Mobile IoT in a 5G Future

NB-IoT and LTE-M in the context of 5G

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Contents

1.0 Mobile IoT in a 5G Future

Already delivering trusted low power wide area connectivity today, Mobile IoT is forming a foundation of the 5G future and massive IoT.

Existing cellular networks have evolved to be able to deliver Mobile IoT connectivity to billions of new devices in the 5G era. Leading mobile operators, global vendors and developers have launched NB-IoT and LTE-M networks as an integral part of their long-term 5G IoT strategies. These operator-managed Mobile IoT networks provide secure low power wide area (LPWA) connectivity in licensed spectrum. They are designed to support IoT applications that are low cost, require low data rates and long battery lives and often operate in remote and hard-to-reach locations.

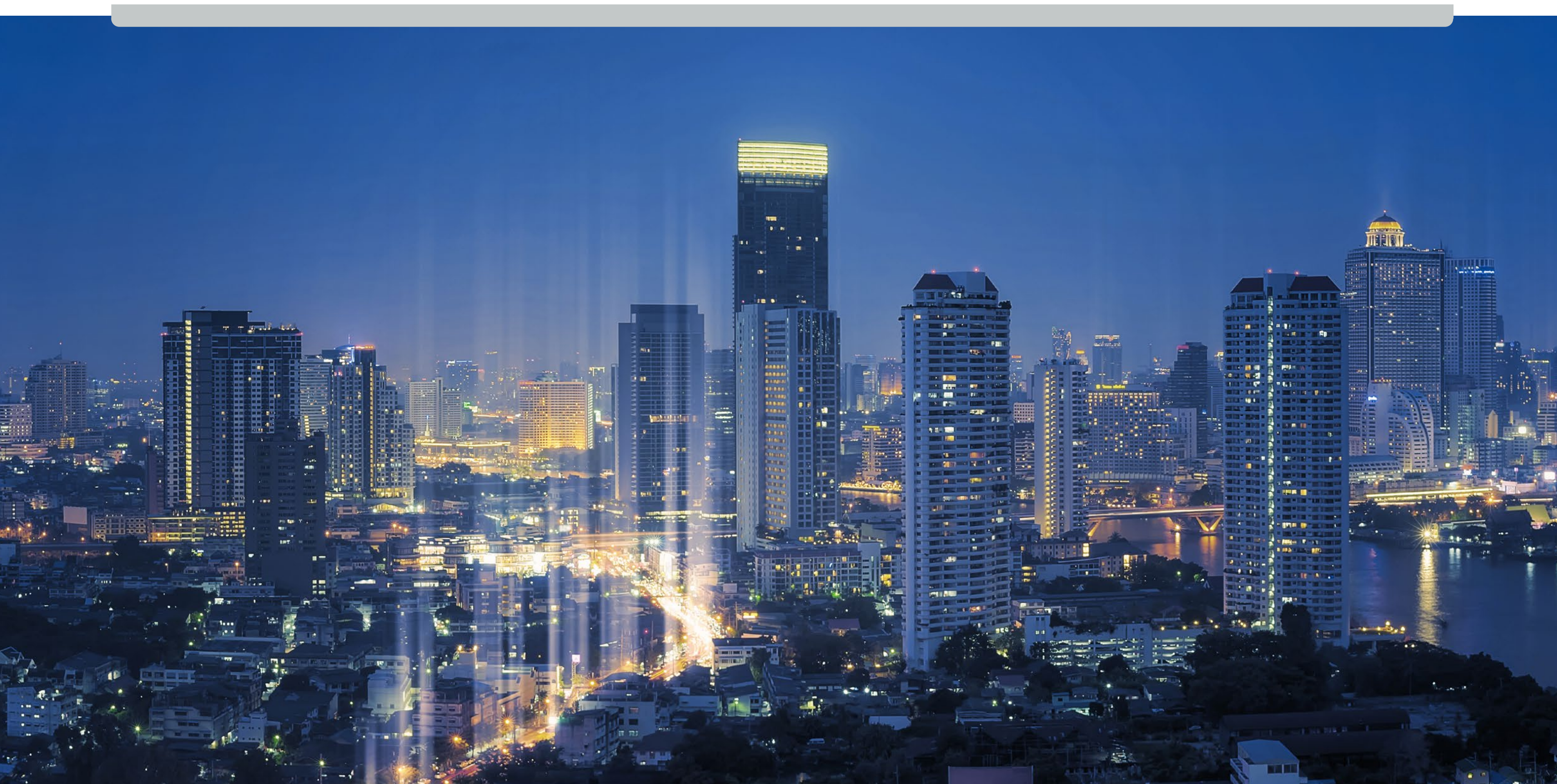
NB-IoT and LTE-M are 3GPP standards that are set to coexist with other 3GPP 5G technologies, fulfilling the long term 5G LPWA requirements. The future of mobile IoT has been guaranteed.

As an integral part of 5G, NB-IoT and LTE-M are set to be supported by mobile operators for the foreseeable future.

