White paper

Narrowband IoT and LTE Machine Type Communications

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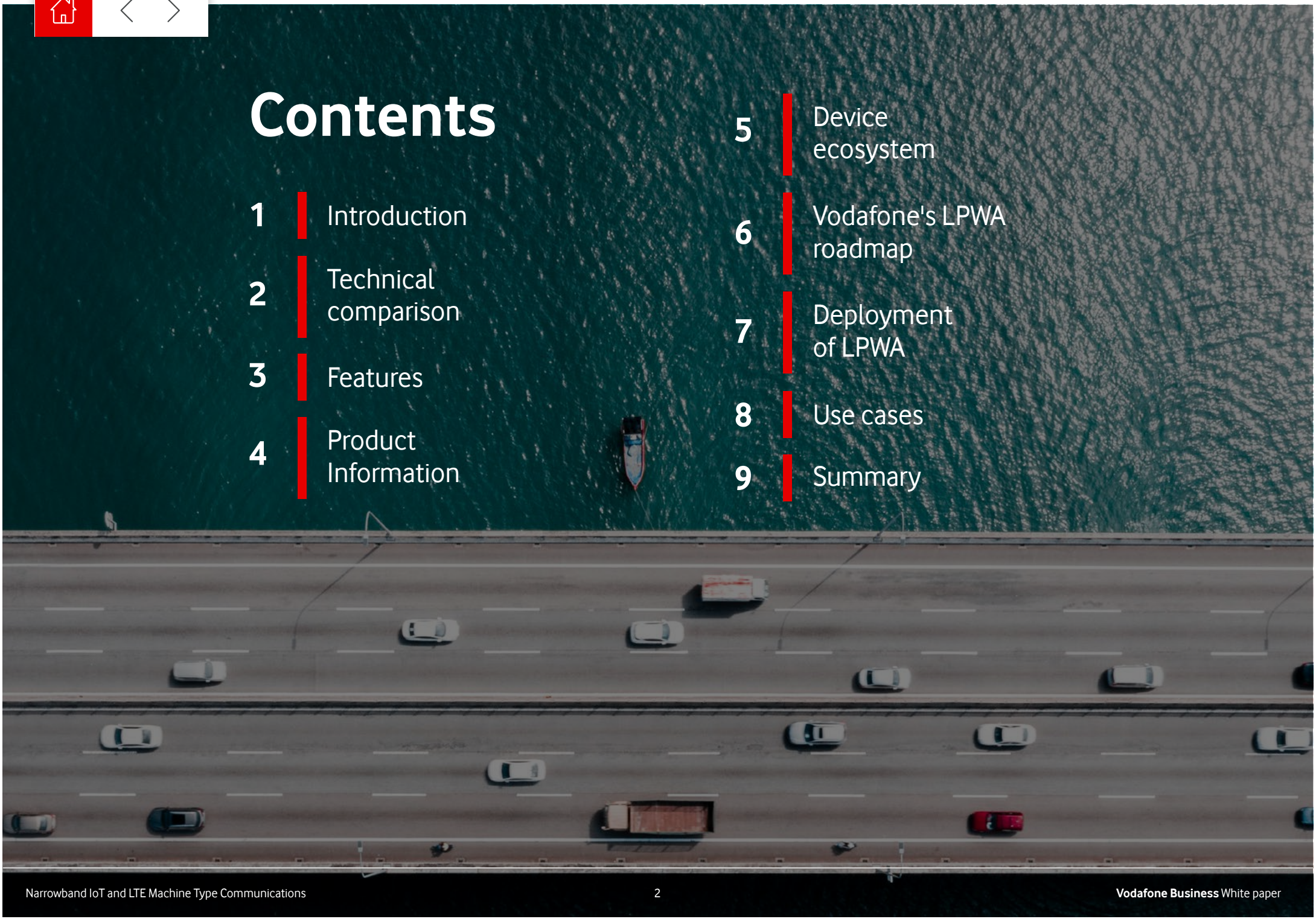
business

Contents



1. Introduction

Narrowband IoT (NB-IoT) and **LTE Machine Type Communications** (LTE-M) are **Low Power Wide Area technologies** (LPWA) which utilises 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 Rel.13 in June 2016, known as CAT NB and CAT M or rather Category Narrowband and Category Machine Type respectively, and are now part of the 5G specifications.

