Qualcomm Technologies, Inc.

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

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Qualcomm Technologies, Inc.

Qualcomm Technologies, Inc.

5775 Morehouse Drive

San Diego, CA 92121

U.S.A.

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1 Executive summary

The Internet of Things (IoT) is bringing a massive surge of smart, connected devices that will enable new services and efficiencies across industries. The IoT is transforming businesses, changing the way people live, and continuing to fuel innovations for many years to come. Over the next decade, it is predicted that there will be 10’s of billions of connected devices deployed globally[1], growing at unprecedented speed to generate multi-trillion dollars of economic value[2] across many key markets. The IoT is the foundation to a totally interconnected world, and it is only a matter of time before it evolves into the Internet of Everything.

In this vision of a totally interconnected world, cellular technologies will play a pivotal role – and they already have; 1G and 2G networks connected people to one another via voice, and 3G and 4G extended connectivity to the mobile Internet, delivering blazing fast mobile broadband services. Not only do cellular networks offer ubiquitous coverage, but they also bring unparalleled level of reliability, security, and performance required by the most demanding IoT applications. 3GPP technologies, such as 4G LTE, can provide wide-area IoT connectivity – LTE is established globally and the fastest growing wireless standard, already delivering over two billion connections worldwide[3]. It will continue to gain momentum and proliferate even further in the decade to come. LTE is also backed by a common, global 3GPP standard with support of a strong, interoperable, end-to-end ecosystem. Altogether, LTE provides a solid foundation for the future growth of IoT, bringing significant benefits over non-3GPP/proprietary solutions.

3GPP has introduced a suite of two complementary narrowband technologies in Release 13, eMTC (enhanced machine-type communication) and NB-IoT (narrowband IoT), or collectively referred to as LTE IoT. Both eMTC and NB-IoT are optimized for lower complexity/power, deeper coverage, and higher device density, while seamlessly coexisting with other LTE services. Together, they expand the LTE technology portfolio beyond mobile broadband and are starting to connect the massive IoT today.

Beyond 3GPP Release 13, there is a rich roadmap of LTE IoT technology inventions that are delivering many further enhancements to meet tomorrow’s massive IoT connectivity needs. For example, 3GPP Release 14 will bring single-cell multicast for easy over-the-air firmware upgrades and device positioning for asset location tracking; in addition, 3GPP Release 15 will introduce TDD support for NB-IoT, as well as a new wake-up receiver design to allow for even better energy efficiency.

LTE IoT will continue to evolve for many years to come, leveraging the scale, longevity and global coverage of LTE networks to not only seamlessly enable migration from 2G, but to also complement the initial 5G NR (New Radio) deployments that focus on enhanced mobile broadband and high-performance IoT. Eventually, there will be a 5G NR-based massive IoT solution, and it will bring advanced design techniques such as RSMA (resources speared multiple access) for grant-free transmissions and multi-hop mesh to further extend coverage. Furthermore, the MulteFire Alliance is adapting LTE IoT for the unlicensed spectrum to expand into new use cases such as private networks for the industrial IoT. All in all, the continued LTE IoT evolution and its expansion to new deployments are integral parts of the 5G Platform – a unified, more capable connectivity fabric for the next decade and beyond.

[1] Machina Research, February 2014; Cisco, July, 2013
[2] Unlocking the potential of the Internet of Things, McKinsey & Company, Jun. 2015; 5G Economy, Qualcomm Technologies, Inc., Jan. 2017
[3] Ericsson Mobility Report, June 2017

2 Ushering in the era of the Internet of Things

The Internet of Things (IoT) broadly describes the concept of an interconnected network of physical objects, including machines, vehicles, buildings, and many other types of devices. And these connected "things" will deliver new services in the homes, businesses, cities, and across industries. The global IoT market is expected to grow aggressively over the next decade, and it is predicted that there will be 25 to 50 billion connected devices by 2020[1], fueling the multi-trillion dollars of economic growth[2] across key markets. IoT will be much more than about connecting people to things, but extending existing networks to also bring machines and devices to work with one another, so they can deliver new levels of efficiency.

2.1 Connecting the IoT will require heterogeneous connectivity

The Internet of Things encompasses a wide variety of applications across many different industries, with devices that can drive very diverse computing and connectivity requirements. In some use cases, devices may only require short-range communication to the network access point, such as ones deployed in connected homes, while many other applications need wider-area, ubiquitous coverage. Connecting the Internet of Things will require heterogeneous connectivity technologies that offer different levels of optimization to address the varying needs. Figure 1 provides a simplified illustration of the different wireless technologies often used to connect the IoT based on how far they can reach. For example, smart lighting in an office building may be best served with a short-range wireless technology, such as Wi-Fi, as light fixtures are usually deployed in areas with reasonable Wi-Fi coverage (i.e., indoors). In contrast, parking meters deployed across a smart city will most likely leverage a wide-area network. Such deployments will require a technology that can provide ubiquitous coverage in both outdoor (e.g., street parking) and indoor (e.g., parking structure) locations.

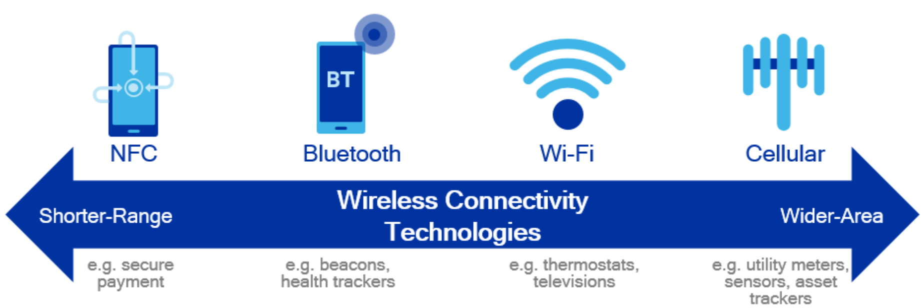

Figure 1: Examples of wireless connectivity technologies for the IoT

2.2 Cellular technologies will enable a wide range of IoT services

For the wide-area Internet of Things, cellular is evolving to become an attractive platform to address the growing connectivity needs. Already serving over 8 billion connections worldwide[4], cellular networks have proliferated in virtually all metropolitan cities, suburban, and rural areas across geographic regions. Not only do cellular-based solutions offer ubiquitous reach into both outdoor and indoor locations, they also bring many additional benefits to the table. The highly-available network design allows IoT devices to reliably access application services around the clock; moreover, the tried-and-true cellular deployments already deliver end-to-end security required by the most demanding users such as governments and financial institutions. And most importantly, the mature ecosystem is backed by global standards that ensure seamless interoperability across regions and devices. Rest assured, cellular technologies will

[4] GSMA Intelligence, June 2017

continue to evolve to deliver even better services for the fast-growing IoT markets, and the total number of cellular connections for IoT/M2M is expected to exceed 5B by 2025[5]. Figure 2 shows a few examples of IoT verticals and use cases that can benefit from adopting cellular-based solutions.