Overall, there are three major use cases for 5G:

- Massive IoT / LPWA
- Critical communications
- Enhanced mobile broadband

Mobile IoT delivers massive IoT for the 5G future while enabling key capabilities for today's IoT applications, such as smart metering to help reduce energy consumption, smart logistics to enhance distribution efficiency and smart environmental monitoring to reduce pollution.



2.0 Introduction

Scope

Since the first 3GPP release of NB-IoT and LTE-M specifications in 2016, the growth in the number of connections and networks across the world has accelerated. By the end of 2023, operators had launched 252 commercial NB-IoT and LTE-M networks[1] to bring LPWA connectivity to their customers.

This paper explains how both NB-IoT and LTE-M technologies are an integral part of 5G. It goes on to highlight how both NB-IoT and LTE-M will continue to serve LPWA 5G use cases and will coexist alongside other components of 5G which addressed other use cases. The design of 5G means operators deploying NB-IoT and LTE-M will be able to leverage their investments in these technologies as they also deploy other components of 5G.

Detailed technical aspects of 5G NR, NB-IoT and LTE-M are out of scope of this paper.

Abbreviations:

TERM	DESCRIPTION
3GPP	3rd Generation Partnership Project
AR	Augmented reality
eMTC	Enhanced machine type communication
eRedCap	Enhanced RedCap
eSIM	Embedded SIM
FR1	Frequency Range 1. That is, from 410 MHz - 7125 MHz
FR2	Frequency Range 2. That is, 24250 MHz - 52600 MHz - 71000 MHz
GEO	Geostationary earth orbit
GHz	Gigahertz

[1] Refer to https://www.gsma.com/iot/mobile-iot-commercial-launches/ for the most up-to-date information

TERM	DESCRIPTION
GSM	Global System Mobile
GSMA	GSM Association
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet protocol
iSIM	Integrated SIM
ITU	International Telecommunications Union
Ka-Band	IEEE designation for the range of frequencies between 26.5 and 40 GHz
L-Band	IEEE designation for the range of frequencies between 1 and 2 GHz
LEO	Low earth orbit
LPWA	Low power wide area
LTE	Long-Term Evolution
LTE-M	Long-Term Evolution machine type communications
M2M	Machine-to-machine
MNO	Mobile network operator
MTC	Machine type communications
mMTC	Massive machine type communications
NB-IoT	Narrowband IoT
NR	New Radio

TERM	DESCRIPTION
NTN	Non-terrestrial networks
OFDM	Orthogonal Frequency Division Multiplexing
QAM	Quadrature Amplitude Modulation
RedCap	Reduced capability
RSP	Remote SIM provisioning
S-band	IEEE designation for the range of frequencies between 2 and 4 GHz
SIM	Subscriber identity module
UICC	Universal integrated circuit card
URLLC	Ultra reliable low latency communications
VoIP	Voice over IP
VoLTE	Voice over LTE
VR	Virtual reality

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3.0
Mobile IoT and 5G

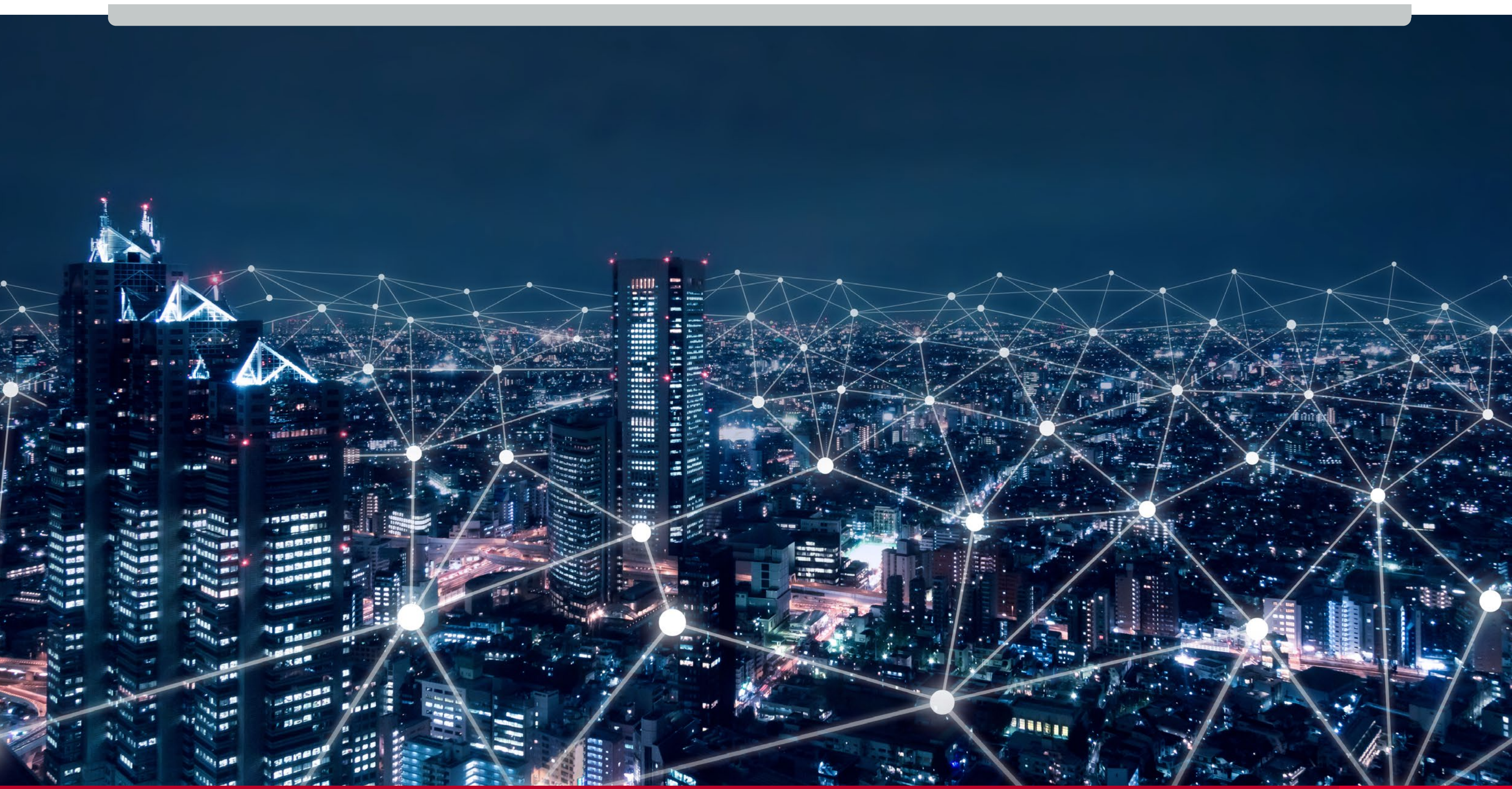
3.1 What is Mobile IoT?

