DEVELOPMENT GUIDE FOR

AGRICULTURE USING NB-IoT

NB-IoT

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The GSMA's Internet of Things Programme is an industry initiative focused on:

COVERAGE of machine friendly, cost effective networks to deliver global and universal benefits

CAPABILITY to capture higher value services beyond connectivity, at scale

CYBERSECURITY to enable a trusted IoT where security is embedded from the beginning, at every stage of the IoT value chainBy developing key enablers, facilitating industry collaboration and supporting network optimisation, the Internet of Things Programme is enabling consumers and businesses to harness a host of rich new services, connected by intelligent and secure mobile networks.

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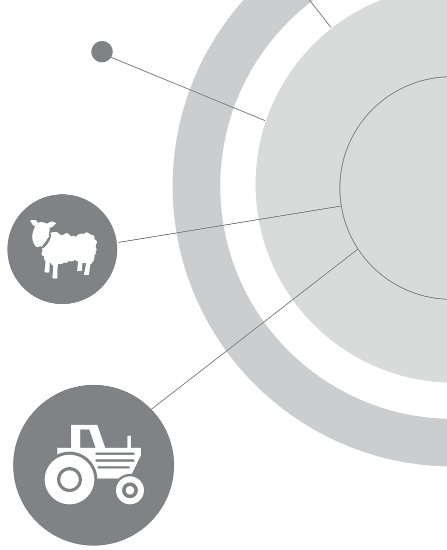
CONTENT



1. Introduction

The GSMA Internet of Things (IoT) programme helps mobile operators add value and accelerate the delivery of new connected devices and services in the IoT. The programme supports industry collaboration, appropriate regulation and the optimisation of networks, as well as developing key enablers to support the growth of the IoT in the longer term. The vision is to enable the IoT to deliver a world in which consumers and businesses enjoy rich new services, connected by an intelligent and secure mobile network.

Narrowband-Internet of Things (NB-IoT) is a standards-based low power wide area (LPWA) technology designed to enable a wide range of new IoT devices and services. NB-IoT significantly improves the power consumption of connected devices, system capacity and spectral efficiency, significantly improving coverage, compared with earlier technologies. NB-IoT can support a device battery life of more than 10 years for a wide range of use cases.

This document provides guidelines to agricultural device manufacturers on the set up and configuration of key NB-IoT features for livestock trackers, greenhouse sensors and other connected equipment.

This guide includes the features standardised in 3GPP Releases 10-13, focusing on the key features that will be deployed over the next 12 months. The features specified in 3GPP Release 14, published in the summer of 2017, are not included in this document.

Non-3GPP LPWA technologies, such as SigFox or LoRa, as well as LTE-M, are out of the scope of this document.

2. Example of Agriculture Applications

This document illustrates how agriculture applications can utilise NB-IoT by describing two examples: livestock trackers and connected greenhouse sensors. These two examples employ a good range of the capabilities provided by NB-IoT in different conditions.

2.1. Livestock Tracker

A livestock tracker is a small device used by a farmer to locate livestock, such as sheep or cows. Such applications regularly provide updates about the location of the livestock to the farmer, together with information about the device that is relevant for the provided service, such as the battery level. This document assumes that:

- The device is battery powered;
- The location information can be sent periodically at a user-defined interval or under different options/scenarios:
    - Geo-fencing: when the device leaves a pre-defined area (geo-fencing) and/or upon request by the user;
    - Chrono-fencing: the device is configured to send a status update after staying at a location for a certain pre-defined time;
    - On-demand location request: when the user (or an authorised third party) sends a request

to the tracker to update its status and position,

- The service provides the device location, which could be obtained using different technologies, such as the mobile network or a satellite-based system.

