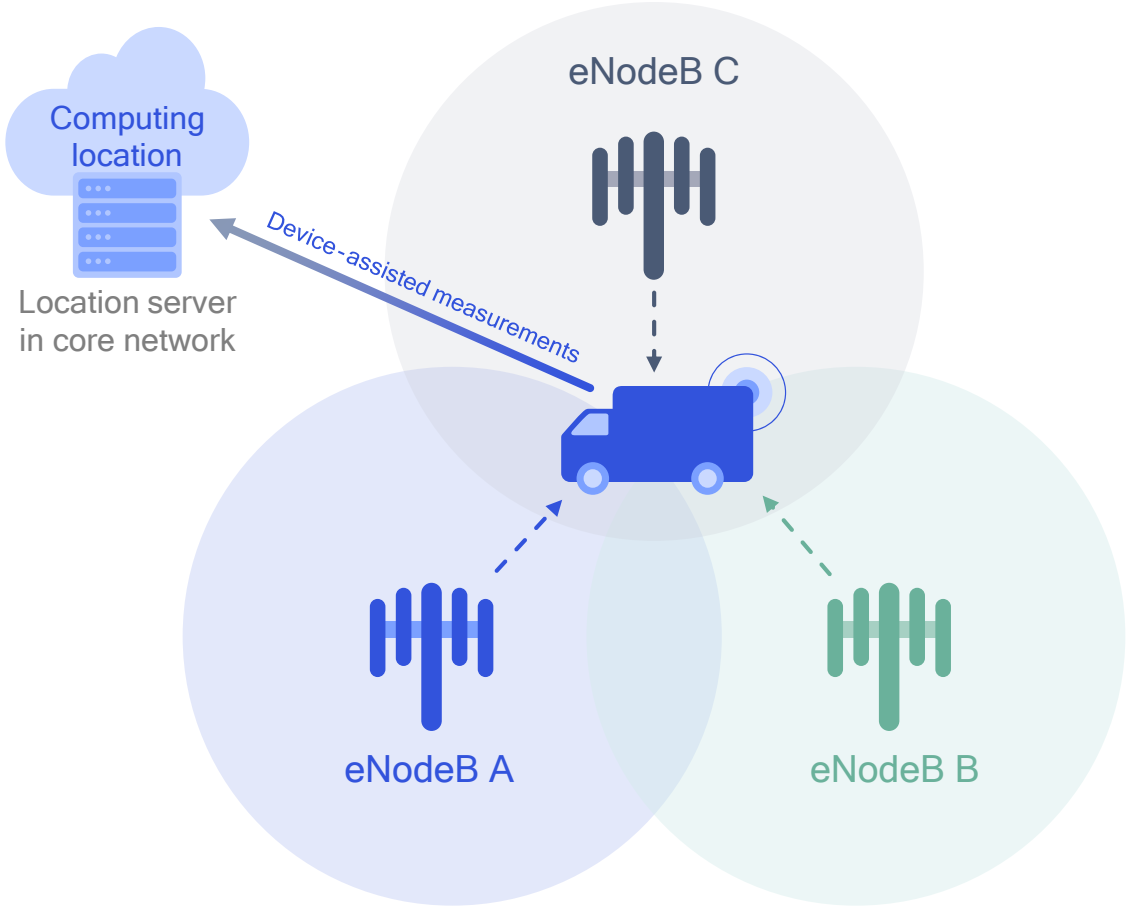
Evolving to deliver faster peak rates, new capabilities, and efficiency optimizations



1. Based on 4008b UL/DL TBS, 10 HARQ's & ACK bundling; 2. Half-duplex; 3. Half-duplex, increase UL TBS to 2984b from 1000b, HARQ's from 8 to 10, & ACK bundling; 4. Increase DL/UL TBS from 600/1000b to 2536b, HARQ's from 1 to 2.

Enabling IoT device positioning with OTDOA[1]

First introduced in Rel-9 for LTE; adapted for LTE IoT in Rel-14



Key enabler for new use cases

Such as asset tracking and eCall services that require always-available device locations

Complements satellite positioning

To provide location services in challenging NLOS[2] settings, such dense urban or inside buildings

Optimized for LTE IoT[3]

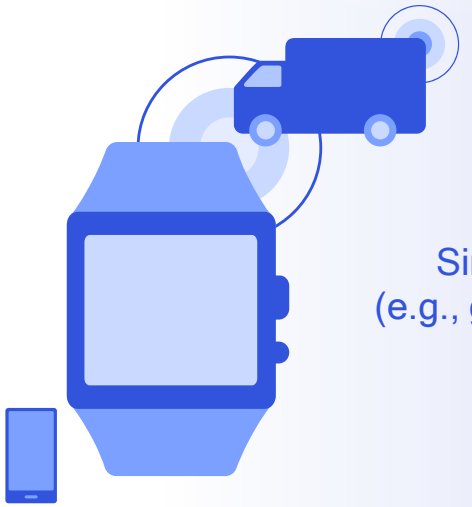
Utilizing a narrower bandwidth PRS[4] with higher repetition factors that extends range

Download Qualcomm Technologies whitepaper for more information: https://www.qualcomm.com/documents/otdoa-positioning-3gpp-lte

1. OTDOA: Observed Time Difference of Arrival; 2. Non-line-of-sight; 3. Idle mode only for NB-IoT, connected and idle mode for eMTC; 4. Positioning reference signal;

