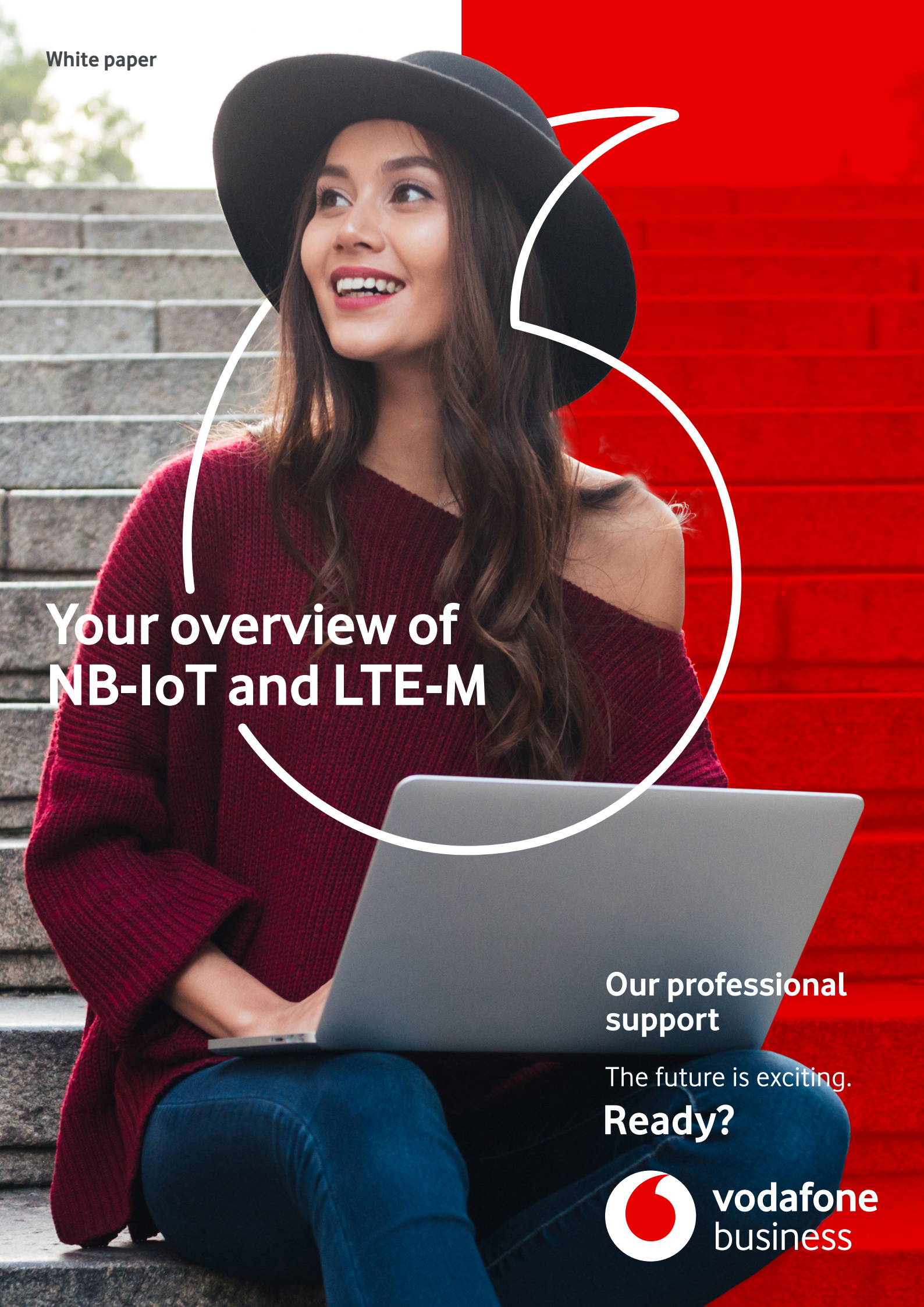
White paper

Your overview of NB-IoT and LTE-M



Our professional support

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Introduction

Narrowband IoT (NB-IoT) and LTE Machine Type Communications (LTE-M) are Low Power Wide Area technologies (LPWA) which utilise the radio access network for connecting devices with low bandwidth requirements, whilst providing increased penetration with the added capability of using low power. The 3GPP released information concerning LTE-M and NB-IoT for Release13 in June 2016, known as CAT NB and CAT M or Category Narrowband and Category Machine Type respectively.

	Unlicensed services (e.g. Sigfox, LoRa)	Unlicensed services (e.g. NB-IoT, LTE-M)
Leverages existing network	●	●
Extended battery life	●	●
Deep indoor coverage	●	●
Security for IoT	●	●
Experienced network support	●	●
Standards-based (non-proprietary)	●	●
Bandwidth available	●	●
2-way communication	●	●
Low device cost	●	●

There are multiple LPWA technologies but only NB-IoT, LTE-M and EC-GSM use a licensed spectrum. With the security provided by MNOs, this gives users an added layer of service assurance.

The benefits of using the unlicensed vs. licensed services can be seen as a trade-off of security vs. quick installation process.