2.2. Connected Greenhouse Sensors

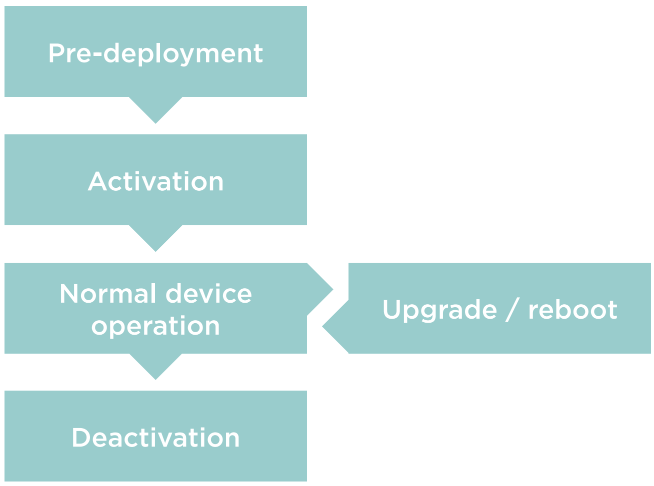
A set of NB-IoT-connected temperature and humidity sensors can accurately monitor the climate inside a greenhouse. The same architecture can be used to track the moisture and temperature levels in both the soil and the air, while also monitoring the acidity levels in water, light levels and energy consumption, among other parameters. The sensors help the grower ensure consistent conditions and increase productivity. The system provides alerts when certain parameters are breached, while also generating trend data for analysis. Note, this paper doesn't aim to describe the full functionality of these devices. The following assumptions for the system are made:

- The device is battery-powered;
- The device is in a fixed location, after installation.
- The device requires two-way communication, in order upgrade firmware and software.

3. NB-IoT in the Agriculture Application Lifecycle

This section considers the phases of the agriculture application lifecycle and describes how the features of NB-IoT can be used and what the benefits are. For further information on the features of NB-IoT see the NB-IoT Deployment Guide.

Generally, there are several phases of the lifecycle of the application and device that need to be considered, as illustrated in the graphic below.



Pre-deployment

The main purpose of this phase is to select the right module and components of the device in order to fulfil the planned service.

Before deploying the service, there are few considerations that need to be taken in account. Understanding these aspects helps to select the right communications module for the application.

- Area of deployment: country of operation, urban or rural, indoors or outdoors;
- Power supply: mains power, battery powered;
- Type of communication required: packet data or SMS;
- Amount of traffic needed;
- Operational life time of the device;
- Need to support upgrades over time;
- Security.

There are many different NB-IoT modules available commercially; some examples are listed on the GSMA website. Each module supports a set of frequency bands that are appropriate for a particular region or mobile operator. The Deployment Guide for NB-IoT provides information about the frequency bands that are required to guarantee global coverage. In addition, identifying if the device will be deployed mainly outdoors or indoors, or in an urban or rural area, will help to determine if extended coverage is required and also to select the right antenna.

For battery-powered devices, it is important to select a battery suitable for the specific application. Furthermore, to optimise the battery lifetime of the device, the solution provider needs to consider the impact of the estimated data traffic on power consumption. It is also important to consider potential device upgrades: how they will be performed and how often.

In all phases of the device life cycle, it is necessary to consider the security aspects and features necessary to provide a secure end-to-end solution: for more information see the GSMA IoT Security Guidelines.

Activation

The purpose of the activation phase is to configure the NB-IoT features appropriately. The activation phase is when the device and service are deployed and switched on for the first time, and the SIM is activated so that the device can send and receive data.

The timing of the activation of the SIM depends on the format of the SIM. For a traditional SIM, the activation is already complete at the time of purchase and the services included in the subscription will be active from the start. The SIM can be inserted into the device, which can then start to send and receive data. In the case of some bulk orders, the activation will take time, so the device will check at regular intervals if the SIM is activated.

In the case of an embedded SIM, the activation might be performed remotely and the process will differ depending on the type of remote provisioning procedure required: remote provisioning for M2M or remote provisioning for consumer. In the case of remote provisioning for M2M, the SIM will have a bootstrap profile that allows the device to obtain the connectivity needed to retrieve the operation profile from the mobile operator. As in the traditional case, the mobile operator needs to provide a profile. All procedures will be initiated by means of a SMS that will open a data channel using the bootstrap profile and download the operational profile. In the case of the remote provisioning for consumer procedure, the mobile operator also needs to provide a profile. However, as soon as the device turns on the module, it will try to contact the GSMA Root Discovery Service to see if there are any profiles waiting for it, coming from any mobile operator in the world. The device will either use a Wi-Fi connection or a connection through the mobile operator's bootstrap profile to enable this initial data transmission.

During the consultation with the selected mobile operator, the solution provider should describe the service and how the various features of NB-IoT will be employed. This will ensure that the mobile operator can provide the best advice for a dedicated service. During this phase, the APNs (access point names) that can be used for the specific profile will also be decided. Generally, APN auto configuration is sufficient for most cases.

