Paving the path to Narrowband 5G with LTE Internet of Things (IoT)

Qualcomm Technologies, Inc.

June, 2016

IoT – a massive surge of smart, interconnected “things”

QUALCOMM®

Qualcomm Technologies, Inc. is a proven, trusted solution provider for IoT

Decades of industry experience

Broad portfolio of technologies

1B+ IoT devices shipped globally[1]

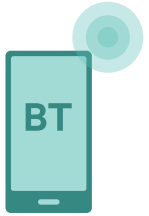
[1] Cumulative shipment using Qualcomm technologies; includes SoC, Cellular, Bluetooth, Wi-Fi , GNSS and PLC, stats as of April 2016

Connecting the IoT requires heterogeneous connectivity

Powered by global standards with seamless interoperability across multiple vendors

Cellular

Wi-Fi



Bluetooth

GNSS/Location

NFC

Powerline

Creating a connectivity fabric for everything

To support the wide range of IoT use cases with varying requirements

Throughput

Reliability

Node density

Coverage

Security

Cost

Battery life

Latency

Mobility

Cellular technologies enable a wide range of IoT services

Smart cities
Lighting, traffic sensors, smart parking,…

Mobile health
Wearables, gateways, remote patient,…

Smart utilities
Smart grid, gas/water/ electric meters

Environmental monitoring
Agriculture, forecast fire/ air pollution sensors,…

>5B
IoT connections by 2025[1]

Connected building
Security, video surveillance, smoke detectors,…

Connected industrial
Process/equipment monitoring, HVAC, …

Connected retail
Vending machines, ATM, digital ads,…

Asset tracking
Fleet management, pet/kid trackers, shipping,…

Ubiquitous coverage

Always-on connectivity

Reliable and secure

Global ecosystem

[1] Including Cellular & LPWA M2M connections, Machina Research, June, 2016

We are evolving LTE for the Internet of Things

New narrowband technologies to more efficiently support IoT use cases

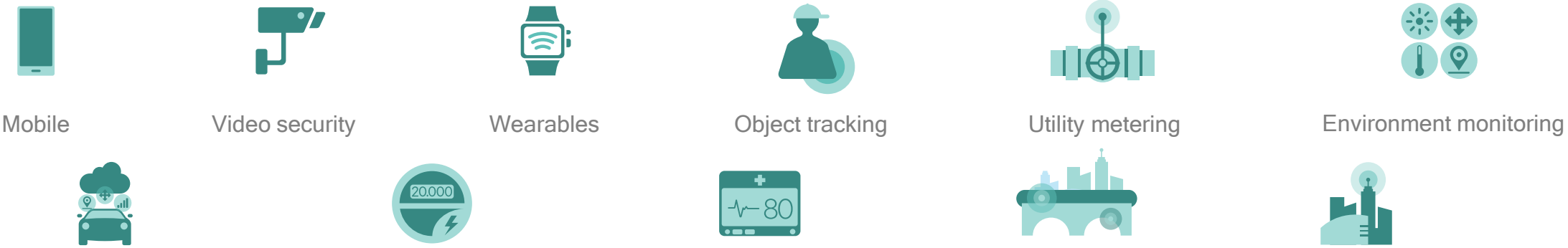
Scaling up in performance and mobility

Scaling down in complexity and power

Today

New narrowband IoT technologies (3GPP Release 13+)

LTE Cat-4 and above	LTE Cat-1	LTE Cat-M1 (eMTC)	Cat-NB1 (NB-IoT)
>10 Mbps	Up to 10 Mbps	Variable rate up to 1 Mbps	10s of kbps
n x 20 MHz	20 MHz	1.4 MHz narrowband	200 kHz narrowband



Mobile · Video security · Wearables · Object tracking · Utility metering · Environment monitoring

Connected car · Energy management · Connected healthcare · City infrastructure · Smart buildings

LTE IoT delivers significant value for LPWA[1] applications

Over non-3GPP solutions

Ubiquitous coverage
Established networks serving billions of connections worldwide

Mature ecosystem
Backed by global standards with a rich roadmap to 5G

Scalability
To address the wide range of IoT use cases

Managed QoS
Based on licensed spectrum with a redundant network design

Coexistence
Leverages existing and planned LTE infrastructure and spectrum

End-to-end security
Established/trusted security and authentication features built in

[1] Low-power, wide-area

Paving the path to 5G

NB-IoT is the foundation for Narrowband 5G; continuing to evolve in Release 14+

eMTC

Scales down LTE to address the broadest range of IoT use cases

NB-IoT

Optimizes to lowest cost/power for delay-tolerant, low-throughput IoT use cases

NB-5G

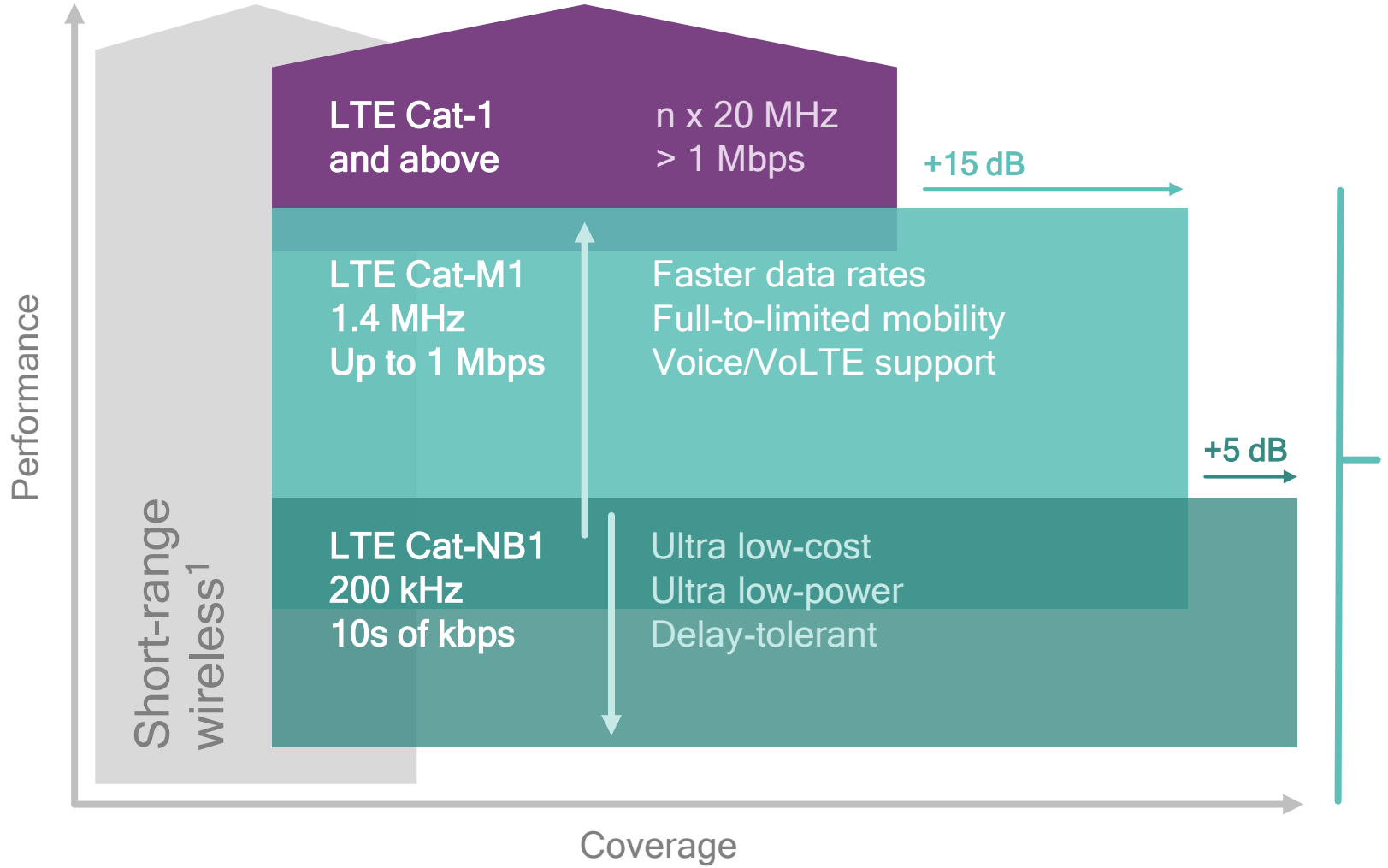
3GPP 5G NR further enhances massive IoT with new capabilities such as RSMA[1] & multi-hop mesh