	Sigfox	LoRaWAN	NB-IoT	LTE-M	EC-GSM-IoT
Coverage	160dB	157dB	164dB	155.7dB	164dB
Technology	Proprietary	Proprietary	Open LTE	Open LTE	Open 2G
Spectrum	Unlicensed	Unlicensed	Licensed (LTE/any)	Licensed (LTE)	Licensed (GSM)
Downlink data rate	<0.1kbps	<10kbps	0.5-200kbps	0.5-1000kbps	0.5-180kbps
Uplink data rate	<0.1kbps	<10kbps	0.3-180kbps	0.3-800kbps	0.3-150kbps
Battery life (200b/day)	10+ years	10+ years	15+ years	10+ years	10+ years
Module cost (today)	-	-	<$6	<$10	<$6
Security	Low	Low	Very high	Very high	Very high

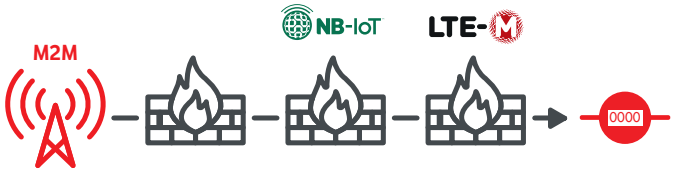
Technical comparison

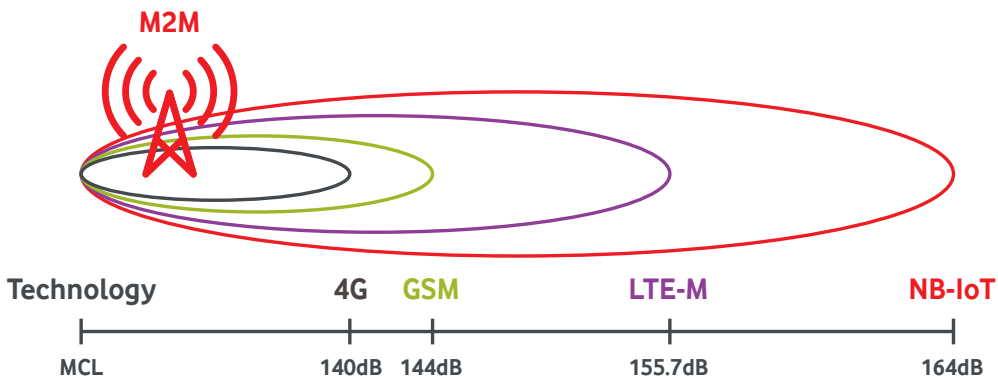
There are various differences between NB-IoT and LTE-M, for example, the carrier bandwidth, throughput and coverage.

LTE-M	Category Name	NB-IoT
Category M1/M2	**Category Name**	**Category NB1/NB2**
Release 13	3GPP Release	Release 13
All	Frequency bands	Some FDD bands
1.4-20 MHz	Cell bandwidth	180 kHz
1.4 MHz	UE bandwidth	180 kHz
TDD, FDD Half duplex FDD type B	Duplex modes	Half duplex FDD type B
1	Receive antennas	1
20/23 dBm	Maximum power	20/23 dBm
32 (Mode A), 2048 (Mode B)	Maximum number of repetitions	128 (uplink) 512 (downlink)
Optional	LTE RAN Support	Dedicated NB-IoT cells
Optional	Power Saving Mode (PSM)	Optional
Optional	Extended DRX	Optional
Mandatory (Mode A), Optional (Mode B)	Repetitions	Mandatory
Optional	Data over NAS signalling	Mandatory
Optional	RRC suspend & resume	Optional
Not supported	SMS without combined attach	Optional
Optional	Attach without PDN connectivity	Optional
Optional	VoLTE	Not supported
800 kbps	Peak DL data rate	250 kbps
800 kbps	Peak UL data rate	250 kbps (multi-tone)
--	DL data rate in extreme coverage	400 (160) bps
--	UL data rate in extreme coverage	200 (160) bps
155.7 dB	Maximum coupling loss	164 dB
10 years	Battery life	10-15 years
EUR 15	2018 price	EUR 10

One of the main features concerning LPWA technologies is the enhanced coverage capability; for LTE-M the Maximum Coupling Loss (MCL) has an additional gain of approximately 10dB and 20dB for NB-IoT when compared to GSM. This is achieved by:

- Repetition of transmissions
- New control channels (usage of non-access stratum)