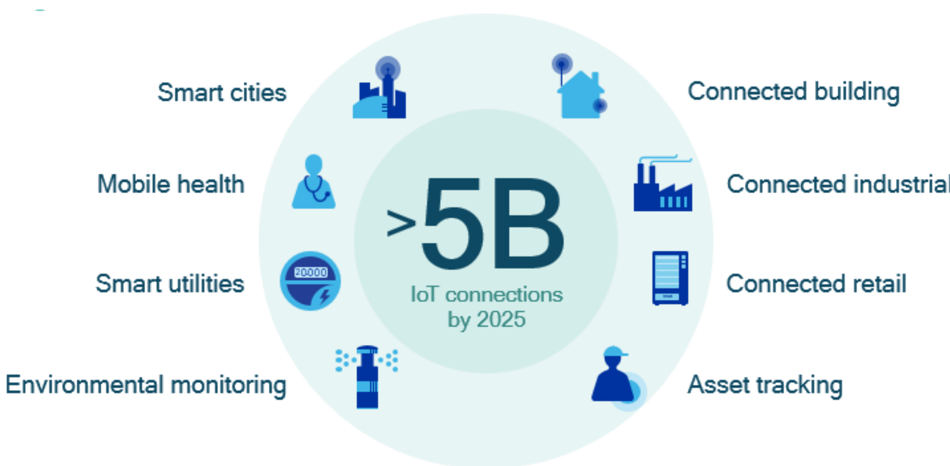

Figure 2: Cellular IoT enable a wide variety of services across many market verticals

2.3 LTE is a unified, scalable platform for connecting the IoT

LTE is globally established and the fastest growing wireless standard, expected to reach 80% world population coverage by 2022[6]. LTE, originally introduced in release 8 of the 3GPP standard, was developed to provide faster mobile broadband access, offering a generational performance leap over 3G. The core LTE technology has evolved over time to adapt to the ever-changing market requirements, ensuring network longevity. LTE Advanced (3GPP release 10, 11, 12) evolved to optimize for better mobile broadband experience, enabling Gigabit-class throughput with the introduction of advanced techniques, such as carrier aggregation and higher-order MIMO. While high-performance IoT can benefit from the improvements introduced in LTE Advanced (e.g., HD security cameras), lower-complexity IoT devices (i.e., the massive IoT) require optimizations for a much-reduced set of functionalities.

Release 13 of the 3GPP standard introduced a suite of two narrowband technologies optimizing for the Internet of Things. Collectively referred to as LTE IoT, it scales down LTE to more efficiently support lower data rate applications. LTE IoT is part of the unified LTE roadmap, providing a seamless path to deliver IoT service in existing network deployments; LTE can scale up to offer Gigabit-class data rates for high-performance IoT, or to scale down for applications requiring high power efficiency.

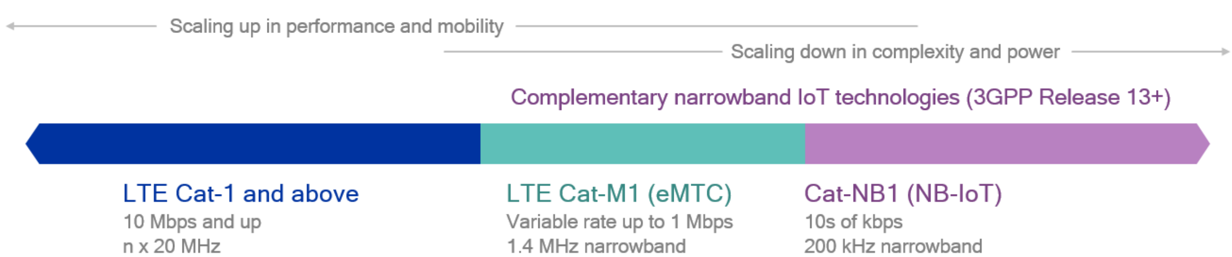

Figure 3: LTE is a scalable platform that can address a wide range of connectivity requirements

[5] Including cellular and LPWA connections, Machina Research, May 2017
[6] Ericsson Mobility Report, June, 2017

2.4 LTE IoT is bringing significant benefits over non-3GPP LPWA solutions

As the number of IoT applications continues to grow, it is expected that many new IoT-enabling connectivity technologies will emerge. While some of these new technologies can potentially address the wide-area coverage requirement, they are likely to fall short in other aspects compared to 3GPP standardized technologies such as eMTC (enhanced machine-type communication) and NB-IoT (narrowband IoT).

Ubiquitous coverage: LTE IoT leverages existing LTE networks without requiring a core network overlay. To date[7], there are already more than 500 LTE networks deployed in over 180 countries, with many more future deployments in planning.

Scalability: LTE IoT is a part of a unified platform that can adapt to application's performance needs. LTE can easily scale up to support IoT use cases that require high bandwidth and low latency, and scale down to optimize for low-performance applications – all using the same network infrastructure.

Coexistence: LTE IoT is compatible with existing and planned LTE networks and spectrum, coexisting with regular LTE traffic without interfering with other devices or services.

Interoperability: LTE IoT is backed by global 3GPP standards with a rich roadmap to 5G. It has a mature ecosystem that delivers devices and networks that interoperate across different vendors and regions.