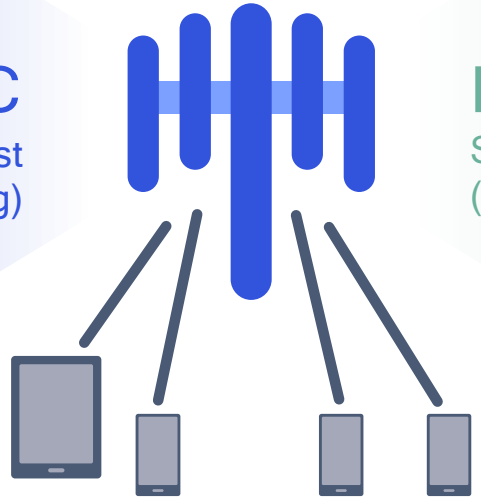
Efficiently communicating with IoT devices using multicast

Extending SC-PTM[1] defined in Rel-13 to LTE IoT in Rel-14



eMTC

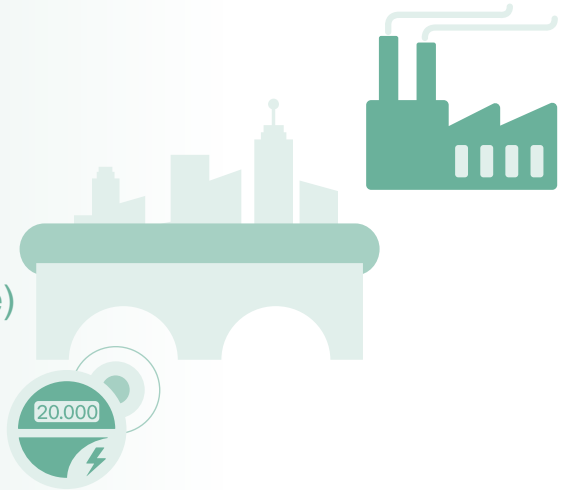
Single-cell multicast
(e.g., group messaging)



Coexisting with LTE unicast services

NB-IoT

Single-cell multicast
(e.g., firmware upgrade)



1. Single Cell Point to Multipoint;

Easy firmware upgrades

Eliminates expensive truck roll maintenance of deployed devices (e.g., environmental sensors)

Longer battery life

Simplified control protocol that reduces amount of time devices need to be awake

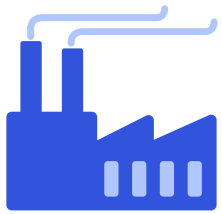
More capacity

Efficient use of network resources by serving a group of devices simultaneously

Small cells bring many benefits for the IoT

Supported by LTE IoT today with further enhancements proposed in Rel-151

Venues



Industrial

Residential

Enterprise/Buildings

Cities

Improved coverage

Bringing the network closer for deeper reach indoors and more reliable connectivity

Longer battery life

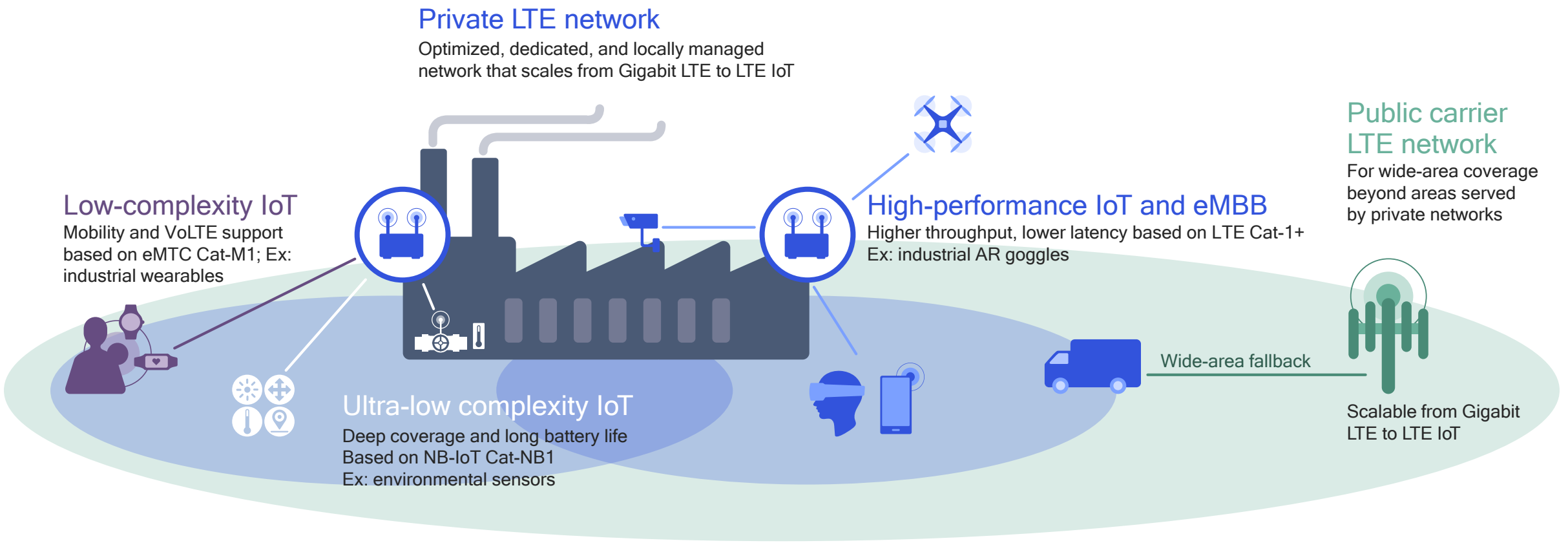
Allowing devices to reduce uplink transmit power, minimizing overall power consumption