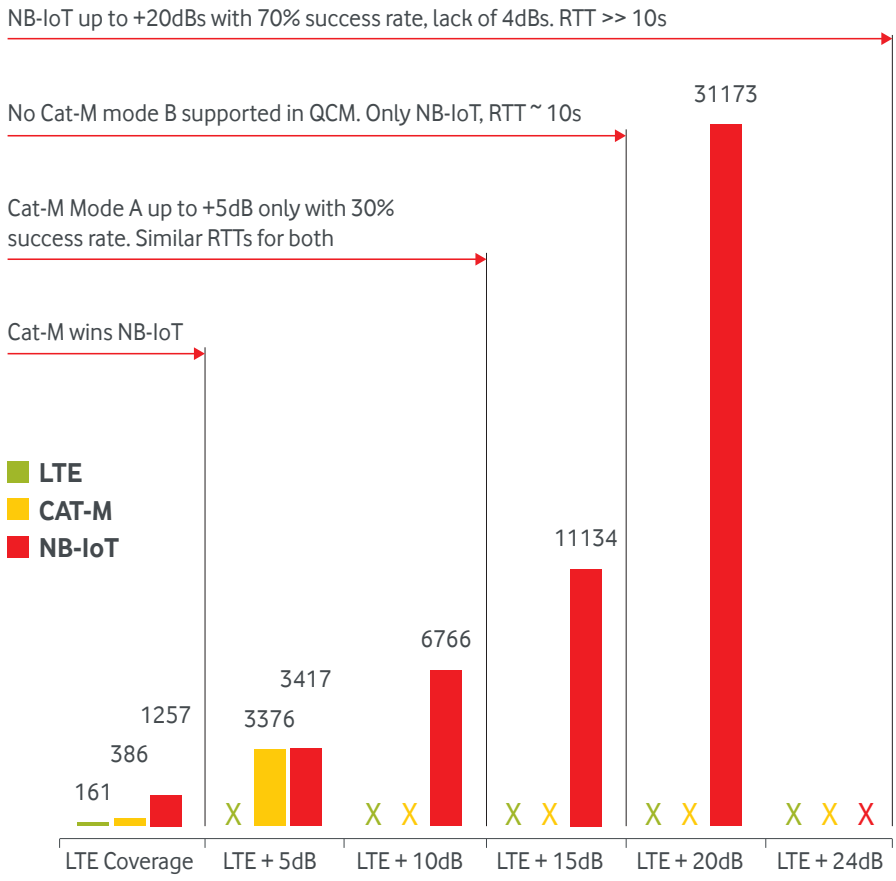




Based on our previous testing, NB-IoT has the ability to penetrate two to three double brick walls, enabling connectivity in underground car parks and basements.

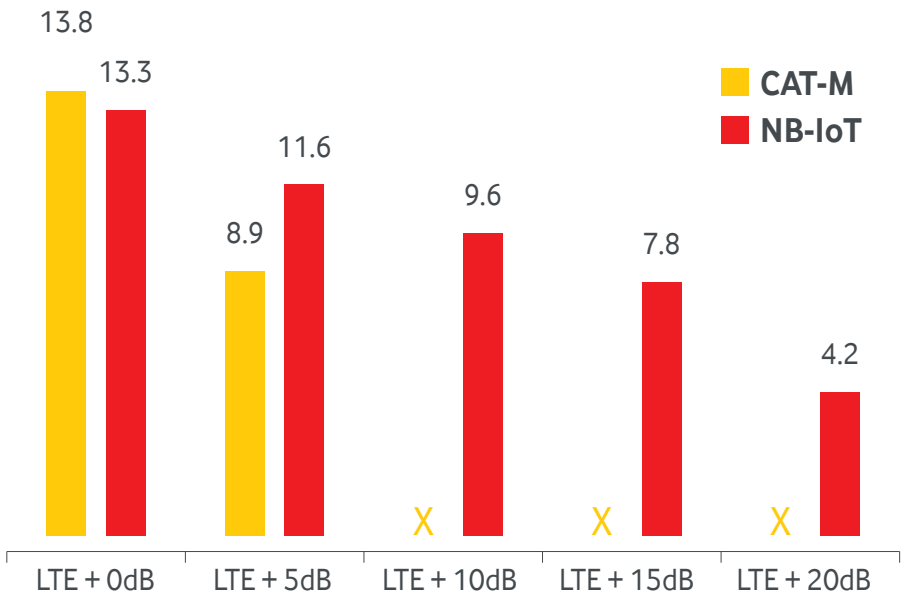
(notes +10dB approximately equates to one brick wall)

For other field tests that were carried out for data delivery times and battery life, the results are shown below



100 Byte Round Trip Time from the device in idle (ms)

Note: X means there was no service



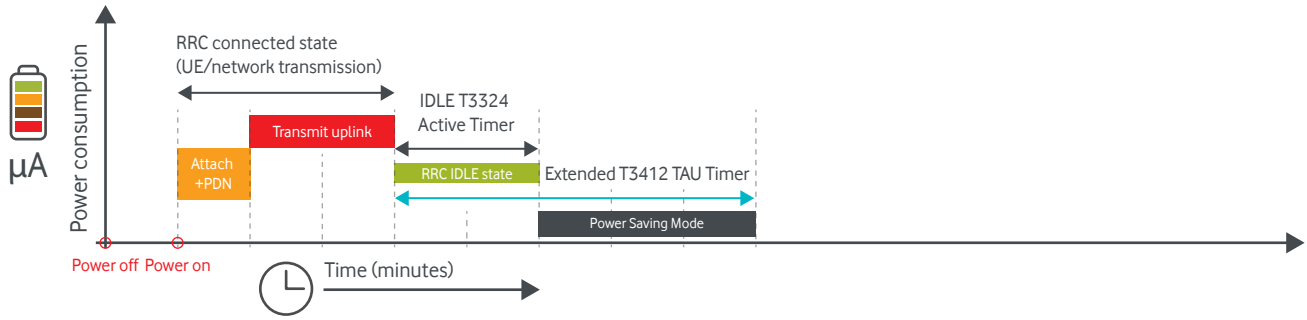
Years battery lifetime comparison (100 Bytes/day)