Managed quality of service (QoS): One of the most important benefits of LTE is its ability to utilize licensed spectrum, as it allows network operators to guarantee QoS by effectively allocating network resources as well as managing and mitigating interferences and congestions. A redundant network design also helps to ensure service availability with minimal downtime.

End-to-end security: LTE IoT will inherit the established/trusted security and authentication features delivered by LTE, meeting the most stringent requirements of many high-security applications.

3 LTE IoT is starting to connect the massive IoT today

The term "massive IoT" refers to the 10's of billions of devices, objects, and machines that require ubiquitous connectivity even in the most remote locations, like sensors buried deep underground. To reach the massive scale (3GPP defines such as at least 1M devices per km^2), mobile networks must more efficiently support the simplest devices that communicate infrequently, and are ultra-energy efficient so they can deliver extremely long, 10+ year battery life.

LTE IoT in 3GPP Release 13 is starting to connect the massive IoT, with commercial networks and products available today, and its continued evolution will also complement the initial 5G NR (New Radio) deployments starting in the 2019 timeframe. The first 5G NR release will deliver eMBB (enhanced mobile broadband) and URLLC (ultra-reliable, low-latency communication), which can also address high-performance IoT use cases. However, it will not target the massive IoT (also referred to as massive machine-type communication or mMTC in 3GPP). It is also notable that NB-IoT can provide a seamless

[7] GSA Status of the LTE Ecosystem Report, April, 2017

migration path for legacy 2G/GPRS deployments, as its narrowband carrier can directly fit into the re-farmed GSM spectrum bandwidth.

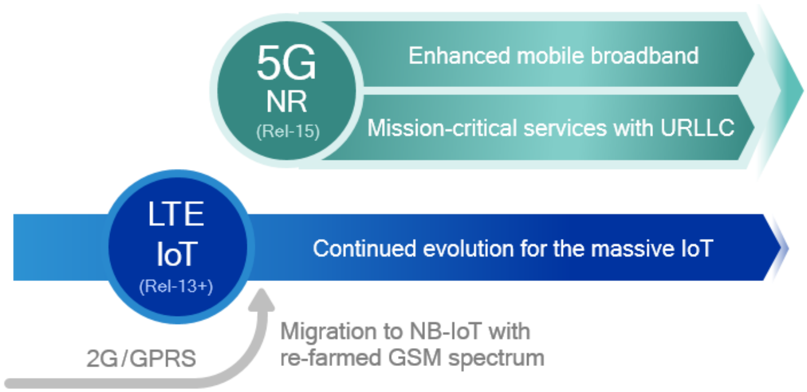

Figure 4: Complements initial 5G NR deployments and provides a migration path for 2G

3.1 eMTC and NB-IoT are complementary narrowband technologies

The 3GPP Release 13 standard has introduced two complementary User Equipment (UE) categories that scale down in functionalities to bring more efficiencies for connecting a wide variety of IoT devices.

LTE IoT Cat-M1, defined by eMTC, provides the broadest range of IoT capabilities, delivering data rates up to 1 Mbps, while utilizing only 1.4 MHz device bandwidth (1.08 MHz in-band transmissions of 6 resource blocks) in existing LTE FDD/TDD spectrum. It is designed to fully coexist with regular LTE traffic (Cat-1 and above). Cat-M1 can also support voice (VoLTE) and full-to-limited mobility. In enhanced coverage mode, it can deliver 15 dB of increased link budget, allowing LTE signals to penetrate more walls and floors to reach devices deployed deep indoors or in remote locations.

LTE IoT Cat-NB1, defined by NB-IoT, further reduces device complexity and extends coverage to address the needs of low-end IoT use cases. Cat-NB1 leverages narrowband operations, using 200 kHz device bandwidth (180 kHz in-band transmissions of 1 resource block) in LTE FDD, to deliver throughputs of 10's of kbps. NB-IoT supports more flexible deployment options: LTE in-band, LTE guard-band, and standalone. To further enhance coverage, it trades off spectral efficiency (e.g., data rate), and capabilities (e.g., no mobility or voice support) to achieve >5 dB of extra gain over Cat-M1.

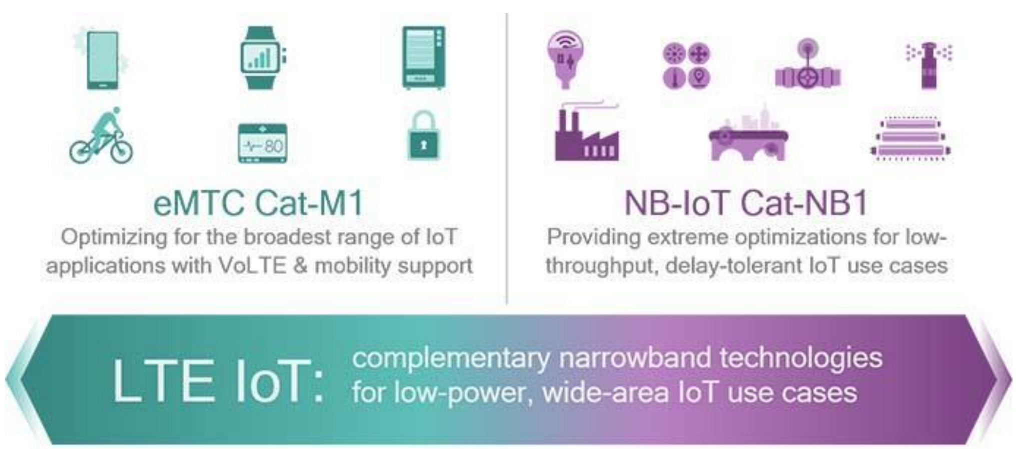

Figure 5: Complementary narrowband technologies for the massive IoT

3.2 LTE IoT coexists with today's services and provides migration path from 2G

Both Cat-M1 and Cat-NB1 can be deployed in existing LTE Advanced infrastructure and spectrum, efficiently coexist with today's mobile broadband services. Cat-M1 utilizes 1.4 MHz bandwidth, leveraging existing LTE numerology (versus NB-IoT's new channel bandwidth of 200 kHz), and can be deployed to operate within a regular LTE carrier (up to 20 MHz). Cat-M1 devices will leverage legacy LTE synchronization signals (e.g., PSS[8], SSS[9]), while introducing new control and data channels that are more efficient for low bandwidth operations. LTE network supporting Cat-M1 can utilize multiple narrowband regions with frequency retuning to enable scalable resource allocation, and frequency hopping for diversity across the entire LTE band.