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

	UNLICENSED SERVICES (e.g. Sigfox, LoRa)	LICENSED 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	●	●

1. Introduction

The benefits of using the licensed vs unlicensed services can be seen as 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	0.45-250kbps	0.3-800kbps	0.5-180kbps
Uplink data rate	<0.1kbps	<10kbps	0.3-220kbps	0.3-600kbps	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

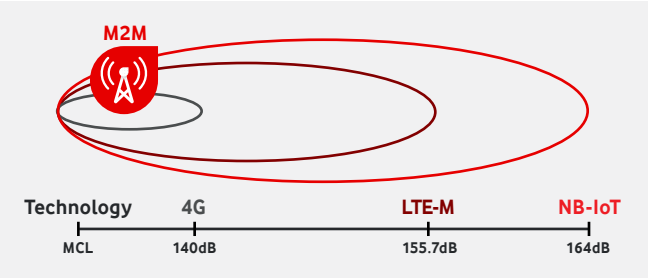
2. Technical comparison

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

LTE-M Category M1/M2	Category Name	NB-IoT 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
600 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 10	Price range	<EUR 6

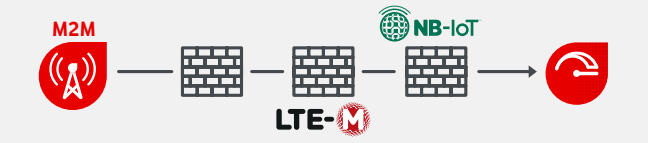
One of the main features concerning LPWA technologies is the enhanced coverage capability; for LTE-M the Maximum Coupling Loss (MCL) has an additional gain of approximately 10dB and 20dB for NB-IoT when compared to GSM. This is achieved by a few factors:

- Repetition of transmissions
- New control channels (usage of Non Access Stratum)
- Size of UE bandwidth



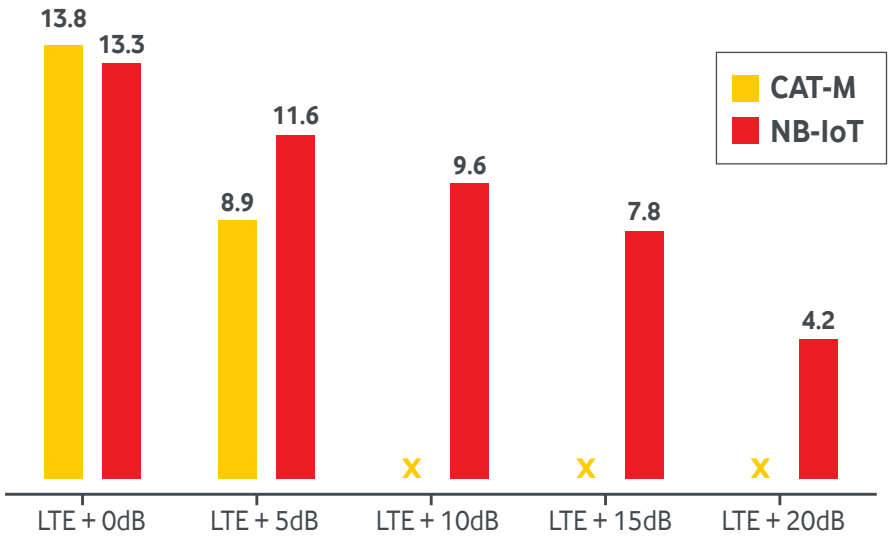
Based on our previous testing, NB-IoT has the ability to penetrate two to three double brick walls, enabling connectivity in underground car parks and basements.

(Note +10dB approximately equates to one brick wall).