More deployment options

Leveraging neutral hosts to provide IoT connectivity in shared/unlicensed spectrum (e.g., MulteFire)

1. With new eNB classes and support for CSG (Closed Subscribers Group)

Private LTE network addresses industrial IoT needs today



Optimized

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

Dedicated

Local network, easy to deploy independently managed

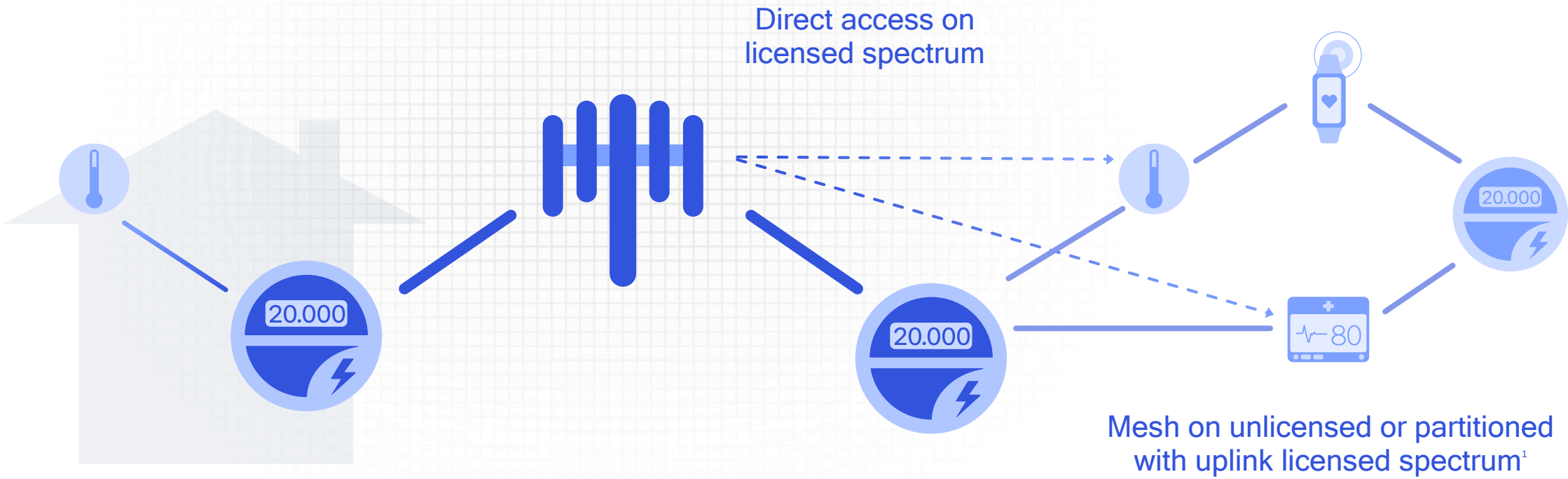
Secure

Industrial grade security with LTE and 5G NR

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

Support for multi-hop mesh with WAN management

Advanced massive IoT design for 3GPP Rel-16+



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

Problem: Uplink coverage

Due to low power devices and challenging placements, in e.g. basement

Solution: Managed uplink mesh

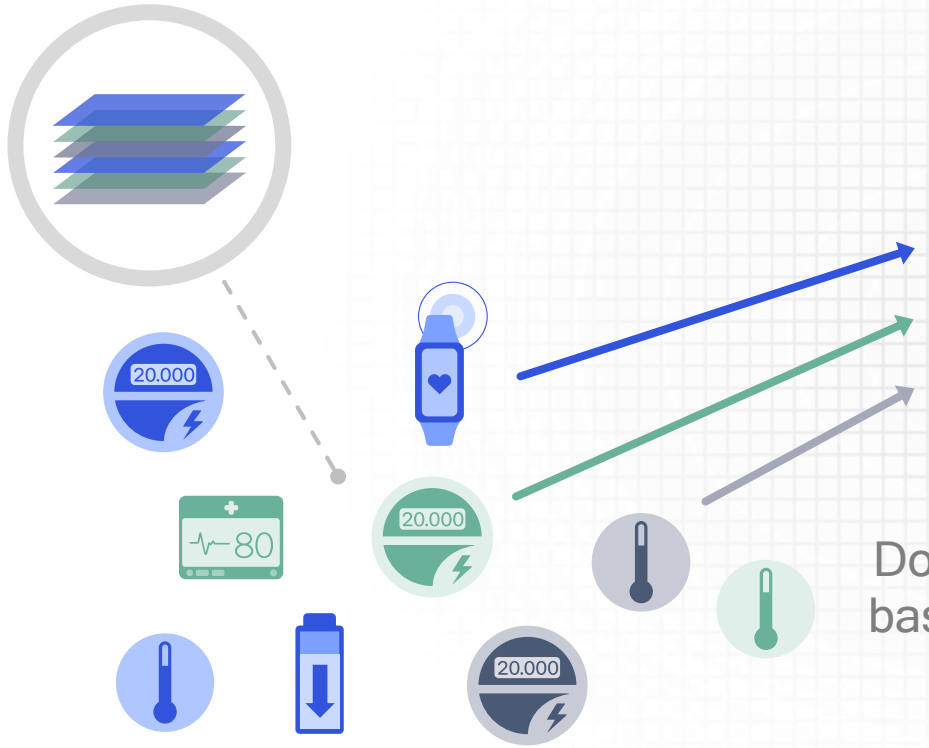
Uplink data relayed via nearby devices – uplink mesh but direct downlink.