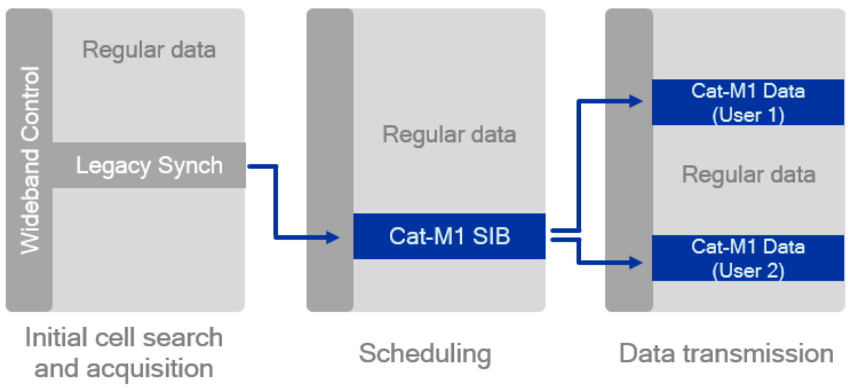

Figure 6: Cat-M1 (eMTC) can operate across entire regular LTE band

Cat-NB1 devices can be deployed in LTE guard-bands or as a standalone carrier in addition to LTE in-band. Nevertheless, the new 200 kHz device numerology (utilizing a single LTE resource block, or RB of 180 kHz) requires a new set of narrowband control and data channels. Unlike Cat-M1 in-band, Cat-NB1 does not allow for frequency retuning or hopping and occupies a fixed spectrum location. For guard-band deployment, NB-IoT leverages unused resource blocks without interfering with neighboring carriers. In standalone mode, Cat-NB1 devices can be deployed in re-farmed 2G/3G bands.

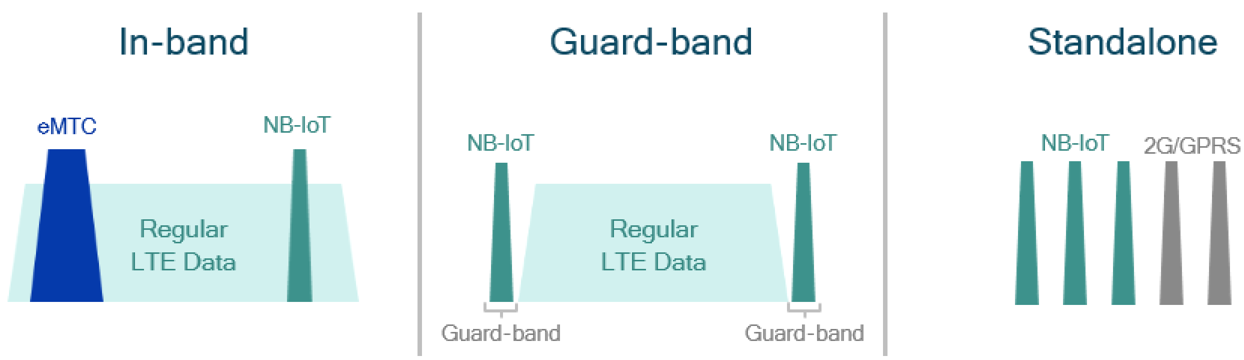

Figure 7: LTE IoT flexible deployment options

[8] Primary Synchronization Signal
[9] Secondary Synchronization Signal

4 3GPP Release 13 establishes a solid LTE IoT foundation

The LTE IoT evolution started in 3GPP Release 13, which provided a solid foundation for all subsequent massive IoT enhancements. In general, it brought four main areas of improvements: reducing complexity, improving battery life, enhancing coverage, and enabling higher device density. Many of these optimizations were shared by eMTC and NB-IoT, including energy reduction and coverage extension techniques, and this shared foundation is being further extended in 3GPP Release 14 and beyond to bring additional capabilities and efficiencies for the massive IoT. In parallel, MulteFire Alliance is leveraging the established LTE IoT foundation to expand into unlicensed spectrum, enabling even more IoT use cases. Figure 8 illustrates the expanding shared foundation.

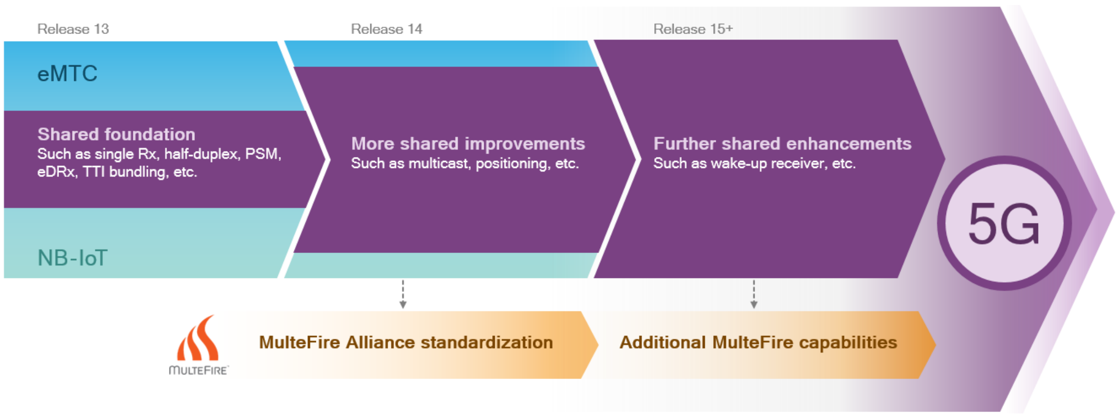

Figure 8: LTE IoT builds on a shared foundation

4.1 Reducing complexity to enable lower cost devices

The proliferation of IoT will bring significant benefits to a diverse set of industries and applications. While there are many IoT use cases that have the potential to drive higher ARPC (average revenue per connection) that is comparable to today's mobile broadband services (e.g., smartphones, tablets), most use cases will require much lower-cost devices and subscriptions to justify massive deployments. For example, the hardware and service cost of a smartphone is very different from a simple sensor that provides temperature measurements a few times a day. For this reason, both Cat-M1 and Cat-NB1 devices scale down in complexity to enable lower cost, while still meeting the application requirements. Figure 9 summarizes the high-level complexity differences of 3GPP Release 13 Cat-M1 and Cat-NB1.