[1] Resource Spread Multiple Access

Delivering new narrowband LTE IoT technologies

As part of 3GPP Release 13

Two new LTE IoT technologies, one unified LTE platform



LTE Cat-M1 (eMTC)

Broadest range of IoT capabilities with support for advanced features, e.g. voice support

Many IoT devices can benefit from multi-mode operations to optimize for different traffic profiles and RF conditions

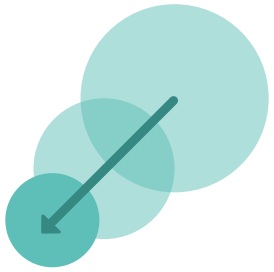
LTE Cat-NB1 (NB-IoT)

Scalable to lowest cost/power for delay-tolerant, low-throughput IoT use cases, e.g. remote sensors

[1] Examples include Bluetooth, Wi-Fi, NFC, and others

LTE IoT reduces complexity, extends battery life & coverage

Through optimizations to both the air interface and core network



Reduced complexity

Narrowband operation (1.4 MHz or 200 kHz) plus further device and core network complexity reductions

Multi-year battery life

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

Deeper coverage

Achieve up to 20 dB increase in link budget for hard-to-reach locations via redundant transmissions

Higher node density

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

Coexistence with today's mobile broadband services

Leveraging existing infrastructure and spectrum

New LTE IoT device categories reduce LTE complexity

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

	LTE Cat-1 (Today)	LTE Cat-M1 (Rel-13)	LTE Cat-NB1 (Rel-13)
Peak data rate	DL: 10 Mbps UL: 5 Mbps	DL: 1 Mbps UL: 1 Mbps	DL: ~20 kbps UL: ~60 kbps
Bandwidth	20 MHz	1.4 MHz	200 kHz
Rx antenna	MIMO	Single Rx	Single Rx
Duplex mode	Full duplex FDD/TDD	Supports half duplex FDD/TDD	Half duplex FDD only
Transmit power	23 dBm	20 dBm[1]	20 dBm[1]

Higher throughput, lower latency, full mobility

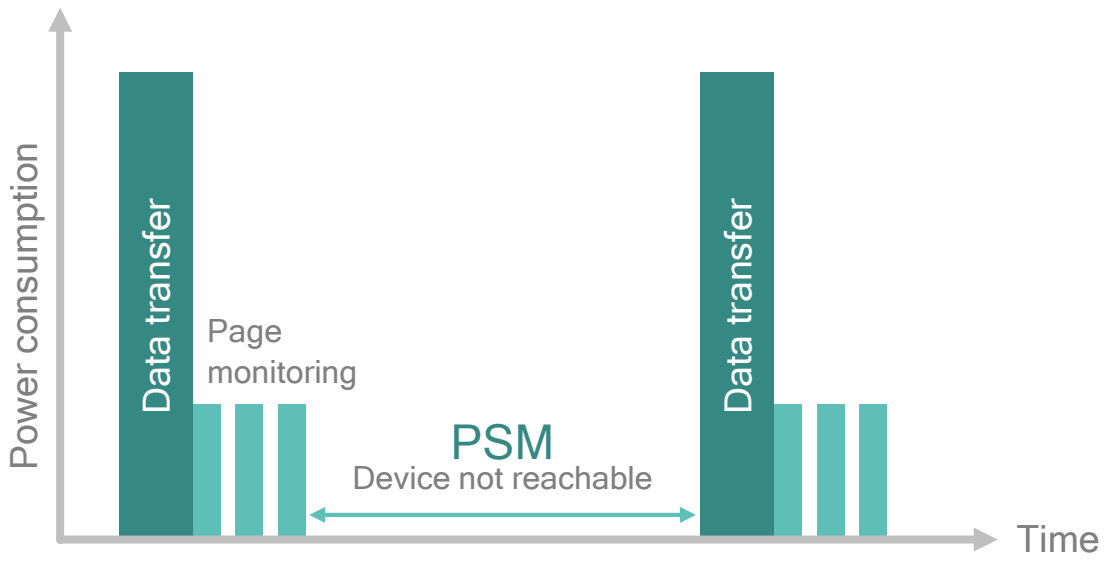
Simplified RF hardware

Reduces baseband complexity and decreases memory

[1] Integrated PA possible

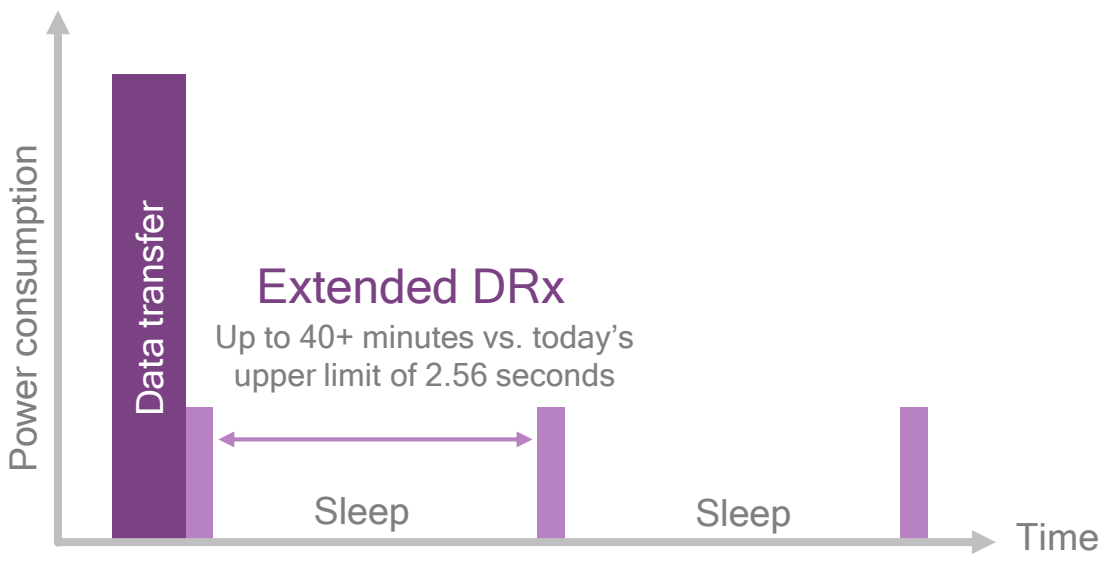
Delivering multi-year battery life

Devices wake up on a per-need basis; stay asleep for minutes, hours, even days



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)