NOMA[1] for efficient IoT communications

Characterized by small data bursts in uplink where signaling overhead is a key issue

Grant-free transmission of small data exchanges

- Eliminates signaling overhead for assigning dedicated resources
- Allows devices to transmit data asynchronously
- Capable of supporting full mobility
- Technically feasible for LTE IoT, but requires spec. formalization



Downlink remains OFDM-based for coexistence with other services

1. Non-orthogonal multiple access

Increased battery life | Scalability to even higher device density | Better link budget

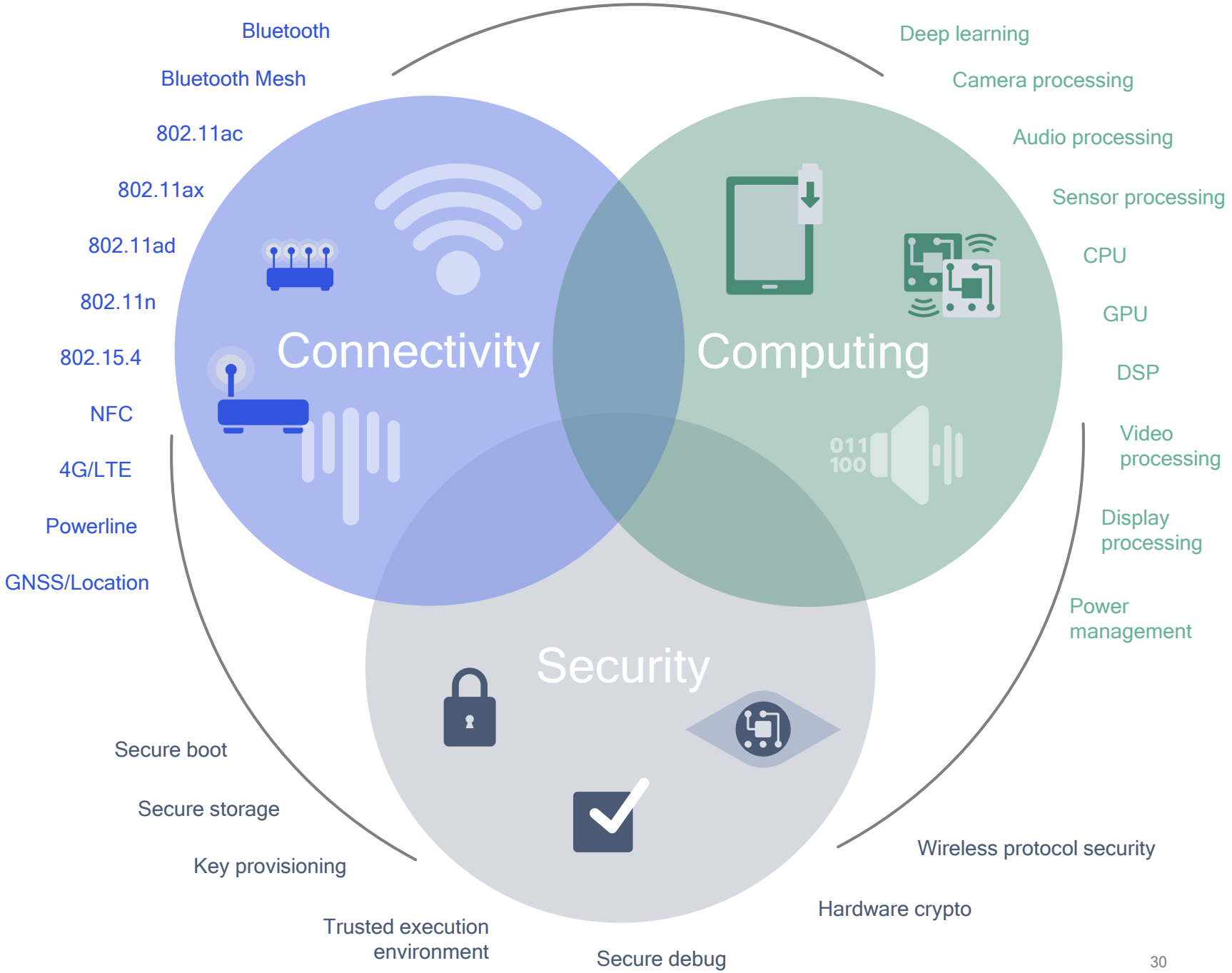
We are driving broad ecosystem adoption of LTE IoT

Strong global momentum with our multi-mode commercial solution – MDM9206

MDM9206 is a product of Qualcomm Technologies, Inc.

Mobile technology drives the IoT

Building on our leadership in mobile inventions



We have an end-to-end platform approach to the IoT

For massive scale deployment and quicker time-to-market

Simplified device development

Reference platforms that include hardware & software; pre-certified modules & devices

Simplified application development

Standardized communication protocols for interoperability & security; e.g., oneM2M

Simplified deployment/management

Full-stack IoT solution that provides data analytics, device management, and more; e.g., Verizon ThingSpace

MDM9206 delivers a

Global narrowband solution for the IoT

Single SKU for diverse deployment needs of carriers/end-users worldwide

One hardware design

Supporting multi-mode for Cat-M1, Cat-NB1, E-GPRS with integrated GNSS and VoLTE

One software image

Supporting dynamic mode selection with flexible configuration, e.g., Cat-M1 only/preferred, or Cat-NB1 only/preferred

One RF

15 LTE bands that cover virtually all of the world (B1-5, B8, B12-13, B17-20, B26, B28, B39)

MDM9206 is a product of Qualcomm Technologies, Inc..