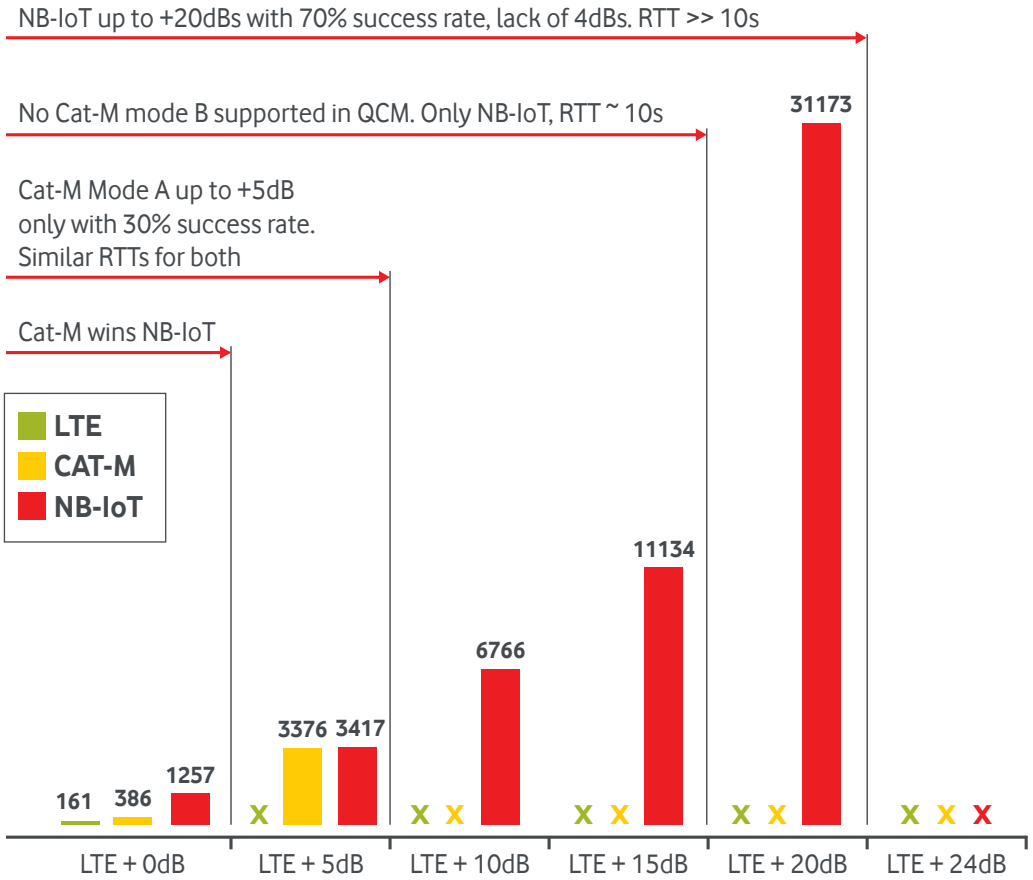


2. Technical comparison

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

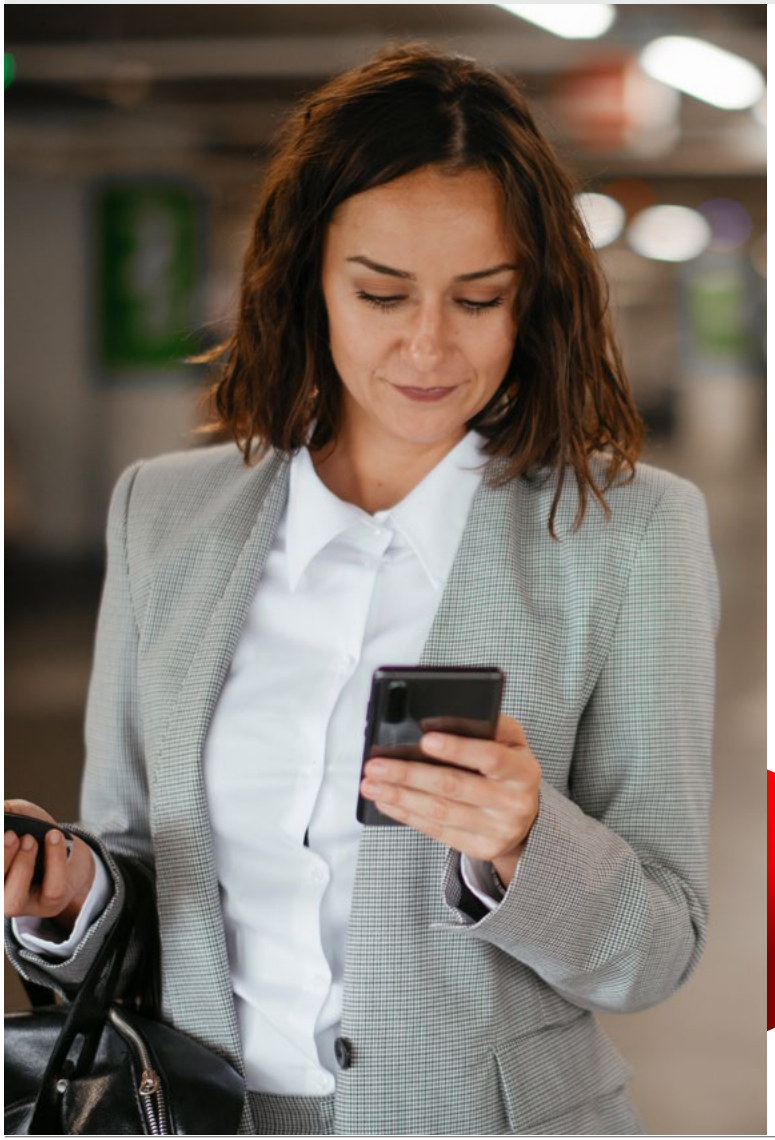


Years battery lifetime comparison (100 Bytes/day)
Note: **x** means there was no service