Note: X means there was no service

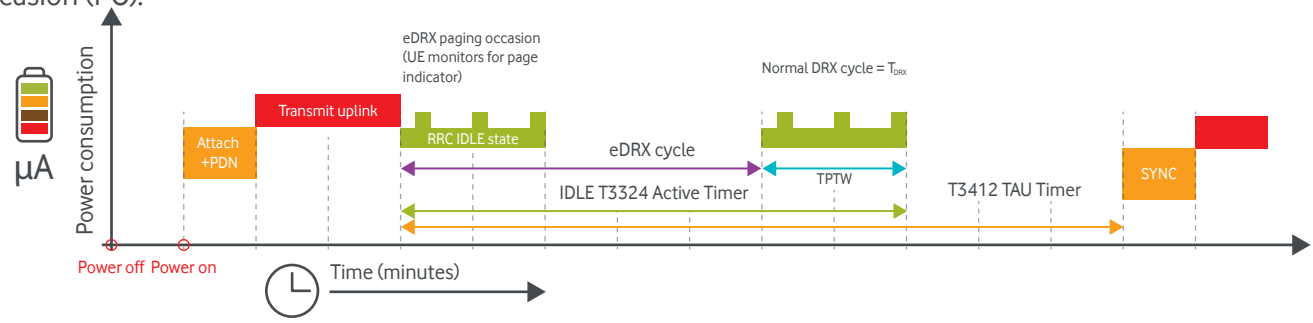
Features

New timers have been introduced to optimise the performance of IoT devices utilising these LPWA technologies. Two of these are Power Save Mode (PSM) and extended Discontinuous Reception (eDRX); released in 3GPP Release12 and Release 13 respectively.

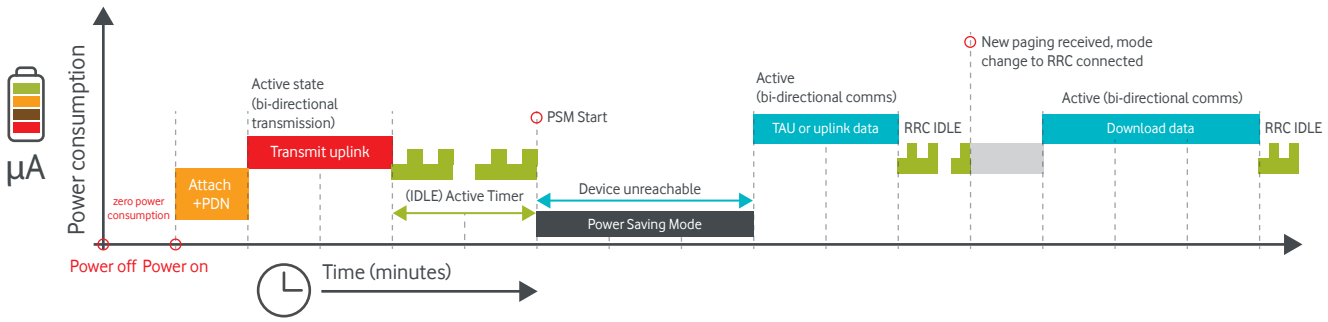
In PSM the UE would maintain its PDP (Packet Data Protocol) context, also known an PDN (Packet Data Networks) connection, with the EPC (Evolved Packet Core), but its radio or antenna would be powered down. This leads to a difficulty in paging the IoT device to receive MT (mobile-terminated) traffic, leading to loss of packets as the local Serving Gateway (SGW) would only keep packets for a previously configured amount of time in its queue before these packets get discarded. So why use PSM? An IoT device should use less power while it is in a power-saving state (PSS) , this in return increases the longevity of an IoT device being powered by a DC battery.



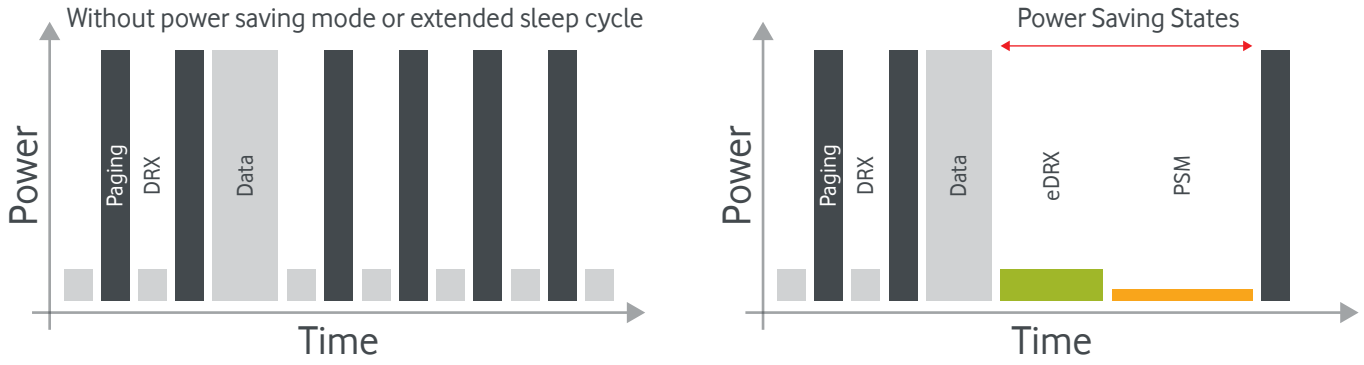
To address the loss of packets, eDRX was introduced. This allowed for more successful delivery attempts of MT traffic while providing support for MO (mobile-originated) traffic. When a device utilises eDRX, it allows the device to be paged while it is in idle state utilising a paging transmission window (PTW) to allow for a paging occasion (PO).