	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	<100 kbps
Bandwidth	Up to 20 MHz	1.4 MHz	200 kHz
Rx antenna	Dual Rx	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	23, 20 dBm

Figure 9: Reducing complexity for LTE IoT devices

Peak data rate: Both Cat-M1 and Cat-NB1 devices will have reduced peak data rates compared to regular LTE devices (e.g., Cat-1). Cat-M1 has limited throughput of up to 1 MBps in both downlink and uplink directions, while Cat-NB1 further reduces peak data rate down to 10's of kbps. The reduced peak data rates allow for both processing and memory savings in the device hardware.

Bandwidth: LTE supports scalable carrier bandwidths from 1.4 MHz to 20 MHz, utilizing 6 to 100 resource blocks. For LTE Cat-M1, the device bandwidth is limited to 1.4 MHz only (1.08 MHz plus guard-band for 6 RBs in-band), to support the lower data rate. On the other hand, Cat-NB1 further reduces device bandwidth to 200 kHz (180 kHz plus guard-band for a single RB). The bandwidth reduction for Cat-M1 requires a new control channel (i.e., M-PDCCH[10]) to replace the legacy control channels (i.e., PCFICH, PHICH, PDCCH[11]), which can no longer fit within the narrower bandwidth. While for Cat-NB1, a new set of NB-IoT synch, control, and data channels are introduced to accommodate the narrower bandwidth.

Rx Antenna: Multiple antennas for MIMO (multiple-input, multiple-output) and receive diversity was introduced in LTE to improve spectral efficiency. For LTE IoT applications, there is little need to push for higher data rates, but important to reduce complexity. For both Cat-M1 and Cat-NB1, the receive RF is reduced to a single antenna, which simplifies the RF frontend. Though there is some RF degradation due to the lack of receive diversity, the lost signal sensitivity can be compensated by other advanced coverage enhancing techniques.

Duplex Modes: Due to the less frequent and latency-tolerant nature of IoT data transmissions, LTE IoT devices can reduce complexity by only supporting half-duplex communications, where only the transmit or receive path is active at a given time. Cat-M1 devices can support half-duplex FDD in addition to TDD, while 3GPP Release 13 Cat-NB1 devices only support half-duplex FDD. This allows the device to implement a simpler RF switch instead of a full duplexer that is more complex and costly.

Mobility: Only Cat-M1 devices support limited-to-full mobility, which is a differentiating feature and is critical for many IoT applications such as asset tracking, where devices can frequently move between different cells. On the other hand, Cat-NB1 devices support cell reselection only, which is optimized for static or nomadic IoT use cases.

Voice: Another key Cat-M1 feature is its ability to support VoLTE, which is needed for IoT applications such as wearables. Cat-NB1 does not support voice due to its simplified hardware and limited bandwidth.

Transmit Power: For both new LTE IoT UE categories, the maximum uplink transmission power is reduced to 20 dBm (100mW) from LTE's 23 dBm (200mW), allowing the power amplifier (PA) to be integrated for lower device cost.

4.2 Improving power efficiency to deliver multi-year battery life

Many IoT devices are battery-operated, and it is highly desirable for them to last for as long as possible on a single charge. The associated cost for field maintenance can be quite daunting, especially in massive deployments. Not only would the planning of scheduled maintenance be an operational overhead, but physically locating these mobile devices (e.g., asset trackers sprinkled all over the world) can also become a nightmare. Thus, maximizing battery life has become one of the most important

[10] MTC Physical Downlink Control Channel
[11] Physical Control Format Indicator Channel, Physical Hybrid-ARQ Indicator Channel, Physical Downlink Control Channel

improvement vectors in LTE IoT. In addition to the power savings realized through reduced device complexity, two new low-power enhancements have been introduced: power save mode (PSM) and extended discontinuous receive (eDRx) – both are applicable to Cat-M1 and Cat-NB1 devices.

Power Save Mode (PSM): PSM is a new low-power mode that allows the device to skip the periodic page monitoring cycles between active data transmissions, allowing the device to sleep for longer. However, the device becomes unreachable when PSM is active; therefore, it is best utilized by device-originated or scheduled applications, where the device initiates communication with the network. Moreover, it enables more efficient low-power mode entry/exit, as the device remains registered with the network during PSM, without having the need to spend additional cycles to setup registration/connection after each PSM exit event. Example applications that can take advantage of PSM include smart meters, sensors, and any IoT devices that periodically push data up to the network.

Extended Discontinuous Reception (eDRx): eDRx optimizes battery life by extending the maximum time between data reception from the network in connected mode to 10.24s, and time between page monitoring and tracking area update in idle mode to 40+ minutes. It allows the network and device to synchronize sleep periods, so that the device can check for network messages less frequently. This; however, increases latency, so eDRx is optimized for device-terminated applications. Use cases such as asset tracking and smart grid can benefit from the lower power consumption realized through the longer eDRx cycles.