100 Byte Round Trip Time from the device in idle (ms)
Note: **x** means there was no service

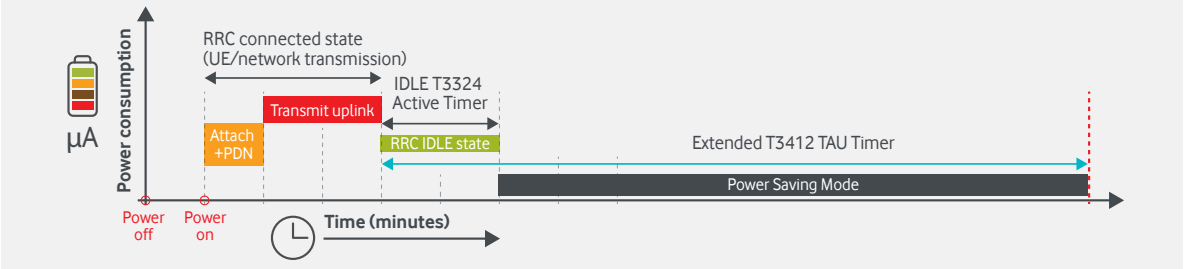
3. Features



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 Rel12 and Rel13 respectively.

Example of implementation of PSM

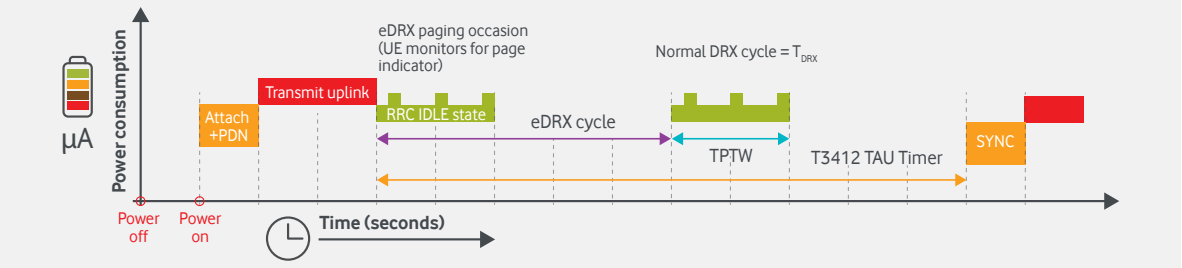
In PSM the UE would maintain its pdp context (packet data protocol), also known an PDN (packet data networks) connection, with the EPC (Evolved Packet Core), but its radio or antenna would be powered down. This leads to a difficulty in paging the IoT device to receive MT (mobile terminated) traffic, leading to loss of packets as a local Serving Gateway (SGW) would only keep packets for previously configured amount of time in its queue before these packets get discarded. So why use PSM? The benefits are based on the fact that an IoT device would be using less power as it is in a power saving state (PSS) and this increases the longevity of an IoT device powered by a DC battery.



3. Features

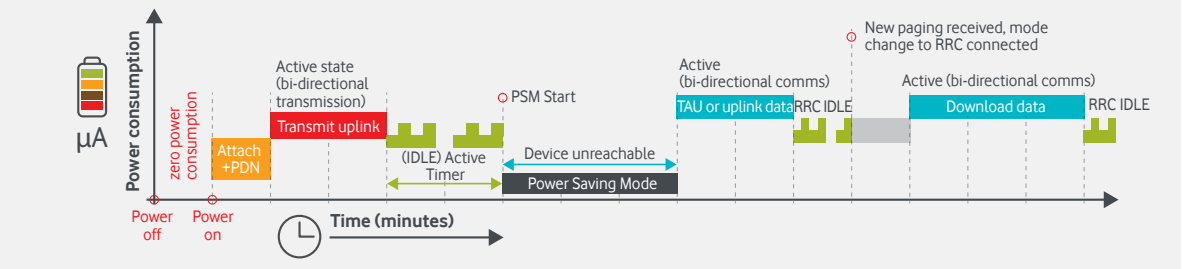
Example of implementation of eDRX

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).

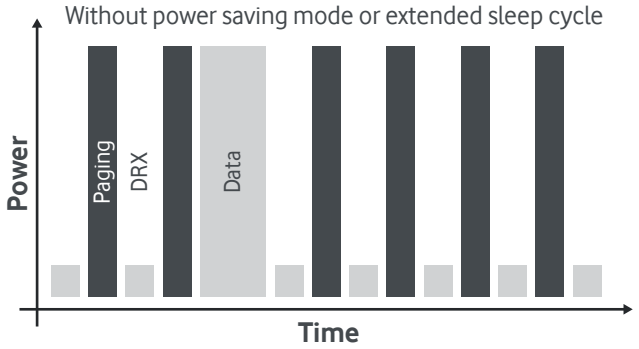


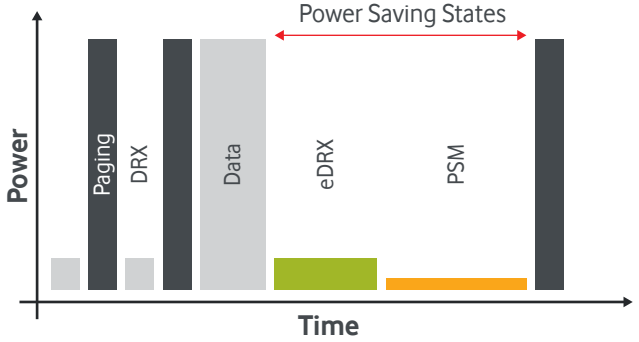
Example of implementation of concurrent eDRX and PSM