Both of these features can be configured so that an IoT device can use them concurrently, giving the device opportunities to be paged in the idle state as well as using the PSS to conserve energy.



Usage of PSM and eDRX is optional for both NB-IoT and LTE-M. However, research shows that using these modes in combination can extend the battery life of an IoT device with ranges of up to 10 years for LTE-M and 15 years for NB-IoT. This is enabled by the extended sleep cycles, eliminating the unnecessary radio channel activation offered by PSM and longer interval cycle between the paging time windows for eDRX.



Product types

NB-IoT bearer can be established in IP and non-IP mode and the services currently supported are:

- NB-IoT IP Bearer Connectivity
- IP Data Messaging (bearer-agnostic)

The services planned to be supported over LTE-M are:

- IP Bearer Connectivity
- IP Data Messaging

There are also plans to support multi-bearer combinations within the same SIM subscription profile:

- NB-IoT + 2G
- NB-IoT + LTE-M
- NB-IoT + 2G + LTE-M

Roaming commercials

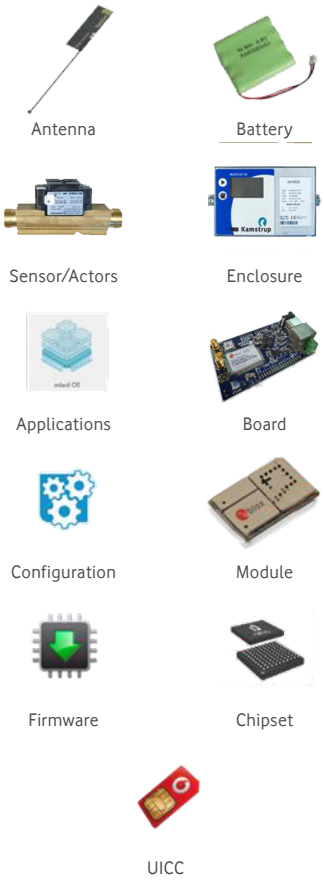
There is currently no guidance in terms of roaming agreement provided by the 3GPP for MNOs to use. There are considerations that LTE-M could be subject to the guidance provided for LTE as this technology is able to use the legacy LTE RAN interface.

Available SIMs (form factors)

All SIM form factors are available except for eUICC. There is currently no offering for eUICC for NB-IoT as this requires SMS capability, which isn't available for NB-IoT. eUICC is not available on LTE-M either.

Device ecosystem

The architecture for LPWA devices does not differ much from the architecture of cellular devices. As an example, the following image outlines main elements of a typical smart meter. In the near term it will be possible to design host-less (app environment inside the chip – no external A-CPU required) for LPWA devices, which allows more efficient (space usage, power consumption) HW designs.



Chipset	• C-CPU responsible for the modulation and demodulaion of the data into/from a RF signal • Offers typically IO interfaces which are exposed by the module • A physical UICC interface is exposed which is wired through by the module

Modules	• Host the chipset
	• Responsible for the RF part: band/frequency support, PA, TX/RX switch
	• Could host a soldered SIM
	• Module manufacturers typically customise the chipset firmware:
	  • AT command set
	  • Value added services: LwM2M, FOTA
	• Modules may be certified to GCF to ensure they meet basis tests.

Board (PCB)	• Hosts the module and an application environment (incl. A-CPU) • Connects all other peripherals (sensors, antenna, battery,...)
Enclosure	Host the PCB and all peripherals
Battery	Key component for battery powered use cases
Antenna	Crucial element for NB-IoT devices because of possible extended coverage (e.g. deep indoor) use cases
SIM	All IoT form factors from the Vodafone catalogue are supported (see section 9)
Chipset firmware	The chipset "firmware" includes the N-IoT protocol stack and the UICC interface
Device Configuration	Configuration changes are more cost effective to manage compared to full SW update • Smaller amount of data • Supported via standard protocols for Device Management (OMA LwM2M)
Application	Businesses logic provided through applications which run within the application environment. The application communicates with the module and manages the peripherals
Sensors/Actors	Any sensor/actor

Today there are a number of chipsets available for NB-IoT and LTE-M and in varying combination with other technologies. These chipsets range from entry-level chipset with basic functionality to more complex chipsets, which also include application-processing capabilities.