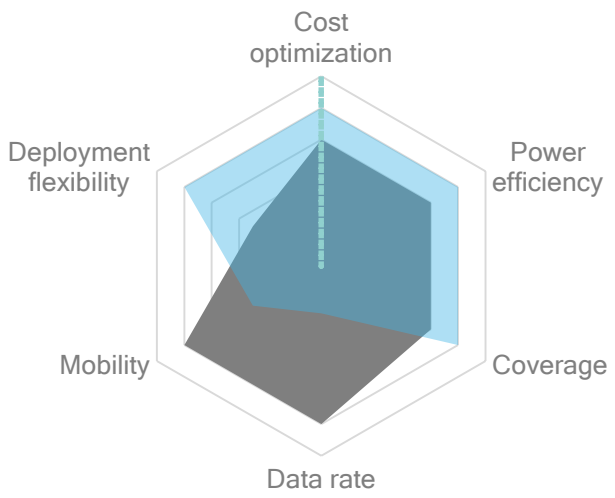
Highly cost-effective | Fast commercialization | Futureproof with OTA upgrade

Global multi-mode Cat-M1/NB1 most optimal approach

Combining the benefits of both technologies to address full range of use cases

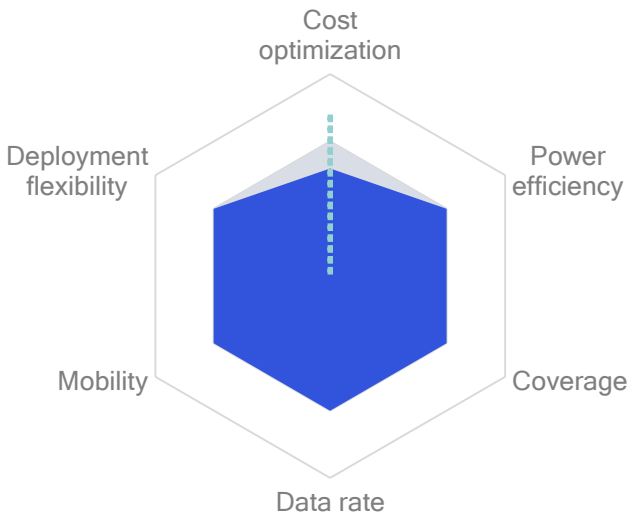
Single-mode

Cat-M1 vs. Cat-NB1



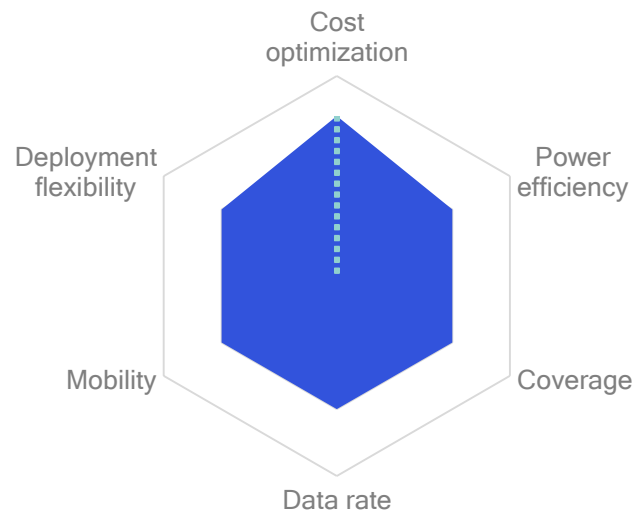
Multi-mode

vs. Single-mode



Global multi-mode

vs. Multi-mode



Cat-M1 Cat-NB1 Multi-mode

Improved OEM profitability with global SKU

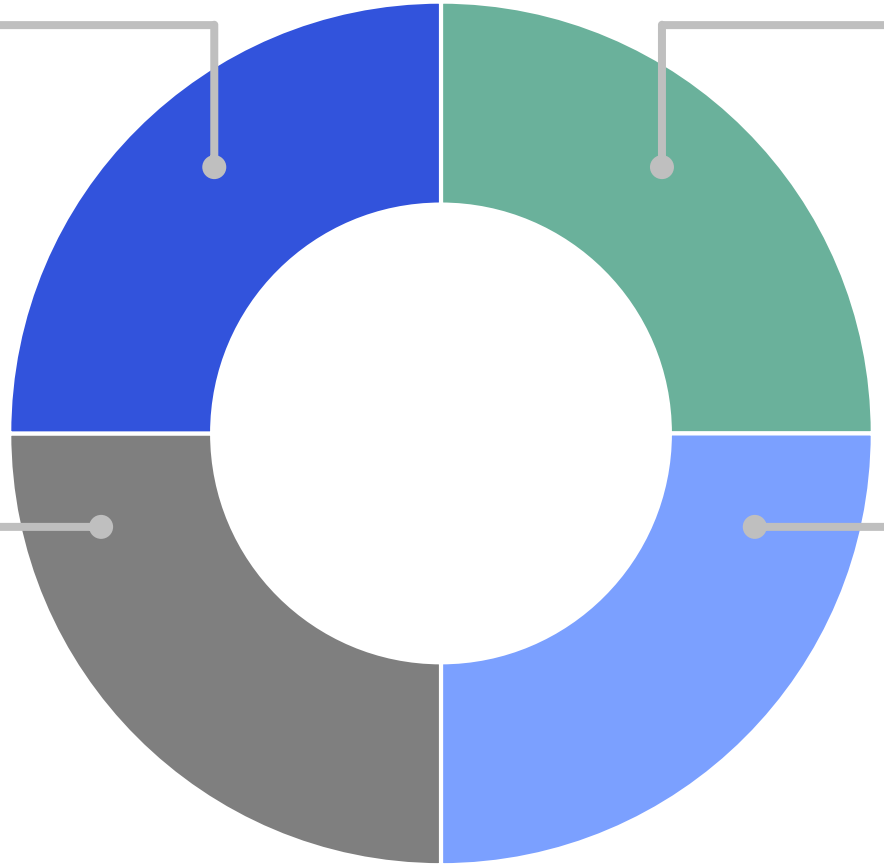
Global multimode offers superior overall device economics