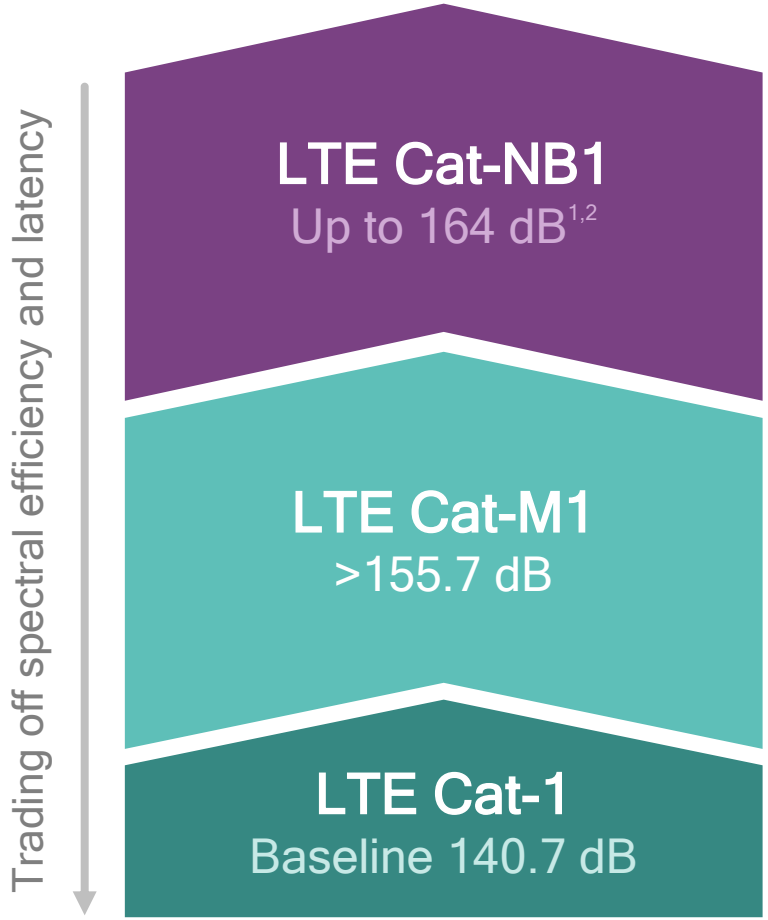
Extends time between monitoring for network messages
For device-terminated applications, e.g., object tracking, smart grid

Also features such as reduced complexity and less channel measurements extend battery life

Note: PSM and eDRx applicable to both Cat-M1 and Cat-NB1; may also be applied to LTE Cat-1 and above

Numerous technology enablers for deeper coverage

To reach challenging locations, e.g. penetrating more walls & floors



Cat-NB1 only

- Further relaxed requirements, e.g. timing
- Low-order modulation, e.g. QPSK
- Option for single-tone uplink transmissions

Cat-M1 and Cat-NB1

- Repetitive transmissions & TTI bundling for redundancy
- Narrowband uplink transmissions

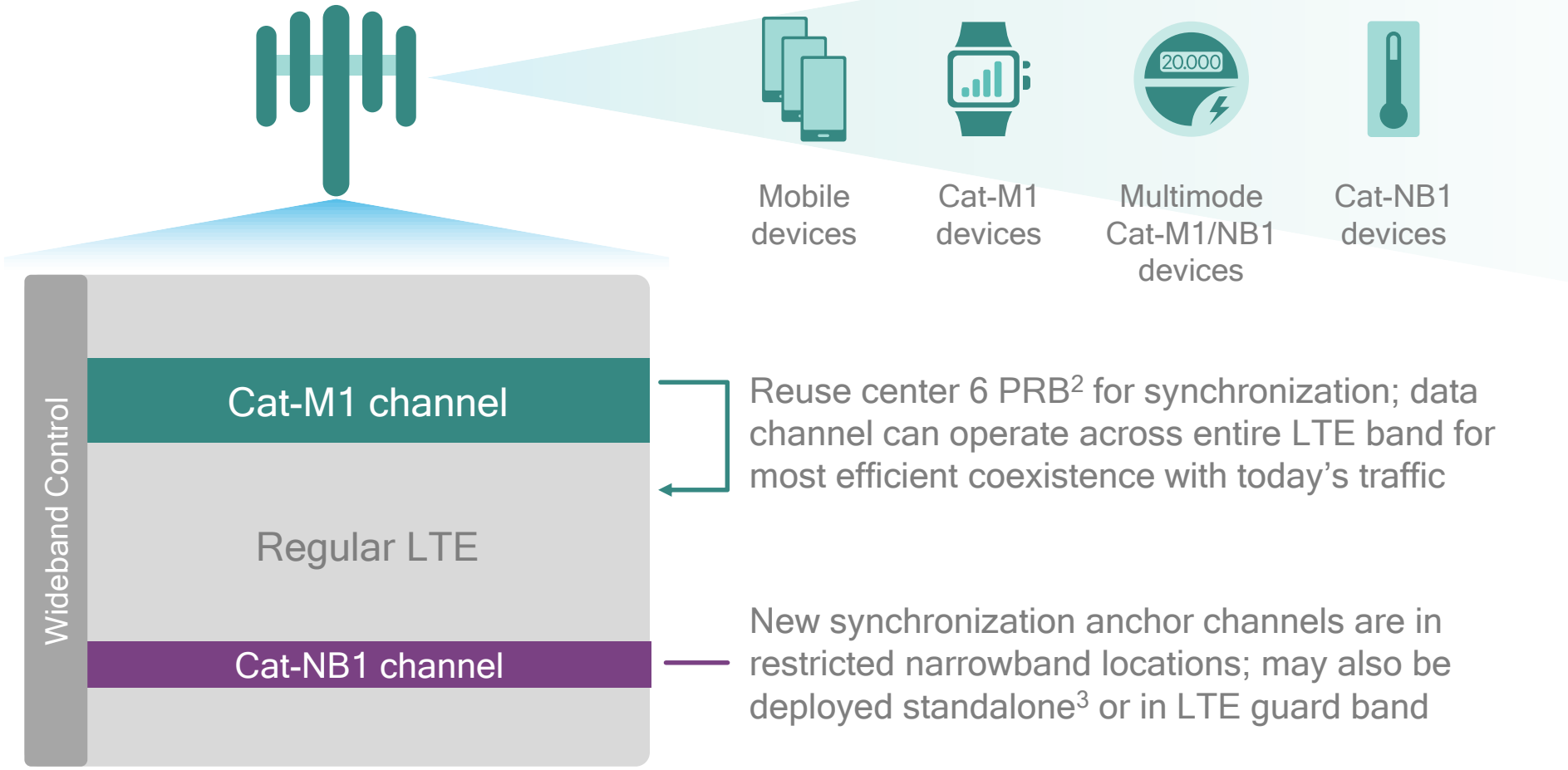
[1] Link budget; [2] At least for standalone operation mode

Coexisting with today's LTE services

Cat-M1 and Cat-NB1 can leverage existing LTE infrastructure and spectrum

<0.1%

Data capacity for IoT traffic based on sample scenario[1]



Reuse center 6 PRB[2] for synchronization; data channel can operate across entire LTE band for most efficient coexistence with today's traffic

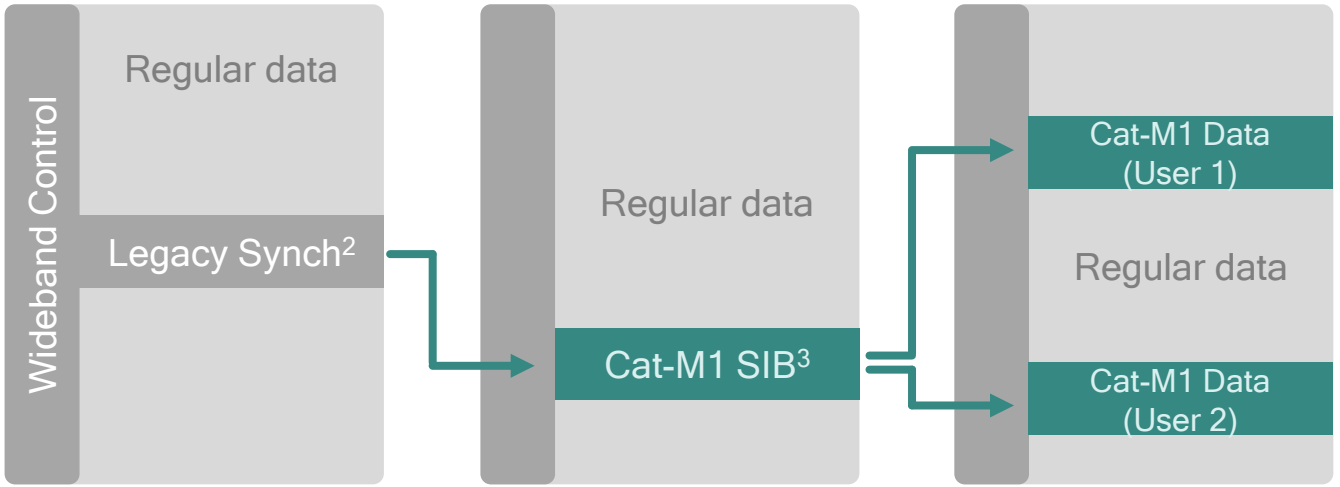
New synchronization anchor channels are in restricted narrowband locations; may also be deployed standalone[3] or in LTE guard band