Normal Device Operation

This phase represents the normal operation of the application, where the relevant information is exchanged between the device and the backend system in line with the intended functionality of the application. The device may also send diagnostic information about itself at regular intervals, as well as the information related to its specific purpose, such as, temperature measured.

For agriculture and aquaculture devices, sensors require periodic calibration. For example, a water dissolved oxygen sensor is usually calibrated once a month depending on the water quality and usage model, while a sensor measuring the electrical conductivity of soil will need to be calibrated every six months. This process ensures the sensor continues to provide the farmer with consistent and good quality data for automated control or analysis. During calibration, there will be no interruption to the NB-IoT connectivity since a link to the data control host is required to be able to calibrate utilising up-link and downlink data transfer. Calibration can be conducted through NB-IoT and does not need to be done in person.

Over the Air Software Upgrade

Depending on the expected lifetime of the device and whether a security vulnerability is found, there might be a need to perform an 'over-the-air' upgrade of the device's firmware or software. A device could require different types of updates, such as firmware for the module, firmware for the device itself, configuration setting, and application software. Depending on the type, the upgrade may be conducted by a module manufacturer or operator, a device manufacturer or third party, or a service provider. All upgrades need to be carefully considered and governed by a schedule based on when they normally happen and how they will be performed.

NB-IoT can support software upgrades, but the size of the upgrades and the number of upgrades required during the lifetime of the device will have an impact on devices that are battery powered. As throughput degrades at the edge of the network coverage, an upgrade at the edge of the coverage may have a major impact on battery consumption. Before performing the upgrade, the battery level of the device should be checked.

Moreover, it is good practice not to try and upgrade all devices at the same time, especially when dealing with a large number of devices. It is best to apply a throttle software update campaign that spreads the updates over a longer period, as the upgrades could affect the network capacity and therefore impact the success of the upgrade. Additionally, a re-try mechanism must also be factored in to the software update campaign.

Another best practice is to design the device software architecture in a modular way so that the software upgrade does not need to be monolithic, allowing small, targeted, software upgrades for the parts that require changes. Other points to consider are: the ability to recover, or fall-back, to the previous software version in case of a failed upgrade, and to make sure the software update mechanism is secure (see GSMA CLP.13 IoT Security Guidelines Endpoint Ecosystem, Section 7.5) to prevent a hacker injecting malware into the devices, for example.

Connection Efficiency and the Prevention of Mass Synchronised Events (e.g. Reboots)

In some circumstances, there might be a need to reboot a device. Normally, this happens after a software update, when an error or unexpected circumstances occurs, such as a wide area power cut, followed by a sudden re-connection of power.

In such scenarios, the application must be designed in a robust way to avoid looping situations or other large-scale synchronised events that can cause a signalling storm in which huge numbers of devices try to attach to the network simultaneously and, upon failure, due to network congestion, retry immediately.

Devices should not try to constantly reconnect to the network, but should follow the recommendations provided in the GSMA TS.34 IoT Device Connection Efficiency Guidelines. Adherence to these guidelines is essential for large deployments of devices.

Deactivation

This paper does not describe this phase in detail, but at the end-of-life of a device, the SIM needs to be deactivated to inform the mobile operator that no more traffic is expected from that SIM, which will help prevent any tampering.

3.1. Livestock Tracker

The following are the stages of the livestock tracker life cycle:

Pre-deployment

As indicated in section 2.1, this paper assumes:

- The device is battery powered, therefore, it is essential to use power saving mode (PSM) for reducing the battery consumption as much as possible. Given that most of the communication is from the device, PSM is absolutely an essential feature.
- Tracking location will require the device to connect regularly to the network. Update requests from the user could be transmitted using the different transport mechanisms provided by NB-IoT.
- There is a requirement for device firmware, software upgrades and other device management functionality, possibly by leveraging existing protocols, such as OMA LwM2M, CoAP, OneM2M or MQTT-sn.

The paper also assumes:

- The solution could be deployed worldwide, meaning it will need to use a NB-IoT module that supports a number of frequency bands for different regions.
- Packet data transmissions are used to send application-specific information and for performing upgrades.
- SMS is used, in cases where it is supported by the mobile operator and by its roaming partners
- The device will connect to the network with a predictable traffic pattern, while firmware and software updates should utilise the scheduled connection. However, in some cases the request to provide a location update will be prompted outside of the regular updates.