The latest chipsets and modules for LPWA technologies (NB-IoT and LTE-M) are provided below. There are some devices which Vodafone has tested and are GCF-certified.

Vodafone is working with IoT module vendors to integrate and test their devices on our network. We have NB-IoT Open Labs available in Newbury, Düsseldorf and Milan.

The Vodafone Innovation Park in Düsseldorf is offering IoT module certification services:

https://www.vodafone.de/innovationpark/en/professional-iot-services.html

Certified modules and devices:

https://www.vodafone.de/innovationpark/en/references.html

The GSMA also provides an overview about the announced NB-IoT modules:

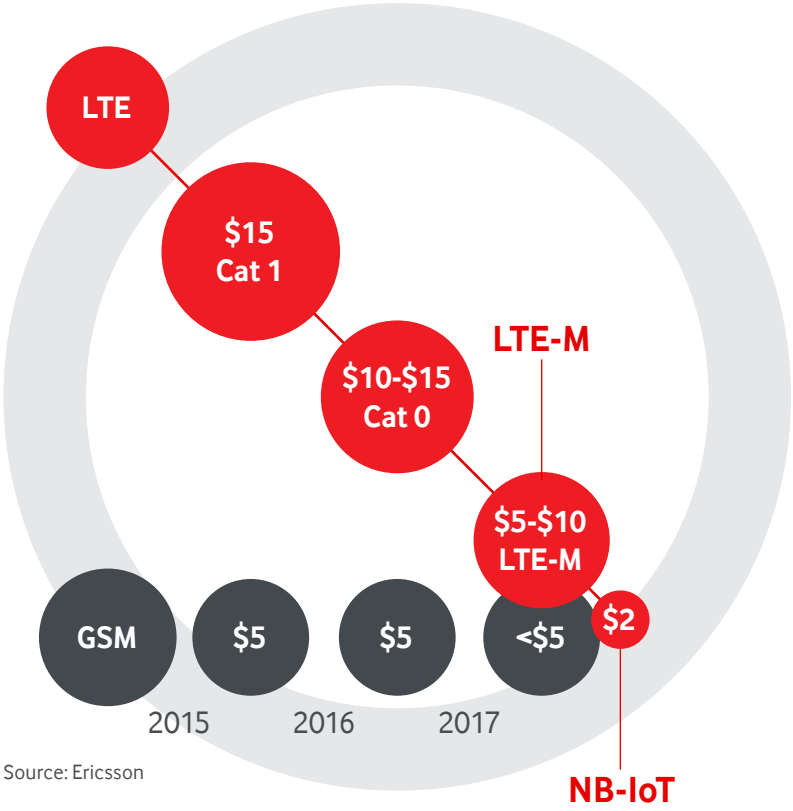
https://www.gsma.com/iot/mobile-iot-modules/

The evolution of these modules have seen a reduction in the price, where devices used to be $15; this is now less than $5 per module.

Having significantly reduced device complexity, functionality and capability, thus the cost has gradually decreased compared to traditional LTE.

Module costs directly reduced by:

- Half duplex operation
- Single antenna
- Reduced memory requirements
- Lack of IPR floor



Source: Ericsson

Vodafone's LPWA roadmap

We have compiled some information to provide guidance to the plans for Vodafone Business, this is only indicative.

IoT Connectivity | Next generation IoT Networks LPWA

NB-IoT data enhancements

API enhancements, Multiple radio bearers on the same SIM (2G and NB-IoT). NB-IoT Extended power savings mode enablement providing additional capabilties

LTE-M support

Provision of LTE-M as a disinctive service and support for LTE-M in The Netherlands and New Zealand

NB-IoT Roaming

NB-IoT Roaming support based on bilateral operator agreements

Automated setup

Faster delivery with automated customer setup for NB-IoT data connectivity based on shared public APNs.

Data Messaging 2.0

Support for additional protocols for NB-IoT data messaging as well as introduction of new commercial models to supprt more NB-IoT use cases

Automated setup R2

Extension of automation to support data messaging

Flexible customer growth

Flexibility for customer to seamlessy transition from 2G and combine and grow into footprints with different bearer dominance with single global device SKU and management experience