Mobile IoT is a GSMA term which refers to the 3GPP standardised low power wide area (LPWA) technologies using licensed spectrum bands, such as NB-IoT and LTE-M.

LPWA technologies possess the following characteristics:

- Low power consumption that enables devices to operate for many years on a single charge
- Low device unit cost
- Improved outdoor and indoor coverage compared with existing wide area technologies
- Secure connectivity and strong authentication
- Optimised data transfer for small, intermittent blocks of data
- Simplified network topology and deployment
- Network scalability for capacity upgrade

LTE-M is the industry term for the LTE machine-type communications (MTC) LPWA technology standard introduced by 3GPP in Release 13. LTE-M supports lower device complexity, massive connection density, low device power consumption, low latency and provides extended coverage, while allowing the reuse of the LTE installed base. LTE-M can be deployed “in-band” within a normal LTE carrier, or “standalone” in dedicated spectrum. LTE-M can support VoLTE and VoIP applications,



but operators need to activate VoLTE over LTE-M and this service is currently not widely supported by operators.

Narrowband IoT (NB-IoT) is a 3GPP radio technology standard introduced in Release 13 that addresses the LPWA requirements of the IoT. NB-IoT is characterised by improved indoor coverage, support for a massive number of low throughput devices, low delay sensitivity, ultra-low device cost, low device power consumption and optimised network architecture. Like LTE-M, NB-IoT can be deployed "in-band" within a normal LTE carrier, or "standalone" for deployments in dedicated spectrum. NB-IoT can also be deployed in an LTE carrier's guard-band.

3.1.1 Other LTE solutions used in IoT

In addition to the Mobile IoT family of 5G technologies, there are other IoT solutions based on 3GPP standards:

LTE Cat 1 is part of 4G and was initially defined as an LTE category in 3GPP Release 8. While Cat 1 falls outside of the GSMA's scope for Mobile IoT, it is mentioned in this document because some products use Cat 1 for IoT applications.
Cat 1 supports voice, relatively low data rates (up to 10Mbps) and, whilst it consumes less power than higher LTE categories, Cat 1 is not considered a LPWA technology.

LTE Cat 1 bis - a part of the ongoing evolution of LTE - was introduced in Release 13. Like Cat 1, Cat 1-bis employs existing 4G LTE infrastructure and is used for some IoT applications. Originally intended for use in wearable devices where physical space is limited, the main difference between Cat 1 and Cat 1-bis is the latter has been designed to operate using a single antenna (instead of two in the case of Cat 1). The removal of one receive chain simplifies device design and reduces device cost at the expense of ~4 dB coverage loss due to the removal of the diversity receive antenna.

LTE Cat 1 and Cat 1-bis do not require any specific feature activation on the radio access network and can be easily supported on standard LTE networks. However, unlike NB-IoT and LTE-M, the longevity of Cat 1 or Cat 1- bis devices is not warrantied in 5G networks.