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 a IoT device with ranges of up to 10 years for LTE-M and 15 years for NB-IoT. This has been 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.





4. Product Information

Product types

Our service offerings include those to setup and establish separate NB-IoT and LTE-M bearers in IP mode:

- NB-IoT IP Bearer Connectivity
- LTE-M IP Bearer Connectivity

Additional offerings include support for multibearer combinations within the same SIM subscription profile:

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

Roaming commercials

Vodafone is leading the industry on developing LPWA roaming. Inter-carrier roaming agreements allow a larger footprint offering where customers can utilise and experience the benefits offered by LPWA networks, as well as helping to drive industry standards for LPWA networks. Vodafone will continue to invest in the global reach of LPWA networks as we expand our roll-out around the world.

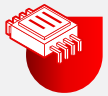
Available SIMs (form factors)

All SIM form factors are readily available except for embedded Universal Integrated Circuit Card (eUICC). There are standards currently being reviewed and discussed for this type of network integration of eUICC for LPWA products.

For additional documentation concerning eUICC, and the latest technical developments please speak to your Account Manager or local IoT Solution Architect.

5. Device ecosystem

The device architecture for LPWA devices does not differ much from the architecture of cellular devices. As an example, the following images outline the 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) hardware 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 NB-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

5. Device ecosystem

Vodafone works with several OEMs, and we have tested and GCF certified a number of their devices some of which are identified below.

Main chipset suppliers for NB-IoT

Selection of IoT Module manufacturers

IoT Chipsets

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.

From a radio perspective, the available options offer a combination of the following:

- NB-IoT
- LTE-M
- 2G GPRS
- GSM

IoT Modules

Manufacturers of IoT modules have adopted NB-IoT as well as LTE-M. This evolution of LPWA modules has facilitated a reduction in the price, where devices used to be EUR 15 this is now less than EUR 6.

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.

From the labs in Düsseldorf we can offer IoT module certification services. For more information please visit our Professional Services website and download the IoT device test and support document which is located here:

https://www.vodafone.com/business/iot/professional-services

The GSMA also provides an overview about the announced NB-IoT and LTE-M modules here:

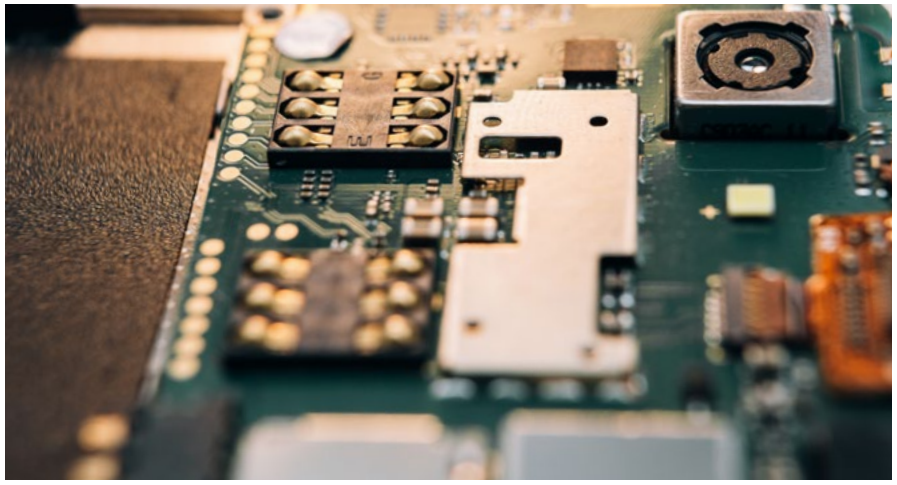
https://www.gsma.com/iot/mobile-iot-modules/