Activation

At this stage, the solution provider needs to select the appropriate subscription for the service and activate the SIM as indicated in the previous section.

Normal device operation

Now the device is active, it can start to use the NB-IoT features as intended. For example, in cases where the livestock roams outside of the geo-fenced area, the system can notify the farmer. The device will also report the location information at the scheduled interval, the system then decides how to contact the famer based on the service configuration. For example, the farmer could receive an SMS or they could receive notification on a dedicated application in the smartphone.

Over the Air Software Upgrade, Connection Efficiency and the Prevention of Mass Synchronised Events

These phases are sufficiently described in the introduction to section 3.

3.2. Connected Greenhouse Sensors

The following are the stages of the connected greenhouse life cycle:

Pre-deployment

As indicated in section 2.2, this paper makes the following assumptions:

- The device is battery powered, so it is essential to use both PSM and eDRX (extended discontinuous reception) to reduce the power consumption as much as possible. eDRX is needed because the device acts as an actuator.
- There is a requirement for device firmware, software upgrades and other device management functionality, possibly by leveraging existing protocols, such as OMA LwM2M, CoAP, OneM2M or MQTT-sn.
- The sensors will require periodic calibration.

The paper also assumes:

- The solution could be deployed worldwide, meaning it will need to use a NB-IoT module that covers a number of frequency bands for different regions.
- Packet data transmissions are used to send application-specific information and for performing upgrades.
- SMS is used, in cases where it is supported by the mobile operator and by its roaming partners
- The device will connect to the network with a predictable traffic pattern, while firmware and software updates should utilise the scheduled connection. However, in some cases, the request to provide a location update will be prompted outside of the regular updates.

Activation

At this stage, the solution provider needs to select the appropriate subscription for the service and activate the SIM as indicated in the previous section.

Normal device operation

Now the device is active, it can start to use the NB-IoT features as intended. In this specific case, the device will already have selected the timers for PSM and eDRX. It will start the cycles as defined in the settings.

Over the Air Software Upgrade, Connection Efficiency and the Prevention of Mass Synchronised Events

These phases are sufficiently described in the introduction to section 3.

4. NB-IoT Features for 'Agriculture Applications'

The following section provides an overview of the various features that are available in the NB-IoT networks that are live today

4.1. Coverage and Connectivity

As NB-IoT networks were first deployed in February 2017, coverage varies from country to country and from mobile operator to mobile operator. Therefore, it is important to check the coverage in the areas of interest. Note, that the 3GPP standard encompasses both the uplink (data sent from the device to the network) and the downlink (data sent from the network to the device).

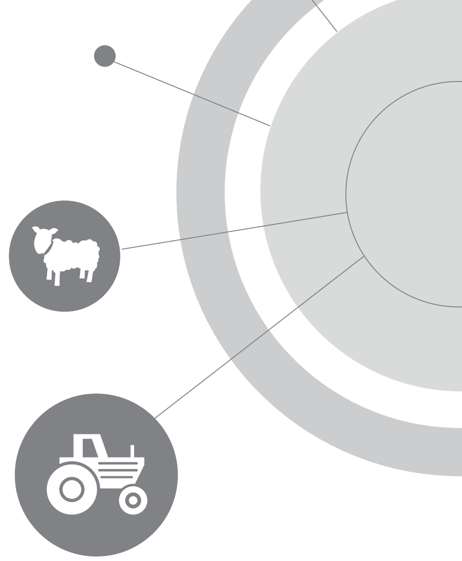
NB-IoT offers various ways to set up a connection to and from the device:

- For packet data communication, it sets up either a control plane or a user plane.
- Alternatively, for transmitting small amounts of data, SMS can be used.

Both mechanisms, which are also supported in conventional LTE, can open a communication either from or to the device. The way to set up and use these features is broadly the same as with LTE, but some small aspects are particular to NB-IoT. Although most of the current modules in the market for NB-IoT do not support the user plane option, NB-IoT can transmit small amounts of data directly in the control plane. As indicated in the NB-IoT Deployment Guide, the recommended option is to transmit IP traffic over the control plane, particularly for devices that are battery powered.

To set up a data connection through the control plane it is necessary to set up the appropriate APN, which enables a connection to the right IP address. Mobile operators might have a generic APN for NB-IoT or they might provide a dedicated APN upon request to enable a secure end-to-end channel for their customer though a virtual private network (a VPN). The mobile operator will provide the right settings for the APN.