3.2 What is 5G?

At its conception, 5G was envisioned to both enhance the human user experience and to enable various machine-related use cases [1][2][3][4][5]. For a technology to be classified as a 5G technology, it needs to meet the requirements established by the International Telecommunications Union (ITU). The ITU's vision for 5G, published in ITU-R M.2803[1], established the framework for what was to become IMT 2020.

Both LTE-M and NB-IoT have been recognised as technologies that meet the IMT 2020 requirements for massive machine type communications and are formally documented in ITU-R M.2150-2.

While 5G is associated with ever higher data rates and lower latency, these aspects are mainly focused on enhancing mobile broadband for human-centric and real-time control use cases. Conversely, many machine-related low power wide area (LPWA) use cases can tolerate low throughput and latency.

To serve a variety of use cases, often with diametrically opposing requirements, 5G systems dynamically allocate network resources depending on the use case.

The 5G requirements defined by ITU-R [1][2][3] and 3GPP [9] broadly cover three main use cases [4]:

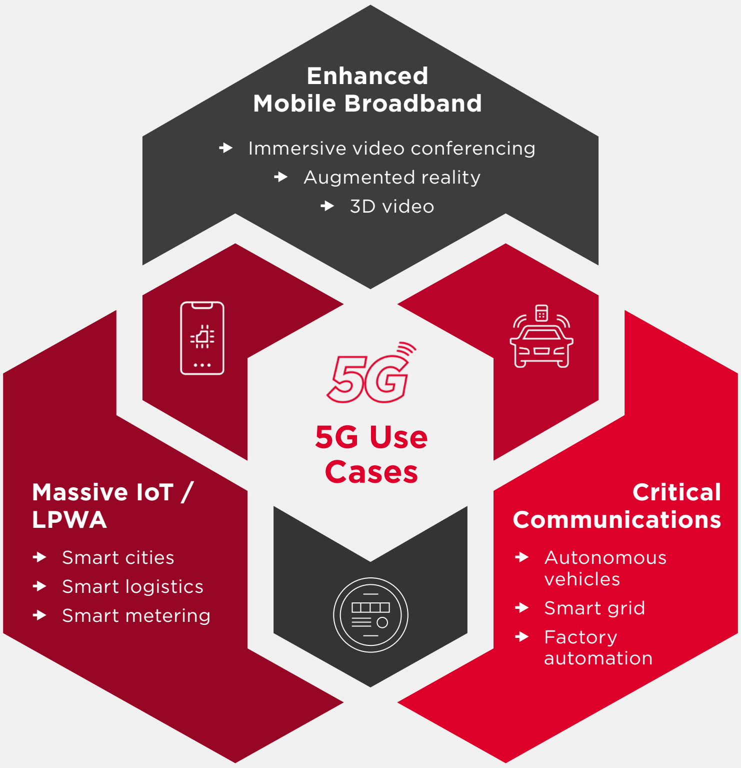
Massive IoT / LPWA: improved network coverage, long device operational lifetime and a high density of connections. This is also known as mMTC (massive MTC).

Critical communications: high performance, ultra-reliable, low latency industrial IoT and mission-critical applications. This is also known as critical IoT or URLLC (ultra reliable low latency communications).

Enhanced mobile broadband: improved performance and a more seamless user experience accessing multimedia content for human-centric communications.

Typical 5G use cases are illustrated in Figure 1.