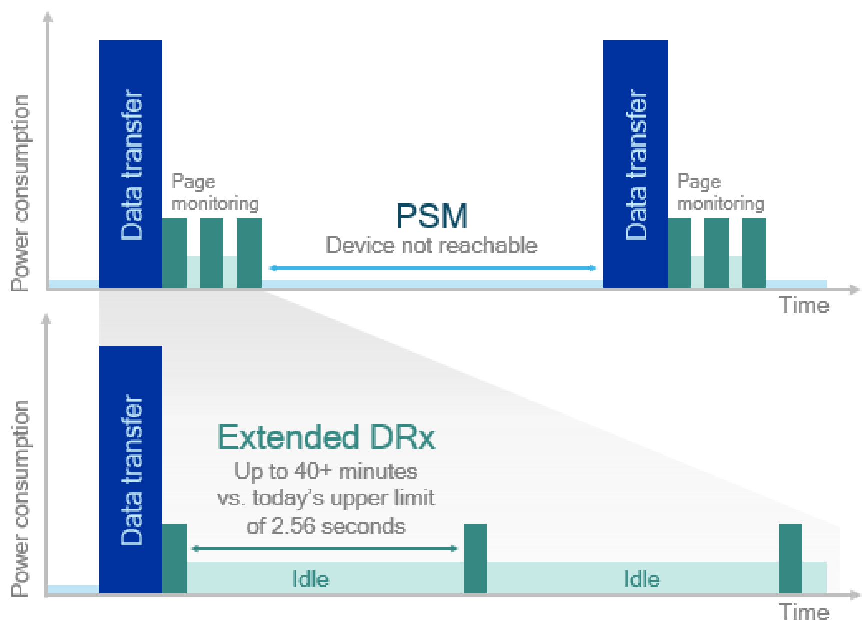

Figure 10: PSM and eDRx optimize device battery life

4.3 Enhancing coverage for better reach into challenging locations

There are many IoT use cases that can benefit from deeper network coverage, especially for devices deployed in challenging locations such as utility meters. In many use cases, trading off uplink spectral efficiency and latency can effectively increase coverage without increasing output power that will negatively impact the device battery life.

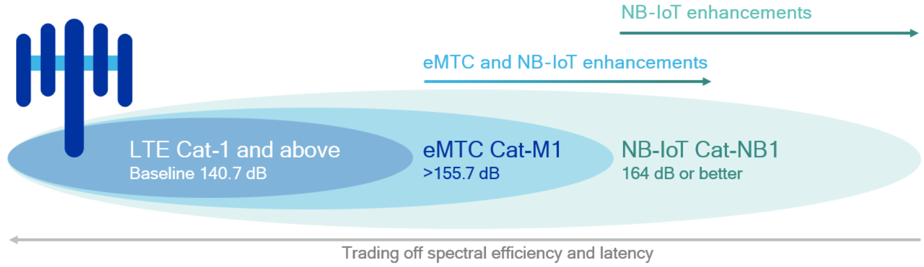

Figure 11: Advanced techniques to deepen coverage

Repetitive transmissions: Transmitting the same transport block multiple times in consecutive sub-frames (TTI bundling) or repeatedly sending the same data over a period of time can significantly increase the probability for the receiver (cell or device) to correctly decode the transmitted messages.

Power Spectral Density (PSD) boosting: While the serving cell can simply increase transmit power in the downlink to extend coverage, it is also possible for the device to put all the power together on some decreased bandwidth (e.g., Cat-NB1 can transmit on 3.75 kHz sub-carrier spacing in a new numerology, vs. 15 kHz in Cat-M1 and LTE) to effectively increase the transmit power density.

Single-tone uplink: Similarly, Cat-NB1 device can utilize single-tone uplink (3.75 kHz or 15 kHz sub-carrier spacing) to further extend coverage, trading off peak data rate (limiting to 10's of kbps).

Lower-order modulation: By utilizing QPSK instead of 16-QAM, the SINR (Signal to Interference plus Noise Ratio) threshold reduces significantly, trading off modulation efficiency (fewer bits per symbol).

With these new coverage enhancements, the link budget of a Cat-M1 device is increased to 155.7dB, a +15dB improvement over regular LTE. For Cat-NB1, it is further increased to 164dB.

4.4 Optimizing LTE core network to more efficiently support IoT devices

IoT is bringing a massive number of connected devices that will push the capability boundary of existing LTE networks. And much different from mobile broadband services, network capacity will not be the limiting factor to support more low-end IoT devices (e.g., meters), as LTE IoT traffic only makes up for a small fraction of the overall capacity requirement, but the ability to handle the increased amount of signaling. Most IoT devices transmit small amount of data sporadically, rather than in large data packets; therefore, the LTE core network also needs to evolve to better support IoT traffic profiles by providing more efficient signaling and resource management.

More efficient signaling: New access control mechanisms such as Extended Access Barring (EAB) prevents devices from generating access requests when the network is congested, thus eliminating unnecessary signaling. The network can also utilize group-based paging and messaging to more efficiently communicate with multiple downlink devices.

Enhanced resource management: The network can allow a large set of devices to share the same subscription, such that resources and device management can be consolidated. For example, a group of water meters in a smart city can be collectively provisioned, controlled, and billed.

Simplified core network (EPC-lite): The LTE core network can be optimized for IoT traffic, allowing more efficient use of resources and consolidation of the MME, S-GW, and P-GW into a single EPC-lite. With this, the operators have the option to optimize for lower OPEX, or to minimize CAPEX spend by leveraging existing LTE core network to support LTE IoT.

4.5 Delivering an end-to-end LTE IoT platform

To make LTE IoT a success, the entire ecosystem needs to be involved to simplify the overall deployment and management of LTE IoT services. In many ways, this effort had already begun. Hardware manufacturers are accelerating device development by delivering certified modules, and the new embedded SIM (eUICC) initiative is picking up momentum, aiming to enable more flexible management of cellular services. For IoT software development, protocol standardization will ensure data transport efficiency and inter-vendor interoperability; for example, oneM2M is driving standardization of the communication protocols to deliver faster time-to-market and reliable end-to-end security. And to enable ease of deployment and management, many mobile operators and service providers around the globe are offering full-stack IoT solutions that provide data analytics, device management, and more.

5 Continued LTE IoT evolution to 5G is broadening use cases

Beyond eMTC and NB-IoT, defined as part of the 3GPP Release 13 foundation, there is a rich roadmap of LTE IoT technologies coming that will meet tomorrow's massive IoT requirements. This includes new capabilities and improvements that will propel LTE IoT to become even more efficient, as well as an expansion into unlicensed spectrum. Figure 12 shows the key enhancements in 3GPP Release 14 and 15, as well as a parallel evolution path in the MulteFire Alliance that enables LTE IoT to be deployed in unlicensed spectrum. In addition, a 5G NR-based massive IoT design is also expected for 3GPP Release 16 or beyond that will elevate massive IoT connectivity to the next level. These are essentially all integral parts of the 5G Platform for connecting the massive Internet of Things.