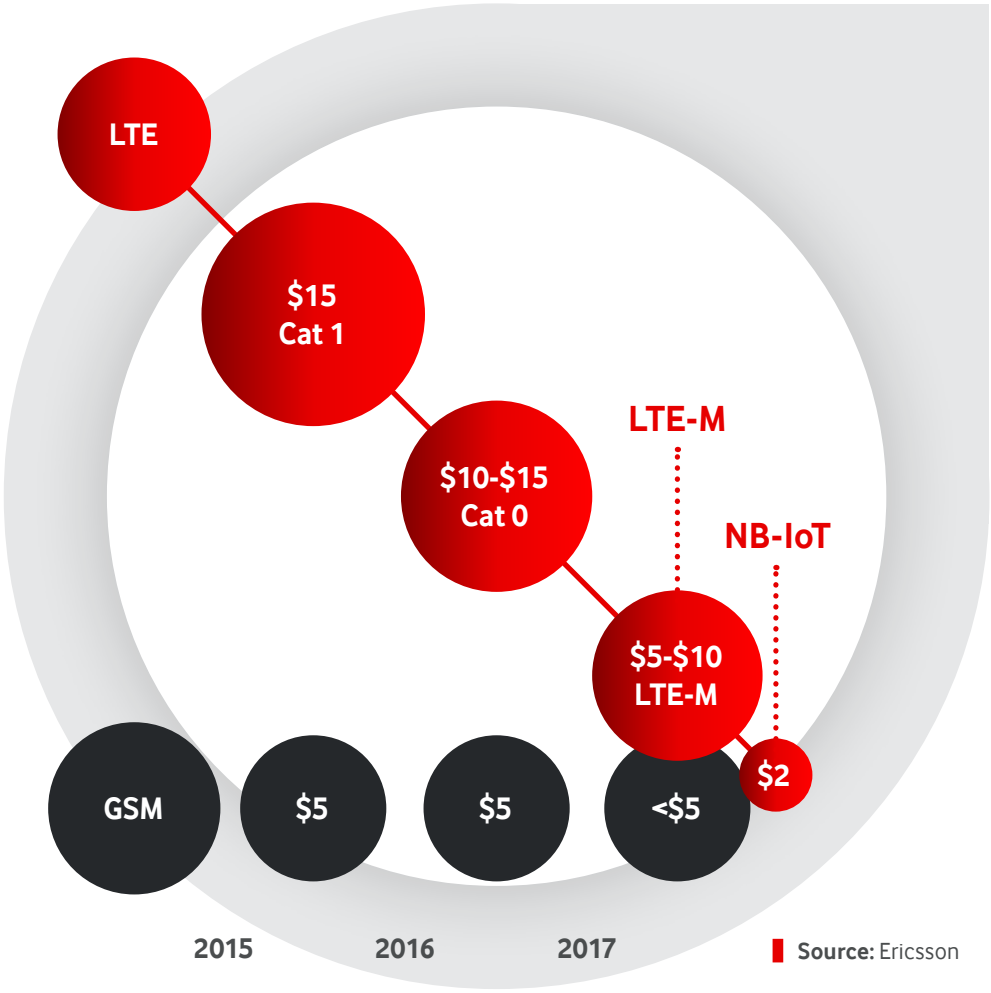
5. Device ecosystem

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

Module costs directly reduced by:

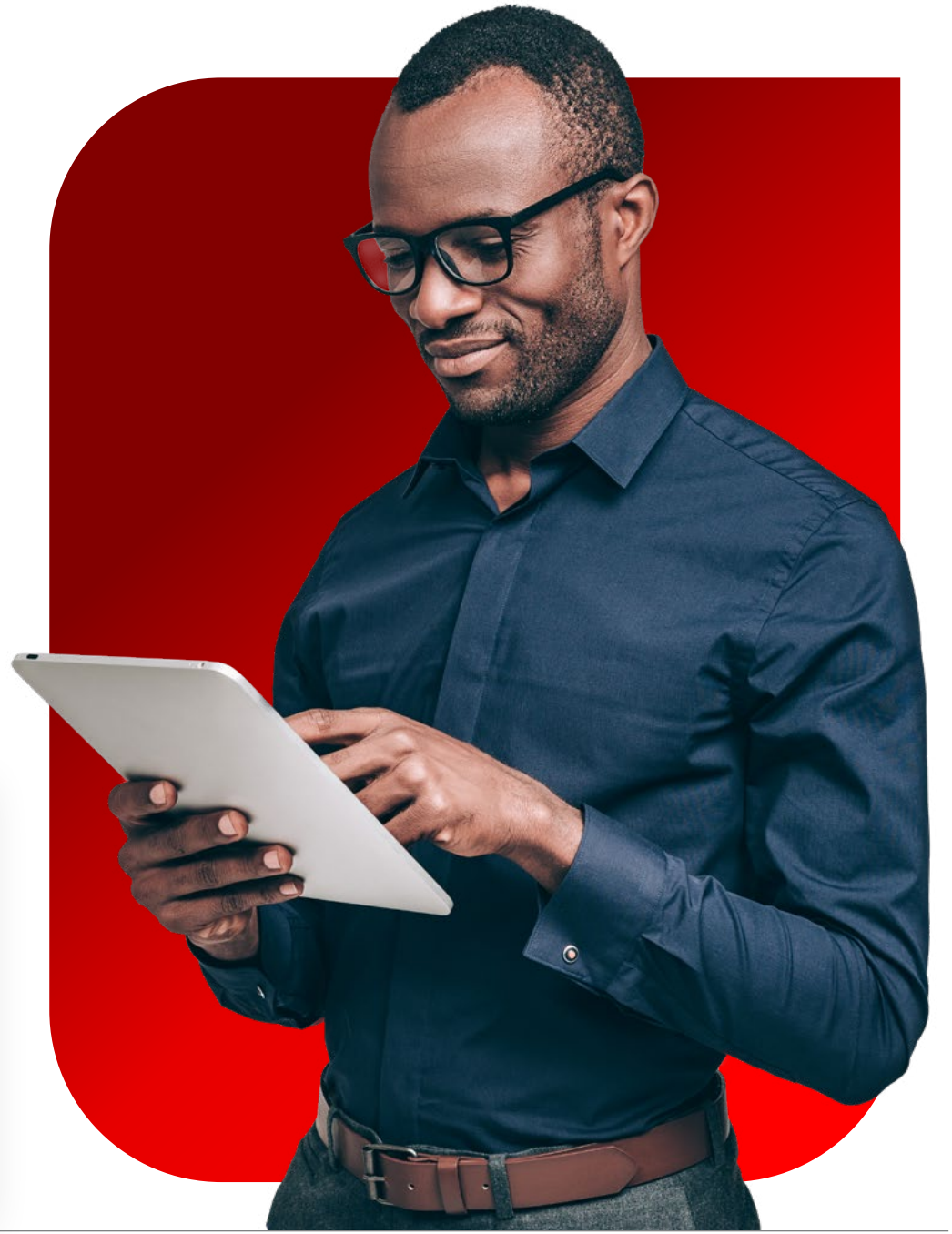
- Half duplex operation
- Single antenna
- Reduced memory requirements
- Lack of IPR floor





6. Vodafone's LPWA roadmap

We have compiled some information to provide some guidance to the plans of Vodafone Business. This information gives some granular data and is indicative and should not be seen as a commitment to deliver.



IoT Connectivity
Next generation IoT Networks LPWA

Industrialisation and expansion of footprint for NB-IoT and roaming

NB-IoT data enhancements

NB-IoT extended power savings mode enablement providing additional capabilities

LPWA roaming

LPWA roaming support based on bilateral operator agreements

Deployment Models

Commercial models

Pricing innovation to cater for more business cases

Simplified development

Work with partners and networks so customers can do development when LPWA services are deployed everywhere

Transformation

eUICC for NB-IoT

Standards-based over-the-air transformation of IMSIs for NB-IoT

Low cost solutions

LPWA integrated SIM solution providing customer cost savings

7. Deployment of LPWA

Confirmed
Preliminary

Vodafone has launched NB-IoT in a number of markets as well as LTE-M, this is through our local markets and partner markets. **Please visit https://www.vodafone.com/business/iot for the latest launches and market updates.**

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/ 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			●		●
Germany	●				

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		●		●	

8. Use cases

LPWA networks allow a wide range of opportunities, the evolved spectrum has introduced some new capabilities which allows 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 un 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 for status reporting
High volume B2C play