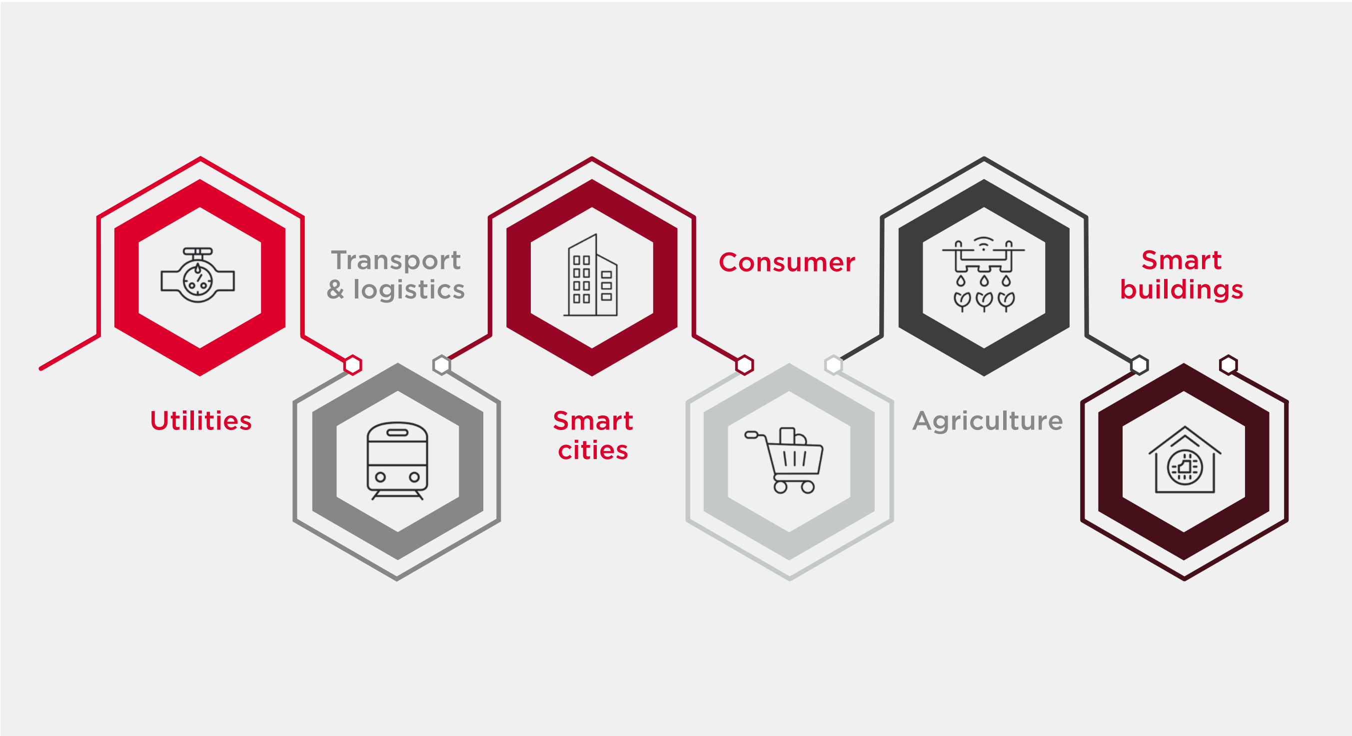
Figure 1
5G use cases



All the three main use cases are covered by 3GPP in the 5G specifications. However, with LTE-M and NB-IoT deployments already well underway, the initial focus for 5G NR deployment was to support enhanced mobile broadband use cases [4].

For massive IoT LPWA, a range of use case categories are presented in Figure 2NB-IoT and LTE-M are designed to address the requirements of these use cases, such as support for a large numbers of devices, low device cost, ultra-long battery life and coverage in challenging locations. These requirements[9] still apply for massive IoT in the 5G context. In addition, there is the ITU-R requirement to support a high connection density in terms of number of connections [1][2][3] in a given geographical area and spectrum allocation [8][9].

Figure 2
Massive IoT LPWA use cases



3.3 NB-IoT and LTE-M are part of 5G

Both NB-IoT and LTE-M fulfil the 5G IMT 2020 requirements for massive machine type communications. Furthermore, 3GPP has agreed that LPWA use cases will continue to be addressed by evolving NB-IoT and LTE-M from Release 16 or 17, as part of the 5G specifications [12].

3GPP has introduced an option for the 5G core network to support a NB-IoT or LTE-M radio access network. As a result, NB-IoT and LTE-M can continue to be supported in 5G networks after the closure of an operator's 4G network.

This will enable a smooth operator migration path to 5G NR frequency bands while preserving NB-IoT and LTE-M deployments. While there is currently no implementation of this 3GPP architecture option in any public operator network, it gives individual operators the flexibility to continue to provide long-term support for NB-IoT and LTE-M.

3.3.1 NB-IoT and LTE-M will coexist with other 5G components

5G NR was designed to support diverse deployment models, spectrum usage and device capabilities.

One of the deployment scenarios that has been supported since the start of the 5G NR work in 3GPP is to allow LTE-M or NB-IoT transmissions to be placed directly into a 5G NR frequency band [14]. This is further illustrated in the annex of this paper.

As new 5G components supporting use cases, in addition to LPWA, are specified and rolled out, NB-IoT and LTE-M will continue to coexist alongside these other 5G components.

3.3.2 NR Evolution for IoT: RedCap and eRedCap

To address IoT use cases with higher performance requirements than NB-IoT / LTE-M, but with a lower complexity and cost than a standard NR Modem, 3GPP Release 17 specifies a new category named RedCap[2] (reduced capabilities). Note, that RedCap devices are only supported by 5G standalone (SA) deployments. The target characteristics and performance for RedCap user equipment are:

- support for 150 Mbps in the downlink and 50 Mbps in the uplink
- support for both FR1 and FR2
- narrower bandwidths, i.e., 20 MHz in FR1 or 100 MHz in FR2
- a single transmit antenna,
- options of single or dual receive antennas,
- optional support for half-duplex FDD,
- lower-order modulation (64QAM mandatory, 256QAM optional)
- support for lower transmit power which may reduce coverage

This reduced complexity contributes to lower cost RedCap user equipment, longer battery life due to lower power consumption and a smaller device footprint compared to standard NR, albeit at the expense of reduced network efficiency for the MNO.