Total cost of ownership

- Lower R&D and engineering costs
- Lower manufacturing overhead
- Simpler supply chain
- Lower inventory management costs

Time to global launch

- Potentially larger market share
- Potentially higher ASPs for longer



De-risk EOL inventory

- Higher forecasting accuracy
- Cost-effective SW-based repurposing of unsold inventory

Higher return on R&D

- Reduce R&D bottleneck from variant support
- Shift development resources to next-gen innovation

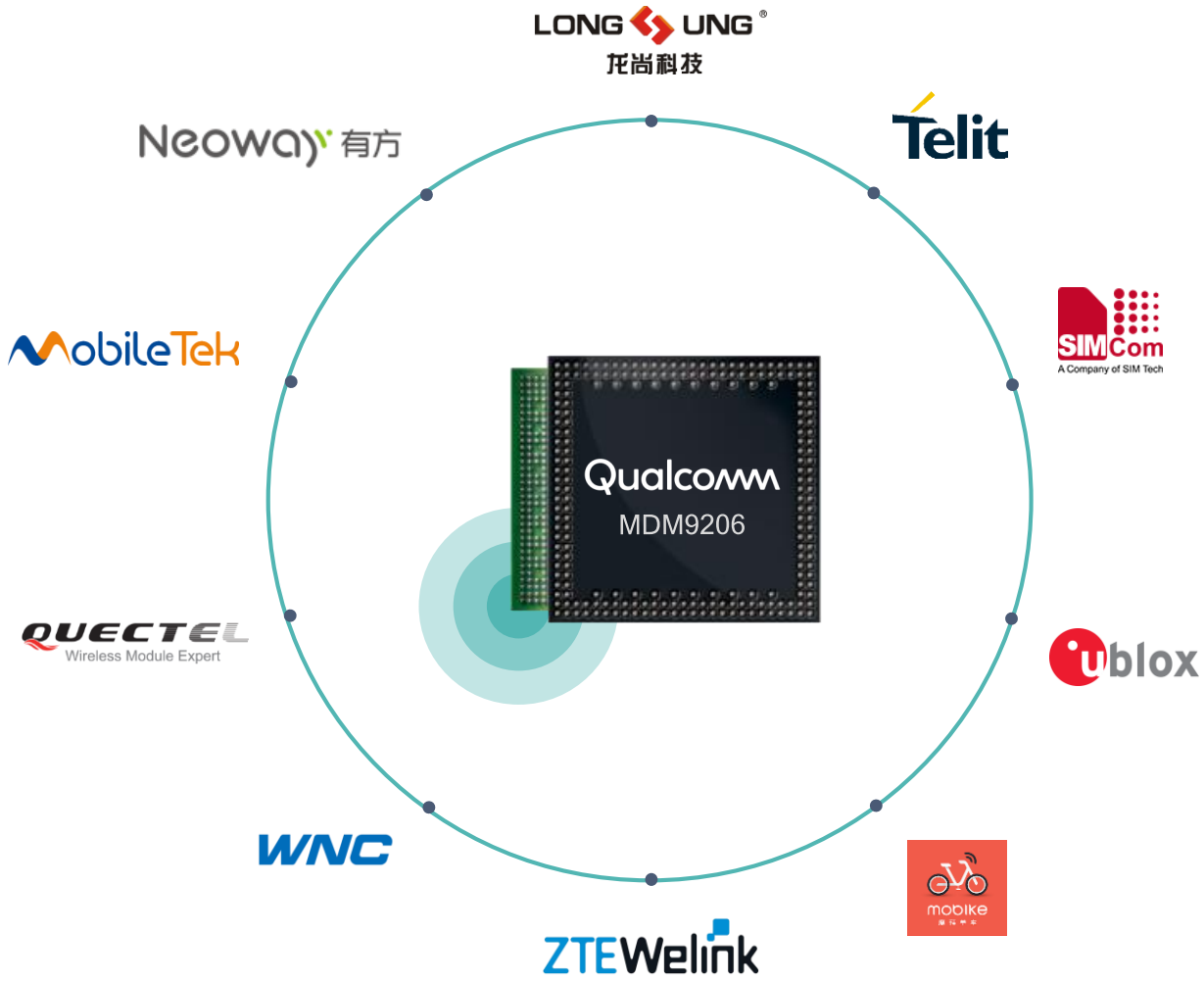
Driving broad ecosystem adoption of LTE IoT

Enabling global deployments today

MDM9206

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

- Multiple design wins across leading module OEMs and operators
- Announced support for Verizon ThingSpace Platform with modules from Quectel and Telit in Jan. 2017
- Jointly demonstrated the performance of a successful IoT VoLTE call with Ericsson and AT&T in Feb. 2017
- Announced 1st multi-mode trial with Mobike and China Mobile, May 2017
- Pre-certified for major global mobile operators that shortens time-to-market