[1] Assumptions: ISD Urban - 500m, 3 cells per site, Channel b/w 10MHz, Cell capacity: DL 14Mbps, UL 9.6Mbps; Traffic types include data and commands for Electric Meter, Water Meter, Security Panel, HVAC - Residential, Outdoor Street Light, Off Street Parking Meter, Parking Space Sensor, Water Assets; 100% of traffic assumed in 6hr. busy period; [2] Physical Resource Block; [3] Including re-farming of GSM spectrum

Cat-M1 (eMTC) efficient coexistence with today's services

Narrowband operation of 1.4 MHz[1] across entire LTE band

Supports FDD or TDD spectrum



Co-existence

Time and Frequency-Division Multiplexing between LTE IoT and today's existing services, e.g. mobile broadband

Flexible capacity

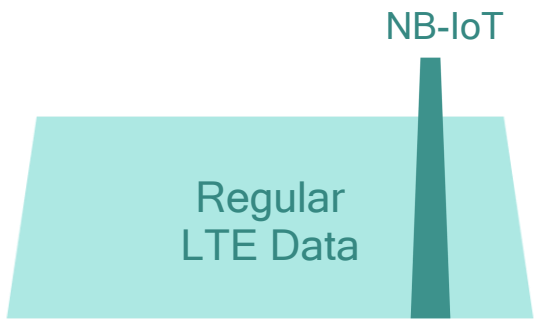
Multiple narrowband regions with frequency retuning to support scalable resource allocation between LTE IoT and non-IoT traffic[4]

[1] 1.08 MHz used by the network to transmit 6 RBs in-band; [2] PSS/SSS/PBCH; [3] SIB (System Information Block); [4] Also supports frequency hopping within LTE band for diversity

Cat-NB1 (NB-IoT) flexible deployment options

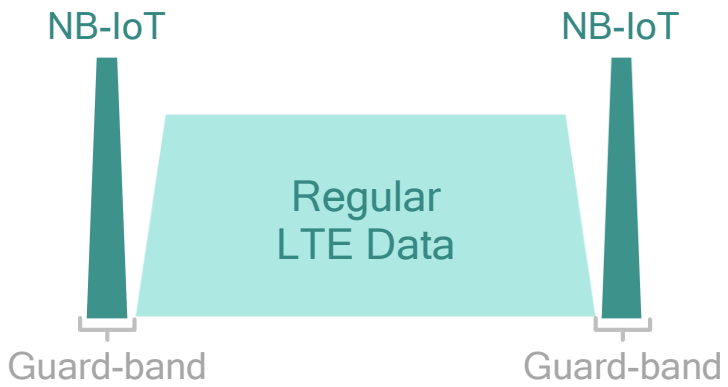
Dedicated NB carrier – supports FDD spectrum only in Rel-13

In-band



Utilizing single Resource Block (180 kHz) within a normal LTE carrier

Guard-band



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

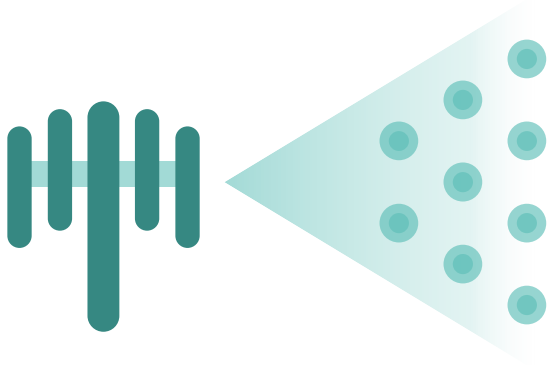
Standalone

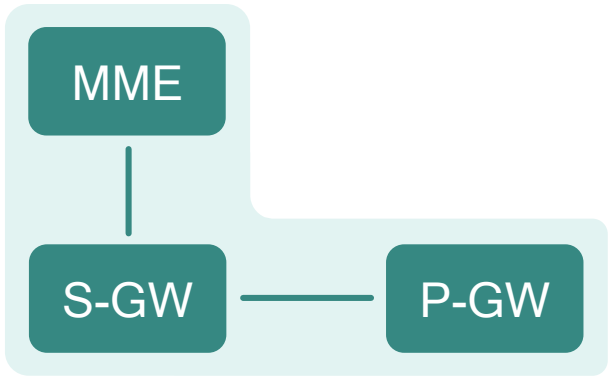
Utilizing stand-alone 200 kHz carrier, e.g. re-farming spectrum currently used by GERAN systems

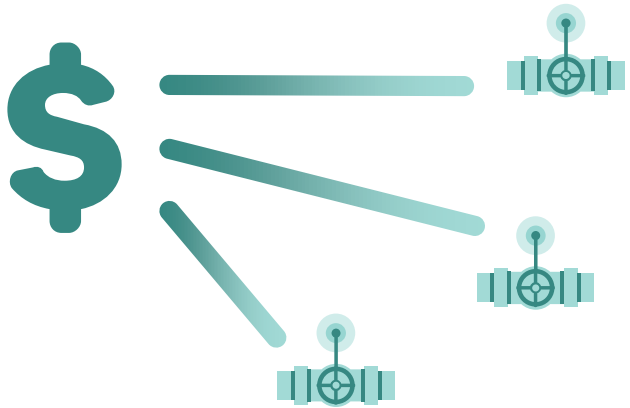
New optimized NB-IoT synchronization, control, and data channels

Delivering IoT optimizations to the network architecture

Also part of 3GPP Release 13







More efficient signaling

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

Simplified Core Network (EPC-lite)

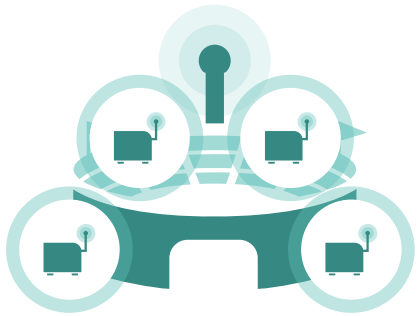
Reduced functionality, e.g. limited mobility and no voice, makes possible for integrating network functions into a single entity

Enhanced resource management

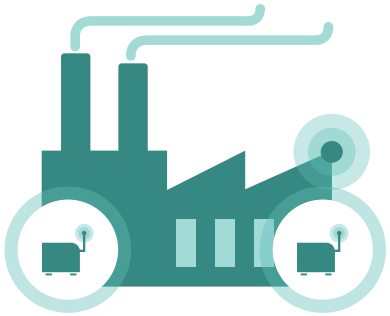
Such as optimizations to allow a large set of devices to share the same subscription, e.g. all the water meters in a city

Optional optimizations so that mobile operators can effectively balance CAPEX vs. OPEX decisions

Small cells add value to LTE IoT deployments

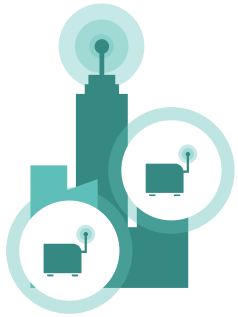


Venues



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)