As new 5G components supporting use cases, in addition to LPWA, are specified and rolled out, NB-IoT and LTE-M will continue to coexist alongside these other 5G components

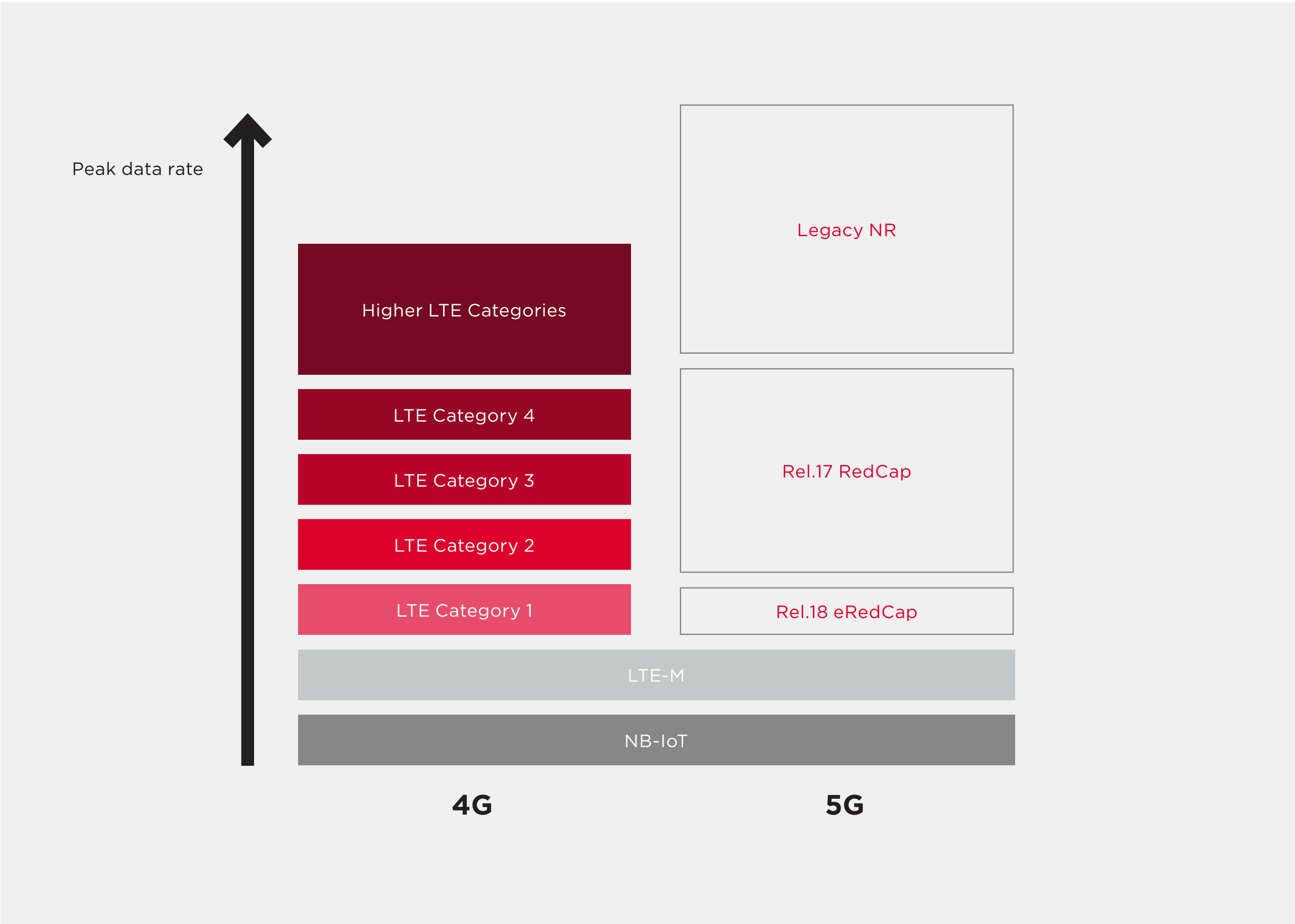
[2] Refer to https://www.gsma.com/iot/mobile-iot-commercial-launches/ for the most up-to-date information

The use cases and devices addressed by NR RedCap include wearables (e.g. smart watches, wearable medical devices, AR/VR goggles, etc.), industrial wireless sensors, video surveillance, and voice connectivity.

Further simplifications and the implementation of power saving features in Release 18 will see enhanced RedCap (eRedCap) target additional use cases, such as smart cities and eHealth.

To explain how these technologies complement each other, Figure 3 illustrates the various 5G network components that can be built up and deployed over time. It highlights that NB-IoT and LTE-M network components, already operational today, can coexist with other 5G NR components, e.g. enhanced mobile broadband and critical communications.

Figure 3
NB-IoT, LTE-M, RedCap and eRedCap in the context of 5G



3.4 IoT over non-terrestrial networks

In 2017, 3GPP examined the potential for integrating non-terrestrial networks (NTNs) into 5G. Whilst NTNs include high altitude platforms and drones, most of the interest is around satellite-based communication. Release 17 of the 3GPP standards, finalised in 2022, includes two relevant elements: NR over NTN and IoT over NTN. NR over NTN addressed regular 5G 'New Radio' for communications and broadband access via satellite, whereas IoT over NTN focused on the LPWA technologies, NB-IoT and LTE-M.