Flexible customer growth

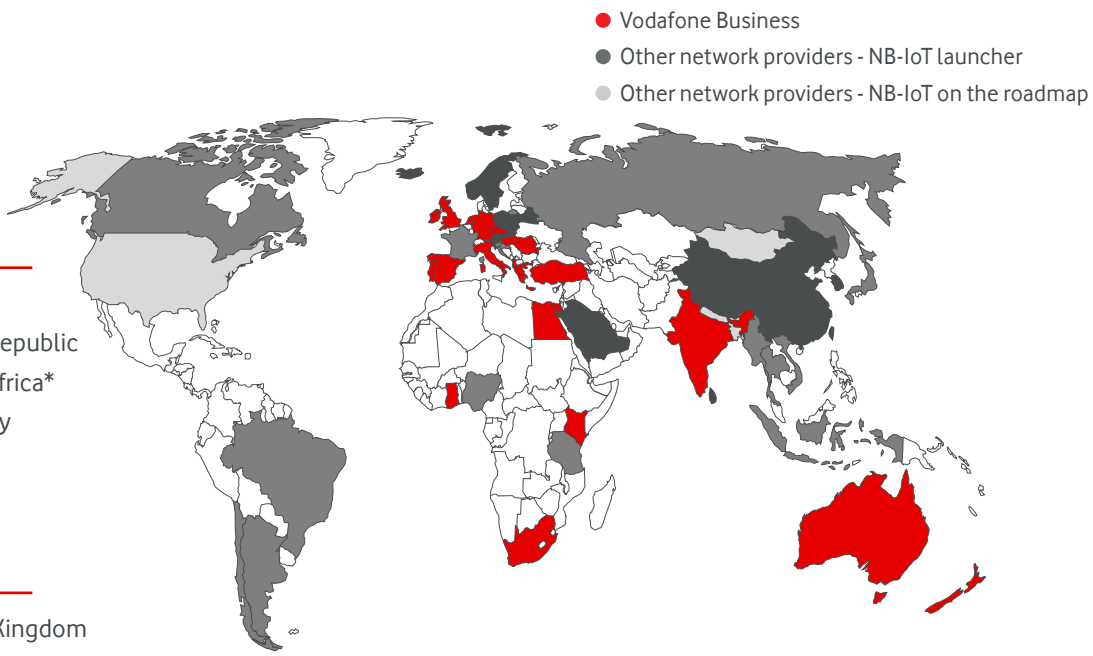
Work with partners and networks to ensure a customer can develop once deployed, allowing for a Vodafone bearer agnostic data messaging platform to simplify customer development; this gets the most performance out of LPWA devices with minimum effort.

Q2 FY18/19	Q3 FY18/19	Q4 FY18/19	H1 FY19/20	H2 FY19/20	FY20/21
Market expansion Deployment of Managed NB-IoT Connectivity in Greece (totalling 8 markets for Managed NB-IoT connectivity) LTE-M support.	**Market expansion** Deployment of Managed NB-IoT Connectivity in UK (totalling 9 countries for Managed NB-IoT connectivity)	**Market expansion** Deployment of Managed NB-IoT Connectivity in Portugal, South Africa, Romania and Hungary as well as at least one partner market (totalling 14 countries for Managed NB-IoT connectivity)	**Leading global footprint** Expand NB-IoT and LTE-M across the full Vodafone footprint, enable LPWA roaming agreements with all Vodafone Partner network and major networks through bilateral agreements and actively driving industry standards for roaming.		

Deployment of LPWA

Vodafone have launched NB-IoT in a number of markets as well as LTE-M.

NB-IoT: a global network



Launched

Spain	Turkey*
Ireland	Czech Republic
Italy	South Africa*
Australia	Germany
Netherlands	Greece
New Zealand	Malta

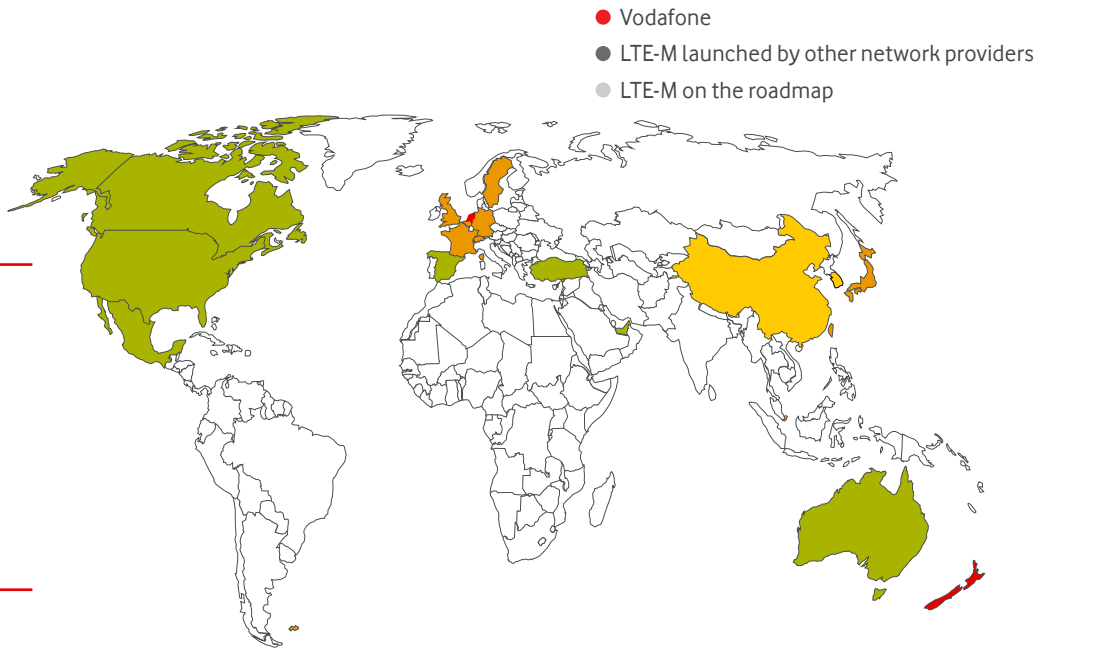
2019 (H1)

Portugal	United Kingdom
Hungary	

* Local SIM only

Target:
All Vodafone Business 4G masts by 2020

LTE-M expected rollout



Launched

Netherlands
New Zealand

2019

TBC*

*Vodafone Business roll-out based on customer demand

The GSMA shares coverage map and latest deployment information concerning these LPWA technologies on their website. Please visit **https://www.gsma.com/iot/deployment-map-v2/** for more information; these maps should only be used as reference.