Generally, traditional M2M applications, which run on GPRS, only use SMS for collecting data from the devices. However, SMS has some constraints: higher power consumption and limits of 140 bytes for the payload. The selection of the best connection type to minimise the signalling overhead will be governed by the application's payload raw data size and upload frequency. For data below 100 bytes, SMS might be more efficient, but not for a higher amount of data. For applications that are sensitive to power consumption, it is advisable to use the user datagram protocol (UDP) over the control plane, rather than SMS. The NB-IoT Deployment Guide makes no particular recommendation on supporting SMS, since only a few operators are planning to provide SMS capabilities for NB-IoT. Therefore, porting existing applications that rely on SMS might not work properly in NB-IoT: such applications should be re-designed to fully use the capabilities and performance advantage of NB-IoT.



4.1.1. Support Coverage Extension

The NB-IoT standard supports three coverage extension modes that have been defined in 3GPP. These are: Normal Coverage (Coverage Extension Level 0 for 0dB), Robust Coverage (Coverage Extension Level1 up to 10dB) and Extreme Coverage (Coverage Extension 2 up 20dB).

Some IoT applications require devices to be positioned in areas that are not readily accessible by radio coverage, such as grazing areas for livestock and uninhabited areas used for greenhouses. The 3GPP Enhanced Coverage features is an integral characteristic of NB-IoT, as it increases the depth of radio coverage to enable IoT devices to operate in locations that would otherwise not be possible.

The Enhanced Coverages feature increases the power levels of signalling channels together with the ability to repeat transmissions. Repeated transmission improves the ability of receivers to correctly resolve the message sent, but also increases the latency and the power consumption.

The trade-off is that repeating signal transmissions consumes additional power and the time between battery recharges or replacements may be reduced. Therefore, it is important to consider the choice of battery for a device, if the coverage extension feature is required.

4.1.2. Power classes and duplex mode

There are two power classes available for NB-IoT modules: class 3 (23 dBm) and class 5 (20dBm). Class 3 is slightly more demanding in terms of power consumption, but it provides higher performance. Since it is the same power class as conventional LTE, it is also widely supported by NB-IoT modules. All mobile operators support power class 3, as per the NB-IoT Deployment Guide.

NB-IoT only supports operations in half-duplex mode (HDD). In half-duplex operation, the device alternates between transmission and reception. Devices that support half-duplex operation are associated with a lower peak rate compared to devices that support full-duplex operation. Also note, single-tone option modules have lower peak rates compared to multi-tone option modules, but perform better in terms of extreme coverage.

4.1.3. Managing software updates

There are two main ways to upgrade firmware/software or reboot a device: Utilise a connection that is already established by the device or set up an ad-hoc connection by sending an SMS with the request to start an IP connection. In the first case, the network can indicate to the device to keep the connection open since there is some data to be sent to the device. The second case is only possible if the mobile operator supports SMS and the SMS will be only sent when the device reconnects to the network, in any case. Mobile operators may store the requested SMS for some time, but if the PSM cycle is very long, there is no guarantee that the SMS will be sent.

As the device management features offered by each individual mobile operator may vary, the solution provider should check with the selected mobile operator on what is available.

4.1.4. Security

Developing new and innovative services for particular market segments may open up new security threats. If adversaries understand the technology and security weaknesses, they can quickly take advantage if vulnerabilities are exposed. There have been many security attacks that resulted in compromised devices, which may then infiltrate data, attack other devices, or cause disruption for related or unrelated services. To help ensure that the new IoT services coming to the market are secure, mobile operators, together with their network, service and device equipment partners, are seeking to share their security expertise with service providers who are looking to develop IoT services.

The GSMA has, therefore, created a set of security guidelines for the benefit of service providers who are looking to develop new IoT services. The complete GSMA IoT Security Guidelines are available here.

4.1.5. Mode Mobility

Mode mobility is not a supported feature of NB-IoT: only cell reselection is supported. Therefore, if a device loses connection to a cell, the device will need to request connectivity again – this is the case with all mobile operators deploying NB-IoT networks.

4.1.6. Deployment Bands

The solution provider needs to ensure that their modules support the frequency bands used for NB-IoT by operators in the area where the device will be deployed, taking into account dual-mode modules. Further details can be found in the NB-IoT Deployment Guide.