3GPP Release 17 also sought to define the most appropriate frequency bands for NTNs. It proposes that conventional user equipment could use the S-band or L-band, while more capable VSAT (very-small-aperture terminal) devices and other equipment with phased array antennas could use either S-band or Ka-band. This applies to both LEO and GEO satellites.

Commercial deployments of NTN-based solutions are under way.

3.4.1 Evolution of NTNs

Further NTN enhancements in Release 18 consider additional frequency bands and techniques to optimise satellite-based access. As part of Release 19, a new work item has been approved defining further improvements for:

- Optimising terminal performance.
- Increasing capacity performance on uplink.
- Notification of the service area of a broadcast service.
- Support for a non-terrestrial network architecture with 5G system functions on board the NTN vehicle (i.e. regenerative payloads).
- Use of RedCap devices within FR1 NTN.
- Support of store and forward operation based on regenerative payload, including the support of feeder link switchover.

3.5 SIM evolution for 5G IoT

The UICC, commonly referred to as a SIM, was introduced in the 1990s and is still being used today. As cellular communications have evolved, the SIM has also evolved, miniaturising from a regular and large credit card-size form factors, to mini-SIM, micro-SIM and finally nano-SIM. However, for IoT, an even greater size reduction was required.

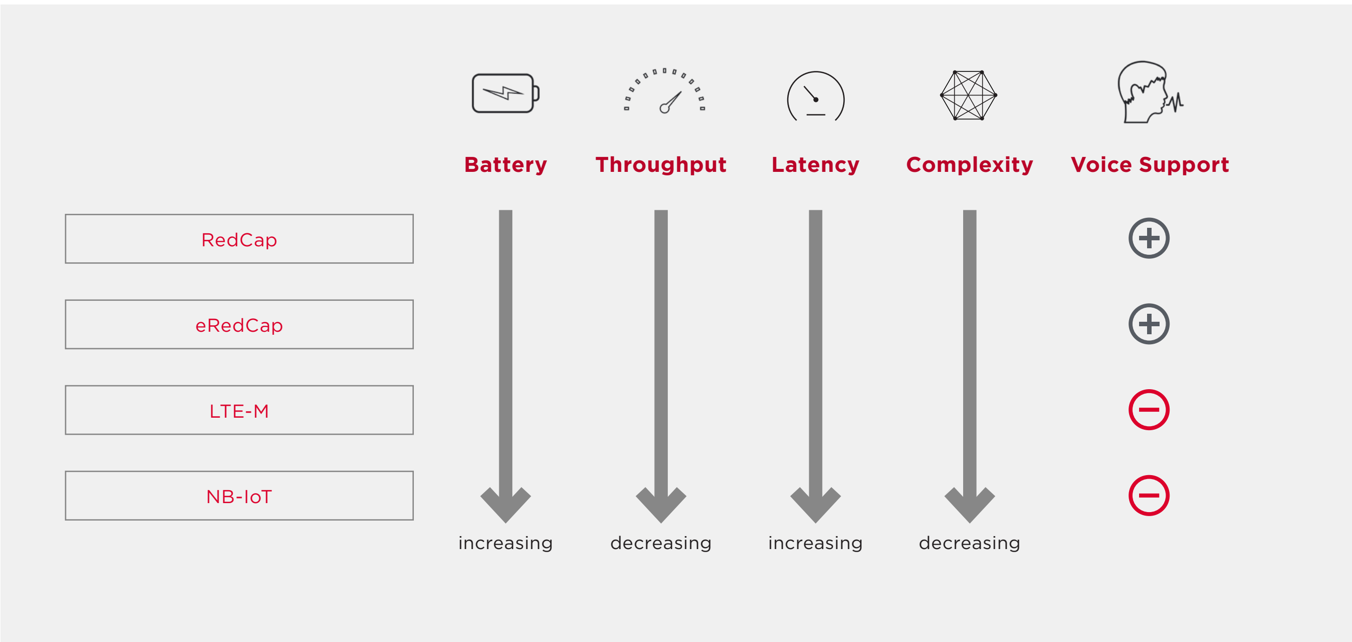
The eSIM brought further miniaturisation and eliminated the need for SIM sockets because the eSIM can be mounted directly on the device's PCB (printed circuit board). However, this miniaturisation was still insufficient and the industry is evolving towards a new generation of SIM. Much smaller and more cost efficient than the previous generations, the iSIM (integrated SIM) complies with the latest GSMA standards SGP.31/32, including support for RSP (remote SIM provisioning), and is a significant enabler of the Mobile IoT.

4.0
Conclusion

Selecting the optimal IoT technology is critical to deliver the desired technical and commercial business outcomes for an IoT deployment. Developers and integrators need to consider multiple aspects, such as battery life, throughput, latency, complexity and voice support, when selecting the appropriate IoT device.