Parking monitoring

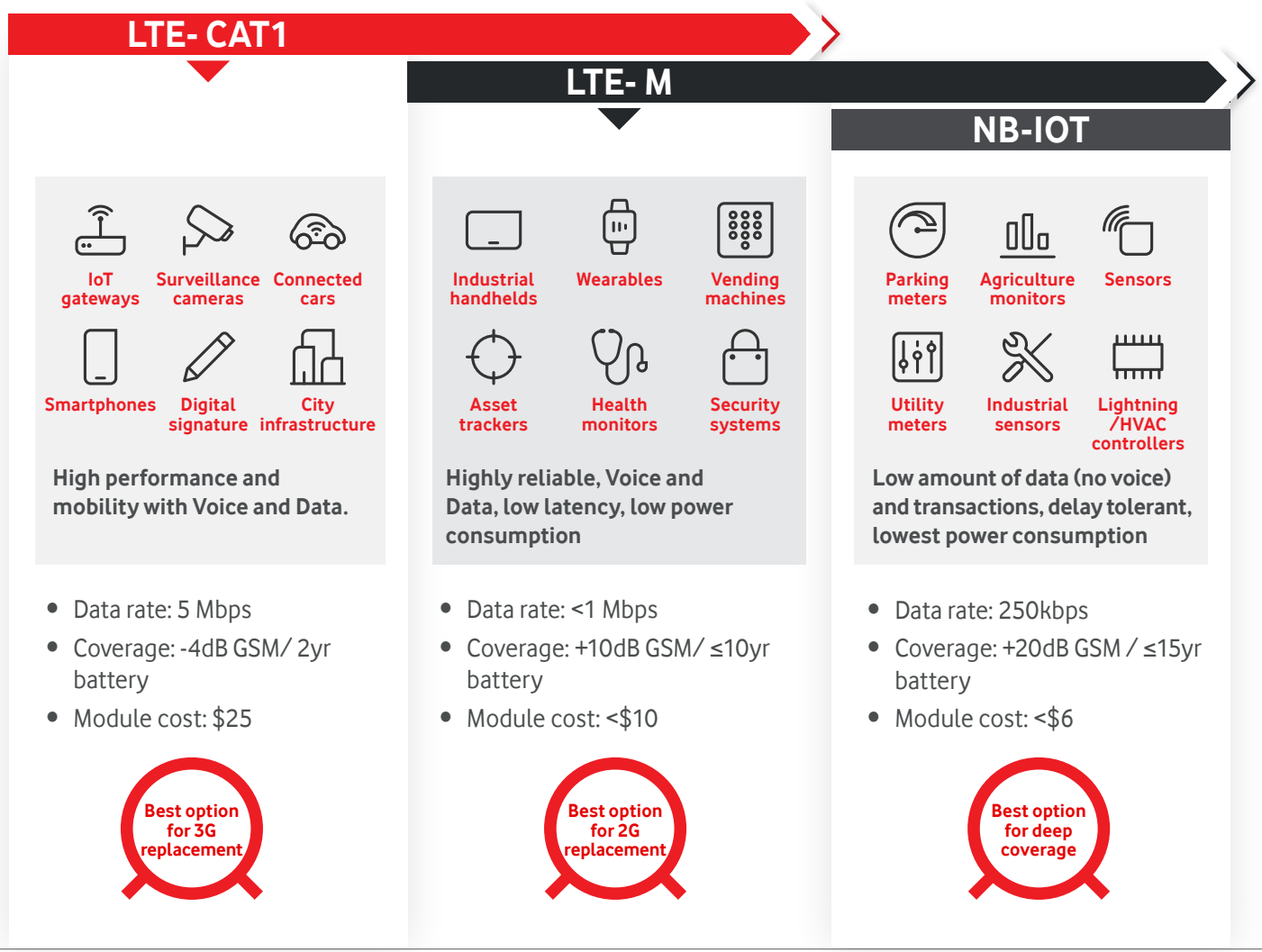
Market measured in hundreds of thousands
Battery life and low install cost are critical
Low data throughput

Alarms and event detectors

Market measured in hundreds of thousands
Battery life status reporting
Very low data throughput on check and trigger

Some of the opportunities which LPWA enable. (Suitable for non-realtime applications)

9. Summary



NB-IoT and LTE-M have evolved as technologies which 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 in some ways reduces the need for LTE-M, whereas NB-IoT with its enhanced coverage capability provides a capability that these network technologies are not able to mimic.

9. Summary

POC and trials and support

For customers who would like to trial Vodafone's NB-IoT and LTE-M networks, 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

- **3GPP** – Third Generation Partnership Program
- **CAT-M/M1** – Category Machine Type Communication (see LTE-M)
- **CAT-NB/CAT-NB1/CAT-NB2** – Category Narrowband, Narrowband Release 1, Narrowband Release 2
- **CPU** – Central Processing Unit
- **EC-GSM IoT** – Extended Coverage Global System for Mobile Communication Internet of Things
- **ECL** – Enhanced Coverage Level
- **eDRX** – extended Discontinuous Reception
- **eNodeB** – enhanced NodeB
- **eUICC** – embedded Universal Integrated Circuit Card
- **FOTA** – Firmware Over The Air
- **GSM** – Global System for Mobile Communications
- **GSMA** – Global System for Mobile Communications Association
- **IoT** – Internet of Things
- **IO** – Input / Output
- **LPWA/LPWAN** – Lower Power Wide Area/Low Power Wide Area Network
- **LTE-M** – Long Term Evolution Machine Type Communication
- **M2M** – Machine to Machine
- **MCL** – Maximum Coupling Loss
- **MTC** – Machine Type Communications
- **NB-IoT** – Narrowband Internet of Things
- **OMA LwM2M** – Open Mobile Alliance Lightweight M2M
- **PDN** – Packet Date Network
- **PDP** – Packet Data Protocol
- **PGW** – Packet Gateway
- **PSM** – Power Save Mode
- **RA/RAI** – Release Assist / Release Assist Indicator
- **SGW** – Serving Gateway

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