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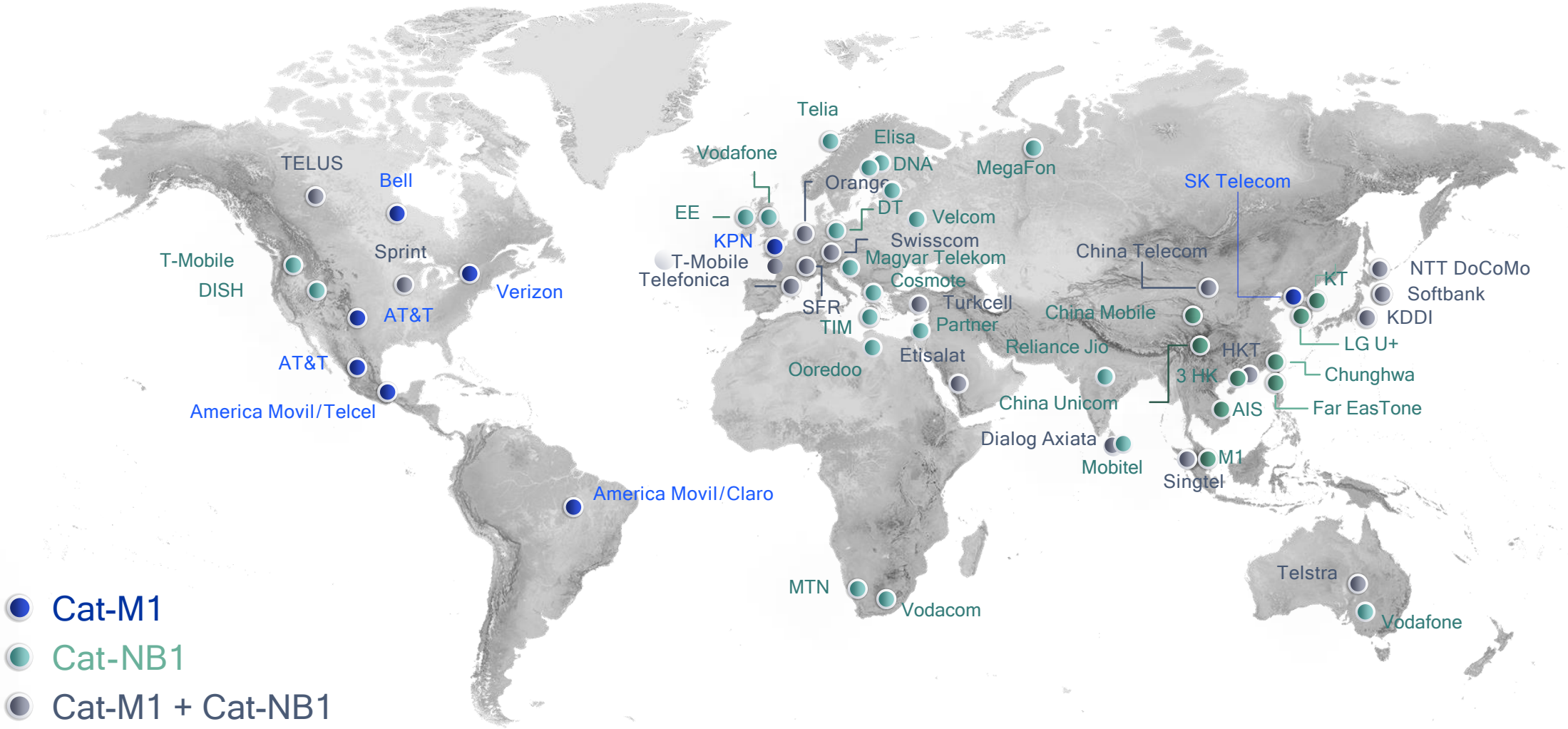
Strong global momentum for LTE IoT—July 2018 status