Providing an end-to-end LTE IoT platform

To simplify the deployment and management of IoT services

Simplified device development

Development platforms
Certified modules
Certified devices

Optimized LTE connectivity

Reduced complexity
Lower power
Deeper coverage

Simplified service management

Billing/cost mgmt.
Remote provisioning
Embedded SIM (eUICC)
Real-time diagnostics

Simplified network architecture

Reduced functionality
Optimized signaling
Virtualization

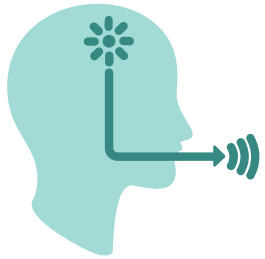
Simplified application development

Standardized protocols
Interoperability
End-to-end security
e.g. oneM2M

Roadmap to 5G will bring even more opportunities for the Internet of Things

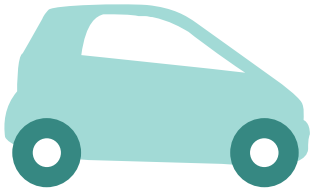
We are continuing to evolve NB-IoT beyond Release 13

The foundation to Narrowband 5G



VoLTE

Adding voice and options to support lower latency services



Mobility

Enabling devices to monitor and report channel conditions for inter-cell handovers

Positioning

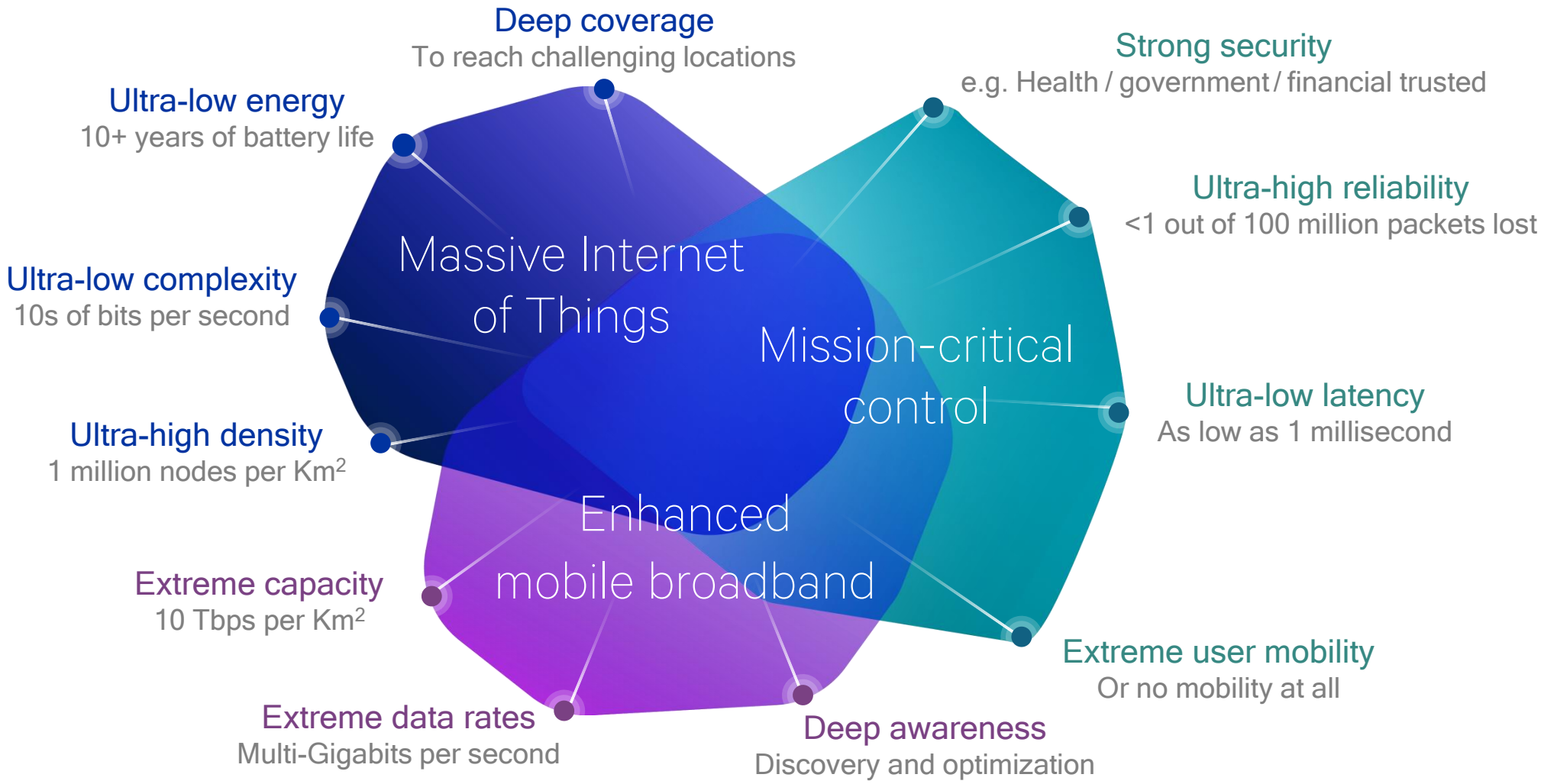
Providing location services for use cases such as mobile asset tracking and emergency call

Broadcast

Allowing more efficient OTA firmware update for large number of devices, e.g. sensors, meters

We are also designing a new 5G NR air interface

5G NR will be scalable to an extreme variation of IoT requirements

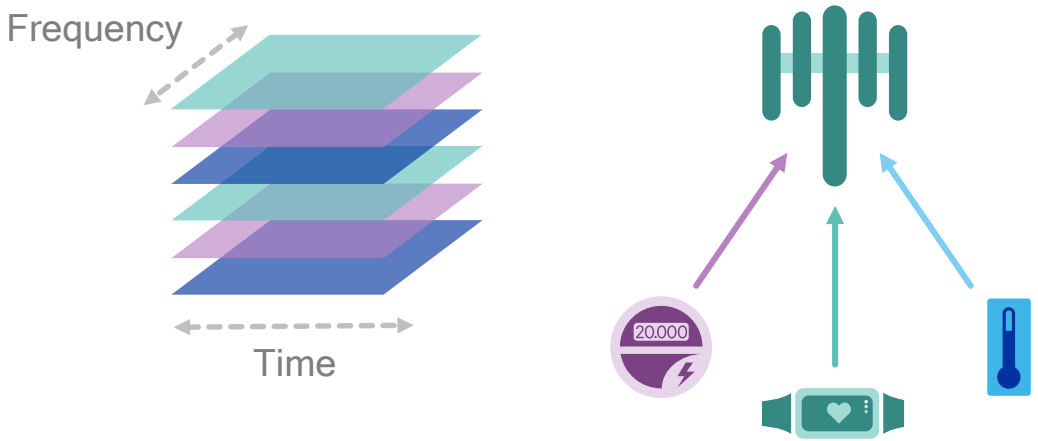


Based on target requirements for the envisioned 5G use cases

Bringing new capabilities for the massive IoT

Grant-free uplink

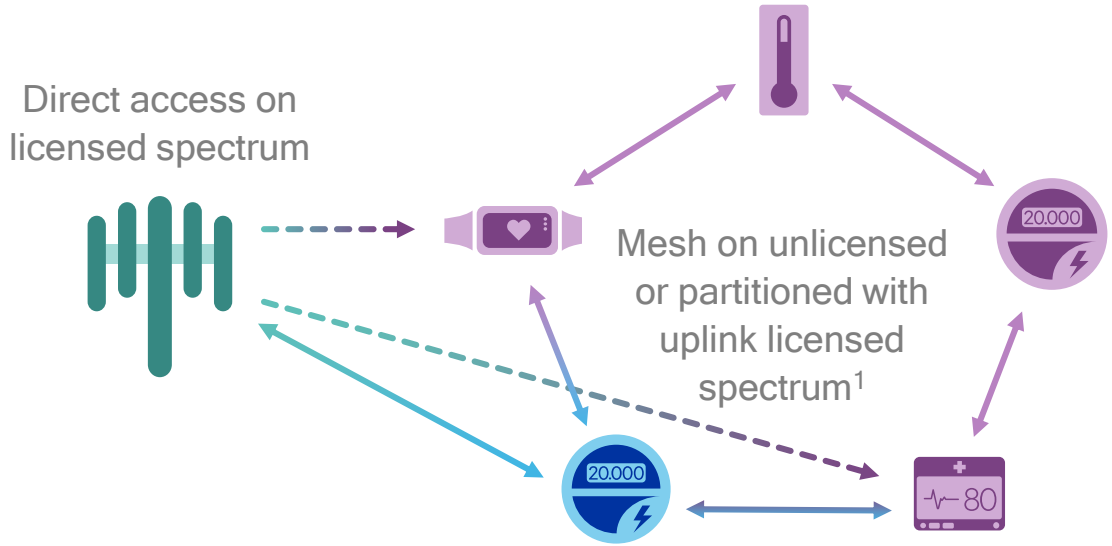
Resource Spread Multiple Access (RSMA)