Figure 4 highlights the general performance of IoT devices across these different aspects. However, this performance may vary on different networks as operators are likely to have different network capabilities and configurations deployed. It is strongly recommended to review the information published by operators and their guidelines to understand their network capabilities, configurations and any specific device requirements to select the optimal IoT technology for a particular use case. Additional information on the features and capabilities of Mobile IoT devices can be found in the GSMA's Mobile IoT deployment Guide[18].

Figure 4
High level performance of IoT devices[3]

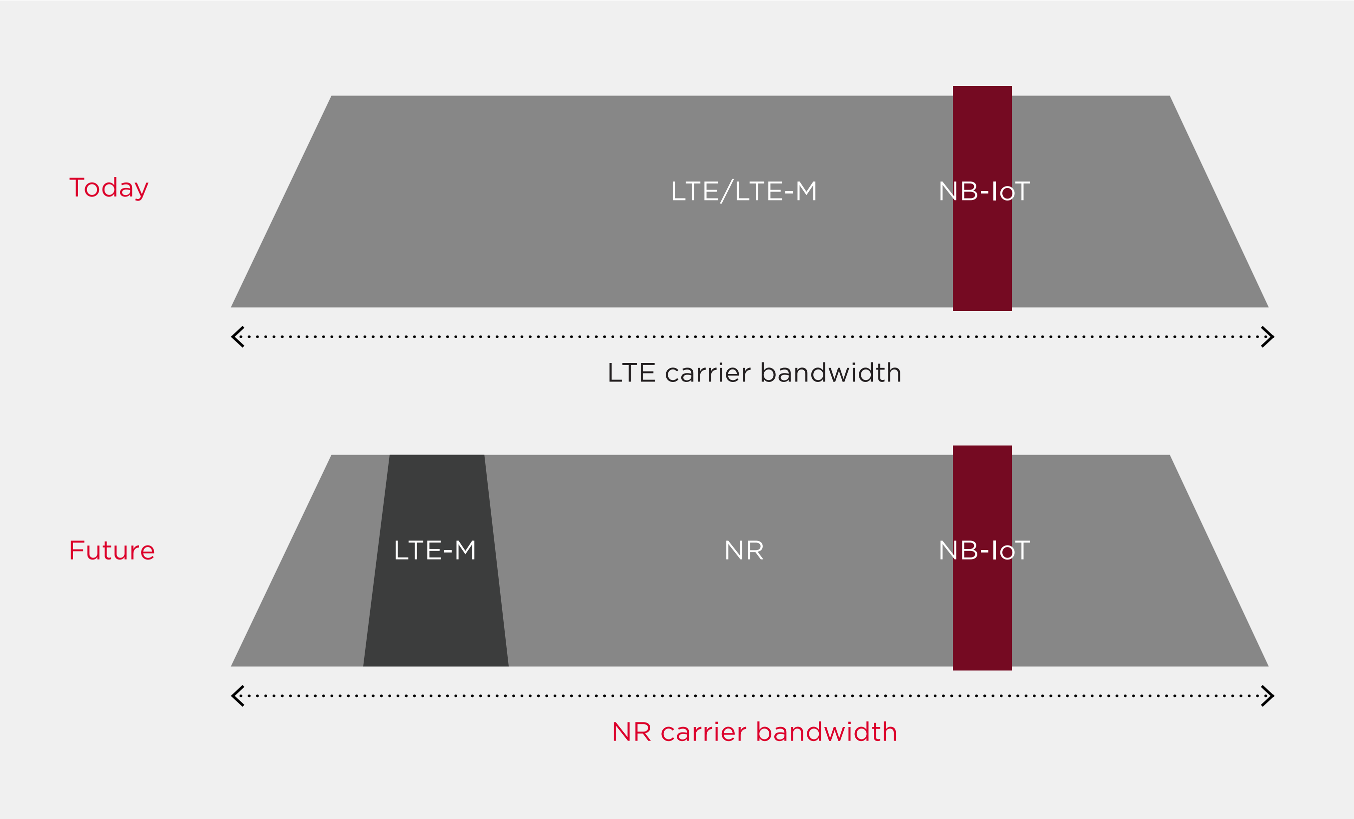


[3] **Note2:** Whilst LTE-M can technically support voice, few or no operators have deployed this. When deploying a voice solution be careful to understand the required local emergency calling regulations that may require compliance against.

Annex

5G NR with in-band NB-IoT and LTE-M

The figures below show in-band operation for NB-IoT and LTE-M within LTE and 5G NR carrier bandwidths.



The in-band operation for NB-IoT and LTE-M within 5G NR carrier bandwidths is achieved by including:

I. a 5G NR OFDM numerology and frame structure compatible with LTE [14],
II. a 5G NR duplex frequency configuration allowing NR, NB-IoT and LTE-M subcarrier grids to be aligned [15], and
III. support for “forward compatibility” configuration making it possible for an 5G NR device to rate match around radio resources that are taken by non-dynamically scheduled NBIoT and LTE-M signals [16].

These features help achieve the desired 5G NR, NB-IoT and LTE-M coexistence performance.

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