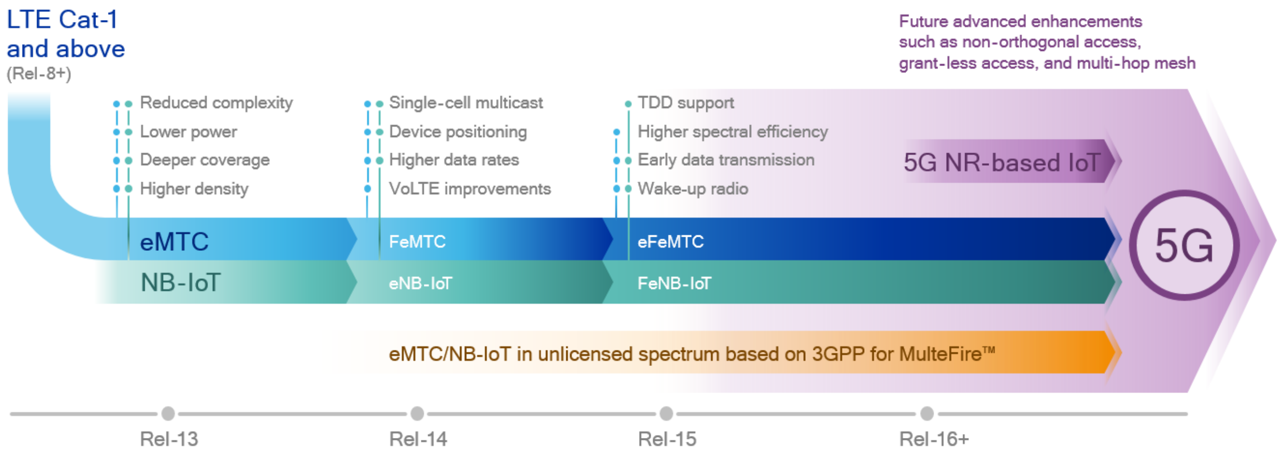

Figure 12: A rich technology roadmap for tomorrow's massive IoT and expansion into unlicensed spectrum

5.1 Driving a rich roadmap of enhancements for eMTC & NB-IoT

Both eMTC and NB-IoT are continuing to evolve in 3GPP Release 14 and 15, delivering more capabilities and better efficiencies for the massive IoT. Figure 13 shows a summary of key new enhancements planned for Release 14 and 15, followed by a short description of each.

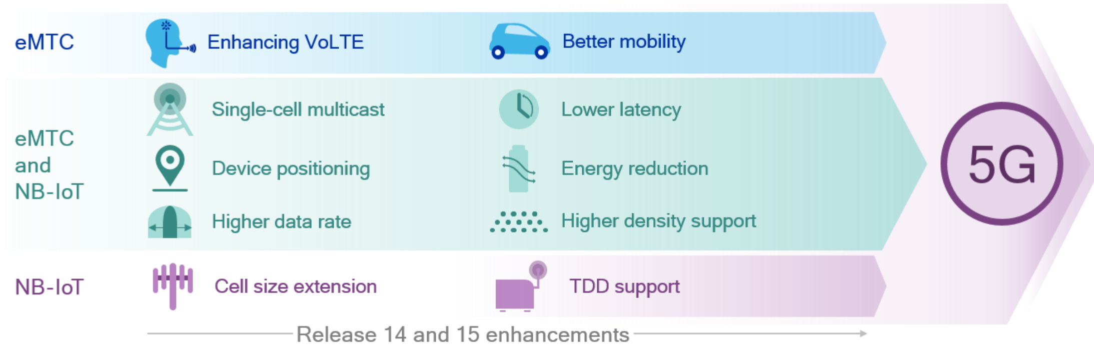

Figure 13: Release 14 and 15 enhancements for eMTC & NB-IoT

Enhancing VoLTE: This 3GPP Release 14 enhancement enables eMTC devices, such as wearables, to more efficiently handle voice traffic in half-duplex mode.

Better mobility: This eMTC enhancement expands support for inter-frequency measurements in 3GPP Release 14, and enables higher velocity (e.g., 200 km/h) in extended coverage mode in 3GPP Release 15.

Single-cell multicast: As an extension to SC-PTM (single cell to multipoint) originally defined for LTE in 3GPP Release 13, both eMTC and NB-IoT can leverage this new 3GPP Release 14 feature to efficiently deliver over-the-air firmware upgrades for large number of devices.

Device positioning: Based on OTDOA (observed time difference of arrival), both eMTC and NB-IoT can leverage this 3GPP Release 14 feature to provide real-time location services for IoT use cases such as asset tracking or eCall.

Higher data rate: In 3GPP Release 14, new UE Categories were introduced for both eMTC and NB-IoT. LTE IoT Cat-M2 (for eMTC) devices will support 5 MHz bandwidth, larger TBS (transport block size), and more HARQ processes, while LTE IoT Cat-NB2 (for NB-IoT) devices will support larger TBS and more HARQ's.

Lower latency: Another area of improvements is to achieve lower latency. This is achieved through more HARQ processes, part of 3GPP Release 14, as well as faster system acquisition and early data transmission, both enhancements in 3GPP Release 15.

Energy reduction: To further increase battery life, 3GPP Release 15 is introducing a new low-power wake-up radio design, as well as relaxed cell reselection monitoring, semi-persistent scheduling, quicker RRC release, and lower transmit power classes (e.g., 14 dBm).

Higher density support: Further enhancements are also being made to load control with level-based access class barring in 3GPP Release 15.

Cell size extension: In 3GPP Release 15, additional cyclic prefixes (CP) are supported to extend cell radius to at least 100km.

TDD support: As pointed out, 3GPP Release 13 and 14 only support NB-IoT in FDD spectrum. For 3GPP Release 15, TDD spectrum support is being added to enable further deployment flexibilities.

5.2 Pioneering tomorrow's massive IoT technologies

To further increase device density, future advanced massive IoT design techniques such as RSMA (resources speared multiple access) will enable grant-free transmissions. RSMA is an asynchronous, non-orthogonal, and contention-based uplink multiple access design that will further reduce device complexity and signaling overhead since it allows IoT devices to transmit without prior network scheduling.