Enables asynchronous, non-orthogonal, contention-based access that is well suited for sporadic uplink transmissions of small data bursts common in IoT use cases

Coverage extension

Multi-hop mesh with WAN management



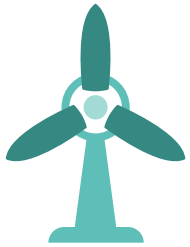
Overcomes uplink coverage issues due to low-power devices and challenging placements by enabling uplink data relayed via nearby devices; opportunity to reduce power/cost even further

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

Also enabling new mission-critical control IoT services

Autonomous vehicles

Robotics



Energy/ Smart grid

Aviation

Industrial automation

Medical

1ms e2e latency

Faster, more flexible frame structure; also new non-orthogonal uplink access

Ultra-high reliability

Ultra-reliable transmissions that can be time multiplexed with nominal traffic through puncturing

Ultra-high availability

Simultaneous links to both 5G and LTE for failure tolerance and extreme mobility

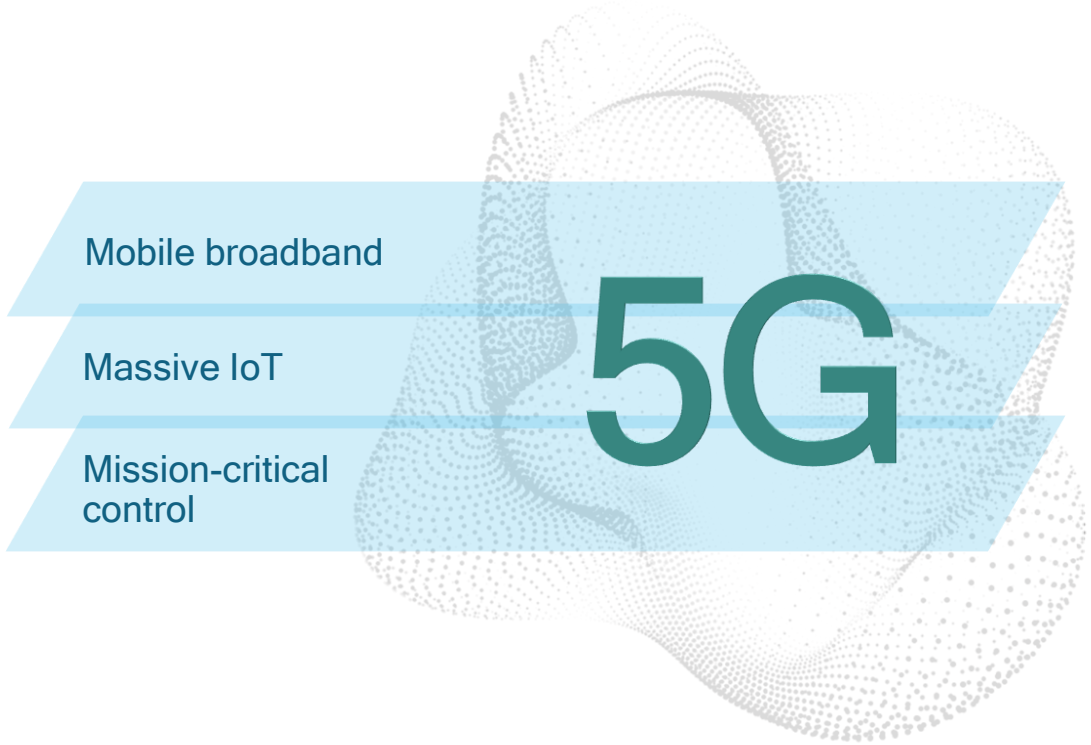
Strong e2e security

Security enhancements to air interface, core network, & service layer across verticals[1]

[1] Also exploring alternative roots of trust beyond the SIM card

Flexible 5G network architecture brings additional benefits

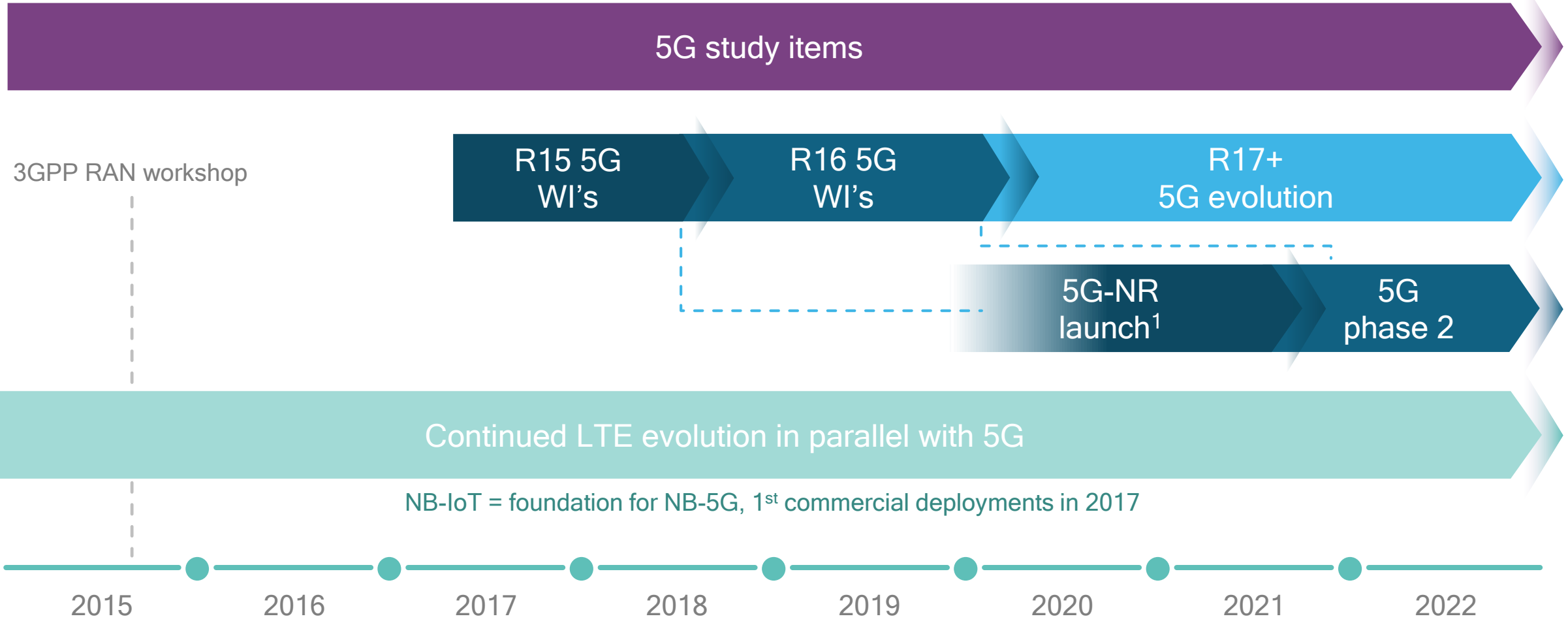
Leveraging virtualized network functions to create optimized network slices