Vodafone is supporting LPWA in the following frequency bands :

LTE-M

	800	900	700	850	1800
Netherlands	●				
New Zealand			●		●

NB-IoT

	800	900	700	850	1800
Albania		●			●
Democratic Republic of Congo					●
Czech Republic	●				
Germany	●				
Egypt		●			
Spain	●				
Ghana					
Greece	●				
Hungary	●				
Ireland	●				
India					●
Italy	●				
Lesotho					●
Malta	●				
Mozambique					
Netherlands	●				
New Zealand			●		
Portugal	●				
Qatar	●				
Romania	●	●			
Turkey					
Tanzania					●
United Kingdom	●				
South Africa		●			
Australia		●		●	

● Confirmed
● Preliminary

Use cases

LPWA networks allow a wide range of opportunities; the evolved spectrum has introduced some new capabilities, which allows for a range of requirements to be addressed.

Gas metering
Large homogenous market measured in millions
Battery life and propagation is critical
Large number of potential meter manufacturers

Water metering
Large homogenous market measured in millions
Battery life and propagation is critical
Large number of potential meter manufacturers

Liquid and pressurised fuels
Large homogenous market measured in millions
Asset is currently not monitored and losses are high
Battery life is critical

Smart bins
Growing market with good business case
Battery life and network coverage is critical
Complements our high-end connected bins

Environmental monitoring
Latent market waiting for a low power solution
Battery life and network coverage is critical
Fragmented channel to market in low volumes

Smoke and fire alarms
Massive market measured in hundreds of millions
Battery life and ability to test device is critical
High volume B2C play

Parking monitoring
Market measured in hundreds of thousands
Battery life and low install cost are critical
Low data throughput

Alarms and event detectors
Market measured in hundreds of thousands
Battery life is ultra critical
Very low data throughput on check and trigger

Summary

LTE- CAT1

IoT gateways
Connected cars
Surveillance cameras
Smartphones
Digital signature

High performance and mobility with Voice and Data.

- Data rate: 5 Mbps
- Coverage: -4dB GSM/ 2yr battery
- Module cost: $25

Best option for 3G replacement

LTE- M

Industrial handhelds
Wearables
Vending machines
Asset trackers
Health monitors
Security systems

Highly reliable, Voice and Data, low latency, low power consumption

- Data rate: <1 Mbps
- Coverage: +10dB GSM/ ≤10yr battery
- Module cost: $10

Best option for 2G replacement

NB-IOT

Parking meters
Agriculture monitors
Sensors
Utility meters
Industrial sensors
City infrastructure
Lightning / HVAC controllers

Low amount of data (no voice) and transactions, delay tolerant, lowest power consumption

- Data rate: 200kbps
- Coverage: +20dB GSM / ≤15yr battery
- Module cost: <$6

Best option for deep coverage

NB-IoT and LTE-M have evolved as technologies that enable the connectivity of a range of devices, using the low power consumption capability with increased coverage footprint. It is obvious that for deeper coverage, whether underground or in a remote region far from any cellular site, NB-IoT outperforms LTE-M by ranges of approximately 10dB.

Also, with NB-IoT, a device has a much longer battery life with around 15 years, while LTE-M is around 10 years. This longer battery life offered by NB-IoT reduces the number of maintenance inspections that such IoT devices would require, allowing for operational savings on expenses.
The modules that offer NB-IoT are generally cheaper and with costs of around half the price in most instances.

Currently NB-IoT has a larger global footprint than LTE-M; this can be attributed to the fact that where there are still 2G and LTE networks, this reduces the need for LTE-M, whereas NB-IoT with its enhanced coverage provides a capability that these network technologies are not able to mimic.

POC and trials and support

If you would like to trial Vodafone's NB-IoT and LTE-M network, please reach out to your local sales representative to get started. If you do not have the contact details for your nearest local sales representative, please email **iot@vodafone.com** for more information.

Appendix

Glossary of terms

eDRX – extended Discontinuous Reception
PSM – Power Save Mode
IoT – Internet of Things
MTC – Machine Type Communications
NB-IoT –Narrowband Internet of Things
CAT –NB/NB1/NB2 – Category Narrowband, Narrowband Release 1, Narrowband Release 2
LTE-M – Long Term Evolution Machine Type Communication
CAT-M – Category Machine Type Communication
GSMA – Global System for Mobile Communications Authority
GSM – Global System for Mobile Communications
LPWA – Lower Power Wide Area
EC-GSM IoT – Extended Coverage Global System for Mobile Communication Internet of Things
CPU – Central Processing Unit
TBC – To be confirmed
PDP – Packet Data Protocol
PDN – Packet Date Network
MCL – Maximum Coupling Loss

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