To extend network coverage for IoT devices to the most extreme locations (e.g., hyper-remote, deep underground), multi-hop mesh will allow out-of-coverage devices to connect directly with devices that can relay data back to the access network. This essentially creates an edgeless network that extends coverage beyond the typical cellular access (e.g., base stations and small cells). More importantly, the core network will also take on WAN management for both devices in access coverage as well as those supported by the peer-connected mesh network.

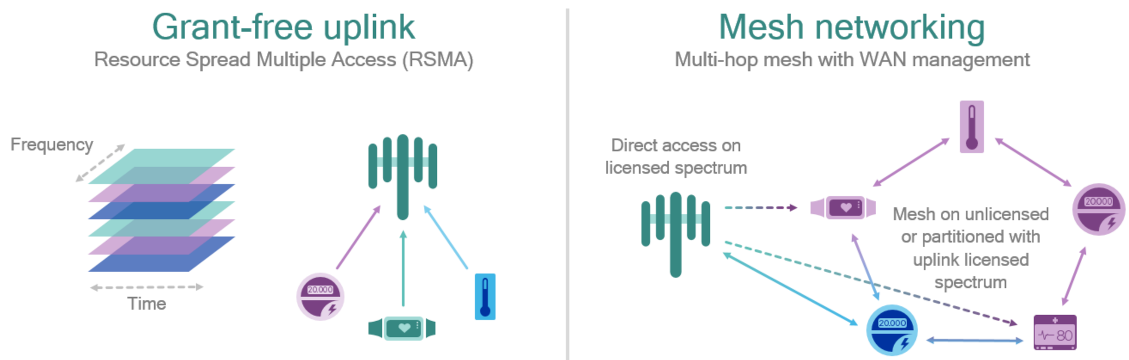

Figure 14: New 5G capabilities to enable massive IoT

5.3 Expanding into unlicensed spectrum for private LTE IoT networks

Another exciting dimension in the LTE IoT evolution is the expansion into unlicensed spectrum. The MulteFire Alliance is adapting LTE IoT to operate in the unlicensed spectrum to expand beyond mobile broadband and high-performance IoT supported by MulteFire 1.0. This will in turn bring new opportunities for private LTE networks and enable LPWA (low-power, wide-area) use cases, leveraging both narrowband LTE IoT technologies, eMTC and NB-IoT in 3GPP Release 13 and beyond.

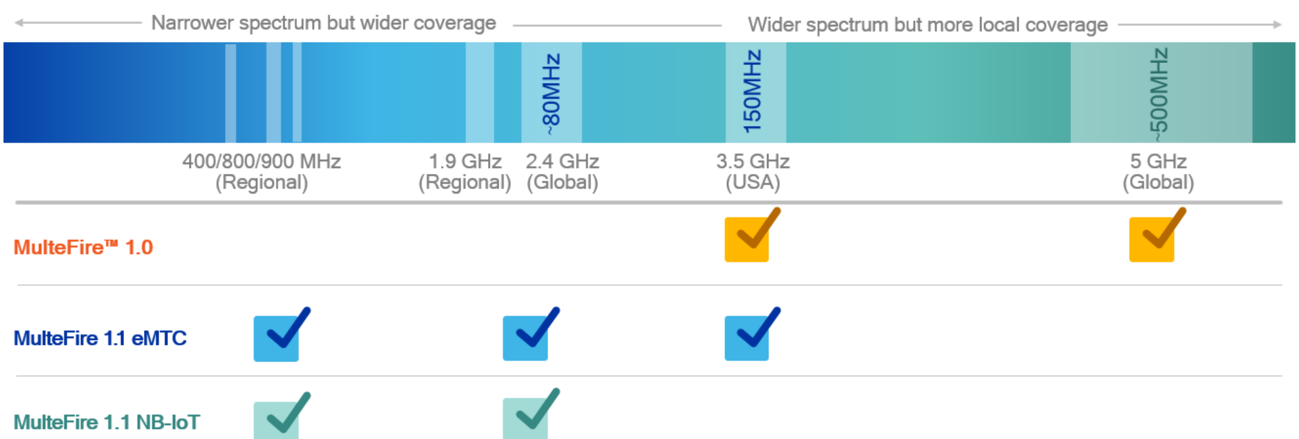

Figure 15: MulteFire expands LTE IoT into unlicensed spectrum

6 Conclusion

The Internet of Things is bringing a massive surge of smart, connected devices that will enable new services and efficiencies across industries. The IoT will transform businesses, change the way people live, and fuel innovations for many years to come. And cellular technologies will play an important role providing connectivity for a wide range of things; LTE is evolving to deliver a unified, scalable IoT platform that brings significant benefits over other non-3GPP LPWA solutions. It not only provides ubiquitous coverage through established global networks, but also brings unparalleled level of reliability, security, and performance required by the most demanding IoT applications.

Narrowband LTE IoT technologies are starting to connect the massive IoT today, delivering lower complexity, increase battery life, deepen coverage, and enable high device density deployments. The solid 3GPP Release 13 foundation introduced two new UE categories (Cat-M1 for eMTC and Cat-NB1 for NB-IoT), which scaled down LTE to enable more efficient IoT communications. Cat-M1 will offer the broadest range of IoT capabilities with support for more advanced features such as full mobility and VoLTE, while Cat-NB1 further scales down to offer the lowest cost and power for delay-tolerant, low-throughput use cases.

Building upon the solid LTE IoT foundation, there is a rich roadmap of new technology inventions in 3GPP Release 14 and beyond, broadening LTE IoT to even more use cases. Release 14 and 15 will enable new capabilities such as multi-cast and positioning, and enhance efficiencies to connect even more devices. There is also a new 5G NR-based massive IoT design on the horizon, which will enable future advanced design techniques such as RSMA for grant-free transmissions and multi-hop mesh to further extend network coverage. The expansion into unlicensed spectrum will bring even more exciting opportunities for LTE IoT, opening doors to new use cases such as private LTE networks for industrial IoT. All in all, the continued LTE IoT evolution and its expansion to new deployments are integral parts of the 5G Platform – a unified, more capable connectivity fabric for the next decade and beyond.

To learn more about LTE IoT and 5G, please visit:

www.qualcomm.com/LTE-IoT

www.qualcomm.com/5G