- Configurable end-to-end connectivity per vertical
- Modular, specialized network functions per services
- Flexible subscription models
- Dynamic control and user planes with more functionality at the edge
- Multi-access core network will provide connectivity to LTE, NB-IOT, and 5G IoT

Better cost/ Energy efficiency | Optimized performance | Flexible business models | Dynamic creation of services

5G standardization progressing for 2020 launch



Learn more at: www.qualcomm.com/5G

Note: Estimated commercial dates; [1] Forward compatibility with R16 and beyond

Qualcomm is uniquely positioned to connect the Internet of Things

An established leader today –
pioneering tomorrow's technologies

Delivering a broad portfolio of technologies for the IoT

To meet diverse connectivity and computing requirements

Bluetooth Smart

Bluetooth Mesh

802.11ac

802.11ad

802.11n

DSRC

NFC

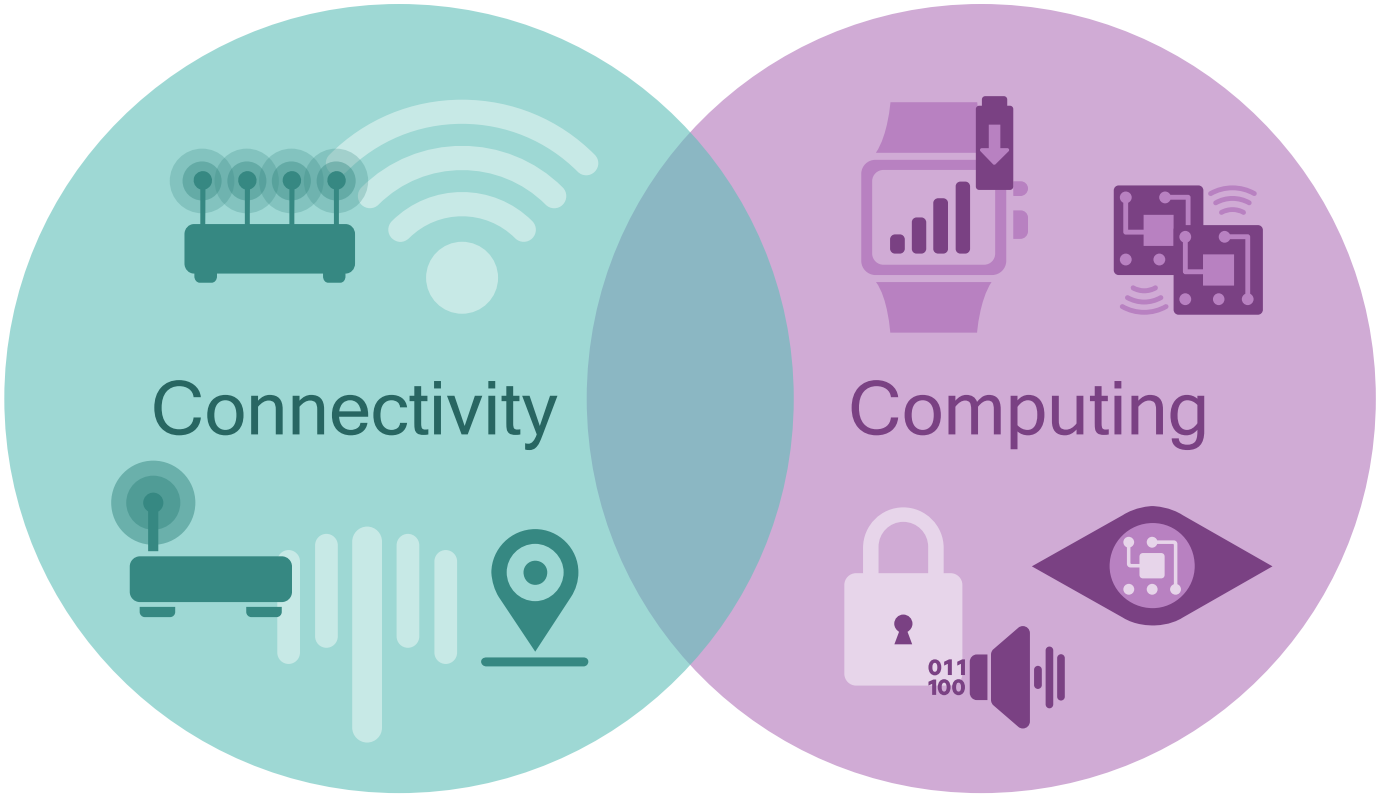
3G

4G LTE

5G

Powerline

GNSS/Location



Cognitive computing

Camera processing

Audio processing

Sensor core

Security

CPU

GPU

DSP

Media processing

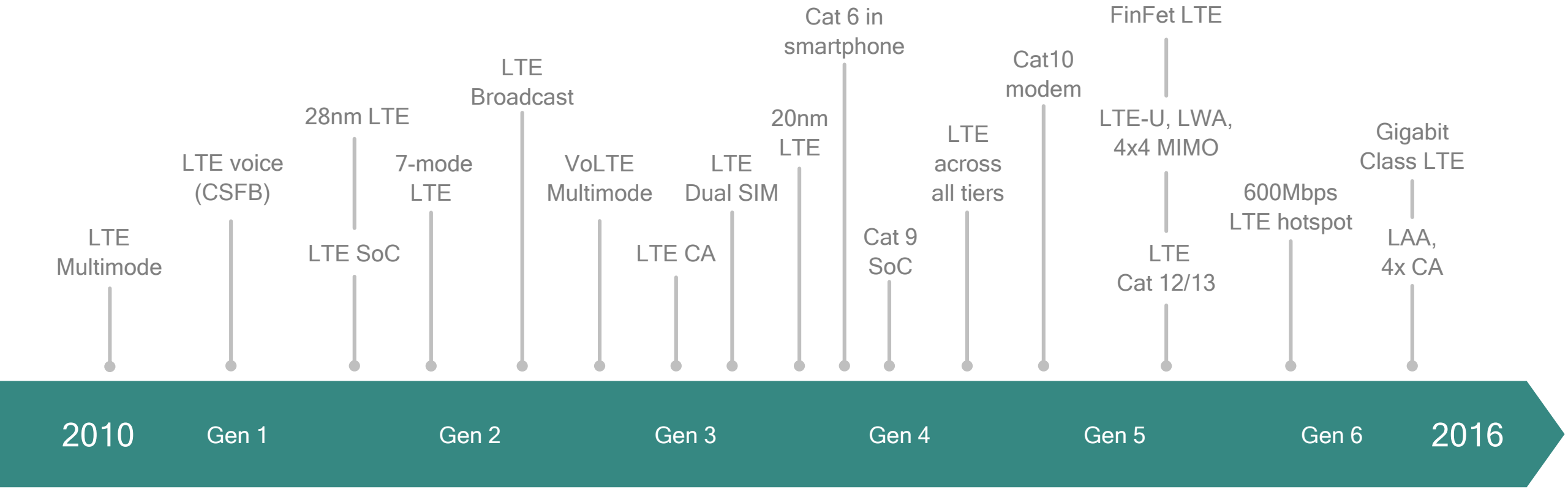
Augmented reality

Display processing

Power management

Qualcomm Technologies' LTE platform leadership

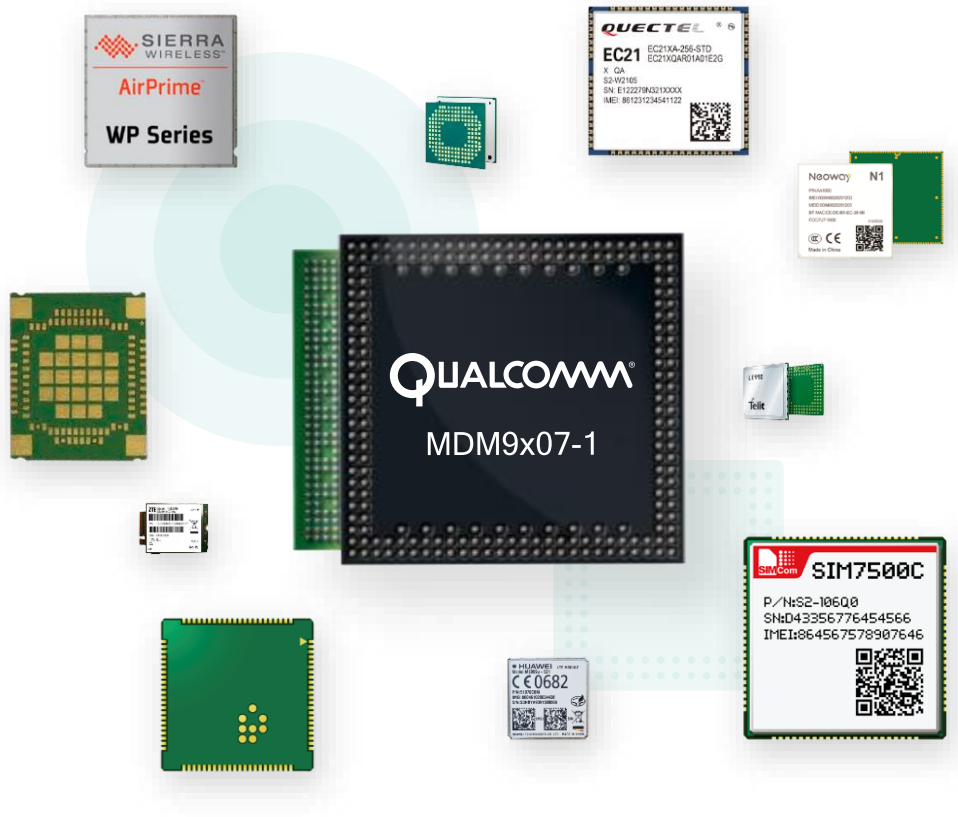
A history of industry firsts



Qualcomm Technologies modem generation and feature

Delivering 3G and 4G LTE solutions for the IoT today

Established ecosystem partners with proven global solutions



Qualcomm MDM9x07-1: LTE Cat-1 modem for the Internet of Things

- 4G/3G global band support (multimode/multiband)
- Highly integrated to reduce cost / complexity
- PSM enabling up to 10+ years battery life
- Scalable to add voice, Wi-Fi, BT capabilities
- Hardware-based security

More than 100 design wins from over 60 manufacturers[1]

[1] Includes Qualcomm Snapdragon X5 LTE (9x07) and MDM9x07-1 modem, as of June 2016

Driving new LTE IoT technologies towards commercialization

Rel-13 specification now complete for LTE Cat-M1 (eMTC) and Cat-NB1 (NB-IoT)

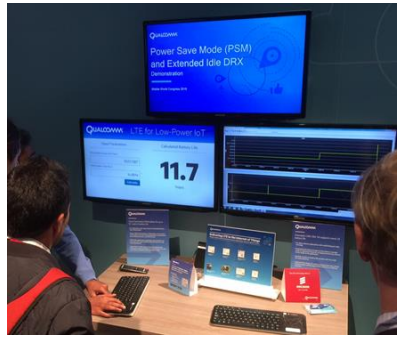
A GLOBAL INITIATIVE

Standards leadership

Main contributor to eMTC and NB-IoT features

Harmonized Industry on narrowband IoT (NB-IoT) specification