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

Bringing new levels of HW-based security to IoT devices

MDM9206 security foundations

Qualcomm Trusted Execution Environment

Isolates secure and non-secure software operations

Small code base, rigorously reviewed

Based on ARM's TrustZone architecture

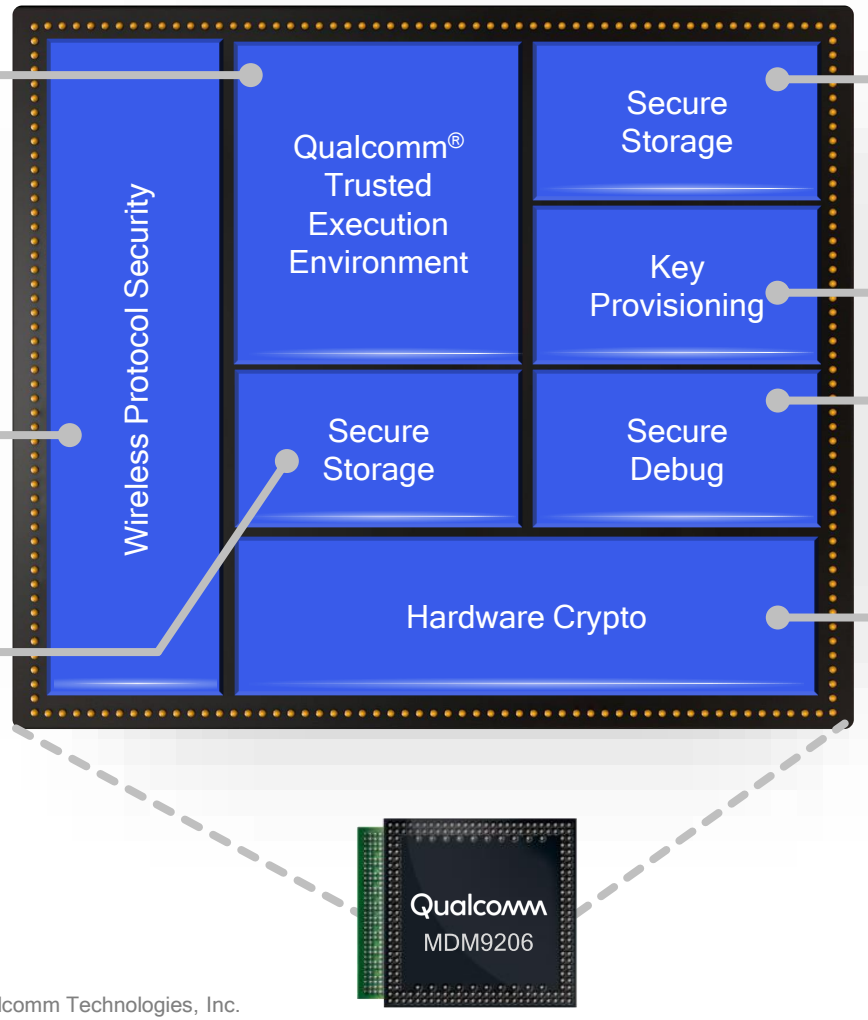
Wireless Protocol Security

WAN security and TLS to protect data-in-transit

Secure Boot

Deters unauthorized code execution

Tamper resistant root of trust in ROM or e-fuses



Secure Storage and Key Provisioning

OTP e-fuse memory for storage of keys and configurations

Encrypted storage capable

Provisioning of Keys

Secure Debug

Prevents JTAG debugger connection in commercial products and reverse engineering

Set by e-fuse, with support for secure RMA

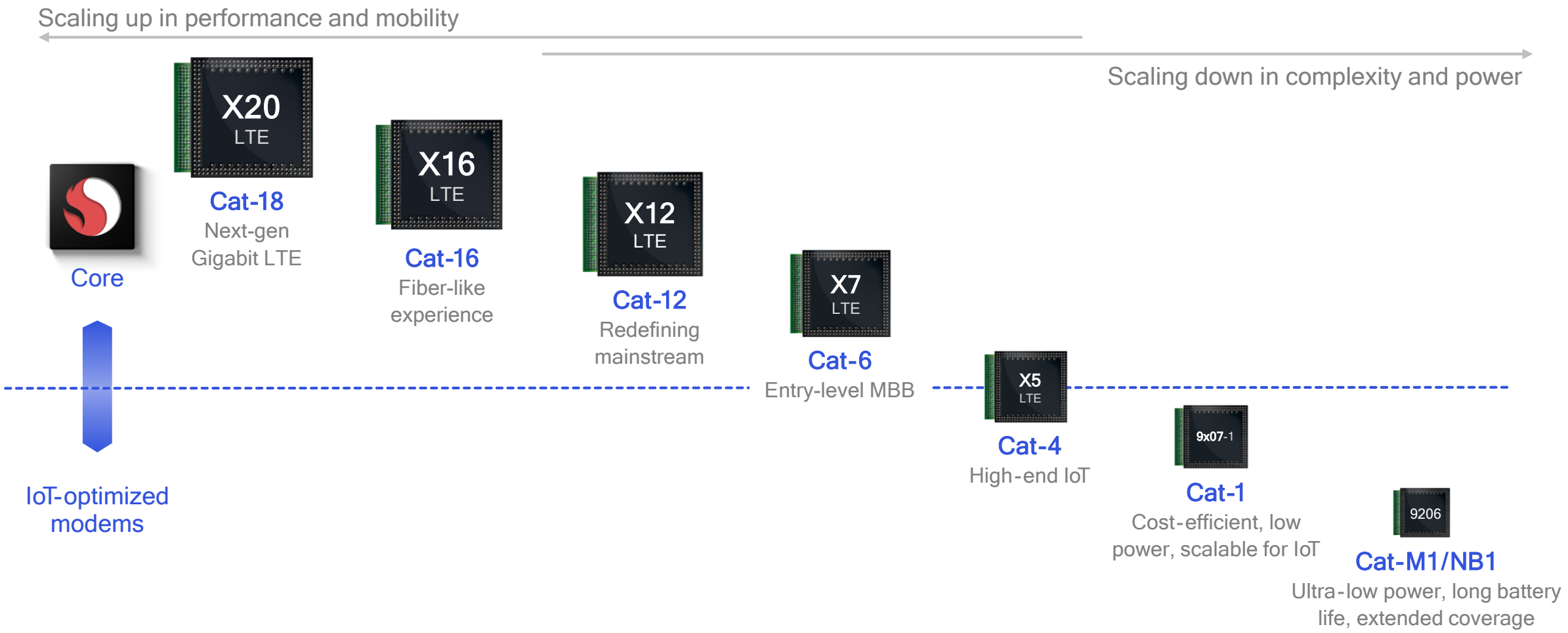
Hardware Crypto

FIPS certifiable cryptographic engines and HW Keys for more robust and fast encrypt/decrypt operations

Qualcomm Trusted Execution Environment and MDM9206 are products of Qualcomm Technologies, Inc.
DISCLAIMER: Reference to "secure" features and functions do not imply total impenetrability.

Delivering a scalable roadmap across all tiers and segments

LTE from gigabit to micro-amp



Note: Showing DL UE categories. Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc.

Leading the LTE IoT evolution to connect the massive IoT

- LTE IoT starts to connect the massive IoT today
- Continued LTE IoT evolution is broadening use cases
- We are driving broad ecosystem adoption of LTE IoT

Learn more at:
https://www.qualcomm.com/invention/5g/internet-of-things

Qualcomm

Thank you!

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