Pioneering work on future IoT technologies, e.g. multi-hop to extend uplink coverage



Prototyping new technologies

PSM & eDRx simulations and system tests, as demonstrated at MWC 2016

Qualcomm MDM9206 Flexible chipset platform

Common hardware solution to enable Cat-M1 and/or Cat-NB1

MDM9206 is a product of Qualcomm Technologies, Inc.

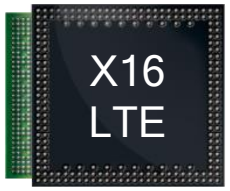
Delivering a scalable roadmap across all tiers & segments

LTE from gigabit to micro-amp

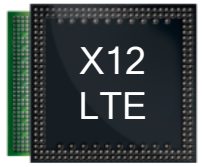
Scaling up in performance and mobility

Scaling down in complexity and power

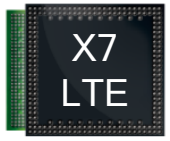
Core



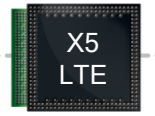
Cat-16
Fiber-like experience



Cat-12
Redefining mainstream



Cat-6
Entry-level MBB



Cat-4
High-end IoT

Cat-1
Cost-efficient, low power, scalable for IoT

Cat-M1/NB1
Ultra-low power, long battery life, extended coverage

IoT-optimized modems

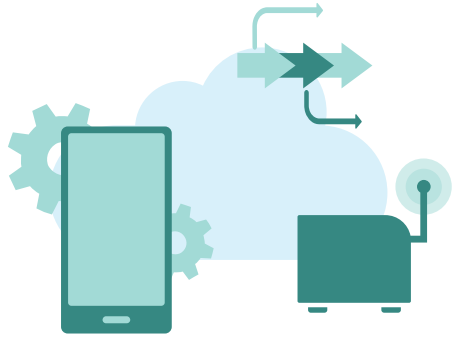
Note: Showing DL UE categories. Snapdragon is a product of Qualcomm Technologies, Inc.

Leading the world to 5G

Investing in 5G for many years—building upon our leadership foundation

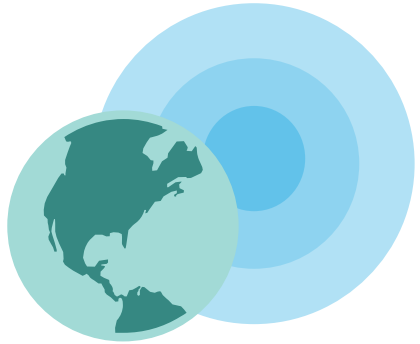
Wireless/OFDM technology and chipset leadership

Pioneering new 5G technologies to meet extreme requirements



End-to-end system approach with advanced prototypes

Driving 5G from standardization to commercialization



Leading global network experience and scale

Providing the experience and scale that 5G demands

In summary

LTE is evolving to deliver a unified, scalable IoT platform that brings significant benefits over non-3GPP LPWA solutions

Delivering new narrowband IoT technologies (Cat-M1/NB1) to lower complexity, increase battery life, and deepen coverage – establishes the foundation for Narrowband 5G

Roadmap to 5G will bring even more opportunities for the Internet of Things including new mission-critical services

Qualcomm is uniquely positioned to connect the Internet of Things and is leading the world to 5G

Learn more at: http://www.qualcomm.com/LTE-IoT

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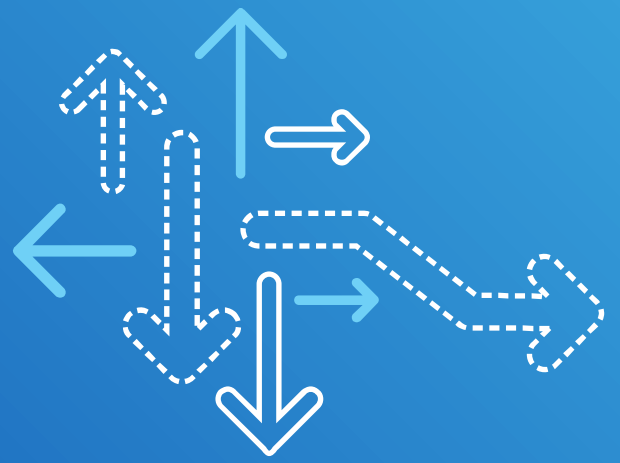

Thank you

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