4.2. Power Consumption (PSM (Power Save Mode) and eDRX (Extended Discontinuous Reception)

Power saving mode (PSM) is a feature designed for IoT devices to help them to reduce power consumption and potentially achieve a 10-year battery life. This capability enables devices to enter a deep sleep mode. PSM is intended for devices designed for infrequent data transmission and that can accept a corresponding latency in the mobile terminating communication. The device decides how often and for how long it needs to be active in order to transmit and receive data. As timers also need to be agreed by the network, in most cases, the timers are negotiated between the device and the network. In general, as recommended in the NB-IoT Deployment Guide, mobile operators will accept the timer requested by the device. PSM mode is similar to power-off, but the device remains registered with the network. When the device becomes active again there is no need to re-attach or re-establish PDN (packet data network) connections. The device requests the PSM simply by including a timer with the desired value in the attach, tracking area update (TAU) or routing area update. The maximum value for the time is ~413 days.

Extended discontinuous reception (eDRX) is an extension of an existing LTE feature, which can be used by IoT devices to reduce power consumption. eDRX can be used without PSM or in conjunction with PSM to obtain additional power savings. It allows the device to turn part of its circuitry off during the eDRX period to save power. During the eDRX, the device is not listening for paging or downlink control channels, so the network should not try to contact the device. For eDRX, the networks and devices negotiate the timer for when devices can sleep. eDRX can be applied in both idle and connected mode. When the device wakes up, the receiver will listen for the physical control channel. For eDRX, there are a pre-defined set of timers that can be used for NB-IoT:

eDRX cycle length for NB-IoT (in seconds)
20.48 seconds
40.96 seconds
81.92 seconds (~1 minute)
163.84 seconds (~ 3 min)
327.68 seconds (~ 5 min)
655.36 seconds (~ 11 min)
1310.72 seconds (~22 min)
2621.44 seconds (~44 min)
5242.88 seconds (~87 min)
10485.76 seconds (~175 min)

4.3. Location

There are two main mechanisms to obtain device location information:

- Provided by the device itself;
- Provided by the mobile network.

For livestock trackers, which require quite accurate positioning information (in the range of a few metres), it is recommended to utilise mechanisms directly in the device. The most common way to obtain accurate information is to use the global navigation satellite system (GNSS). Most of the major manufacturers provide NB-IoT modules with embedded GNSS modules for positioning provided by satellite systems, such as GPS, GLONASS, and Galileo. As GNSS modules consume more power than mobile transmission over NB-IoT, it is important to understand the impact of using GNSS on devices that are battery powered. However, new GNSS modules are much more power efficient than their predecessors. GNSS only works for outdoor scenarios, while for indoor scenarios, other methods, such as the use of beacons, are required.

Alternatively, for trackers that do not require high position accuracy, using mobile network location services could be a better option from a power consumption point of view. The level of accuracy available from mobile operators may differ, based on their network ability. The basic and default feature supported by NB-IoT is Cell-ID, which indicates the cell where the device is attached. This feature is only available for devices connected to the network of the mobile operator and not when the device is roaming on another operator's network. As well as reducing power consumption, using the mobile network to provide position information helps to reduce the risk of tampering.

5. Definitions

Term	Description
IoT	The Internet of Things is a generic term for the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment. The IoT offers functions and services that go beyond the scope of pure M2M
M2M	Machine-to-Machine is a general term referring to any network technology allowing devices, other than phones and laptops, to communicate with each other. For example two industrial robots connected to each other via Ethernet in a factory is a part of M2M, but not MIoT.
Mobile IoT	Mobile Internet of Things is a GSMA term for 3GPP-standardised low power wide area technologies using licensed spectrum (aka LTE-M and NB-IoT). From 3GPP Release 13 and the following releases, the category of user equipment that supports power consumption optimisations, extended coverage and lower complexity are part of Mobile IoT (CAT M1, CAT NB1 from Release 13 and CAT M2, CAT NB2 from Release 14). As this particular term, is widely used throughout the GSMA, it is also used in this document. Not to be confused with the term “mIoT” which means 5G massive IoT in 3GPP terminology.
NB-IoT	Narrowband IoT (NB-IoT) is a new 3GPP radio technology standard that addresses the requirements of the IoT. The technology provides improved indoor coverage, supports a massive number of low throughput devices, low delay sensitivity, ultra-low device cost, low device power consumption and an optimised network architecture. The technology can be deployed “in-band”, utilising resource blocks within a normal LTE carrier, or in the unused resource blocks within a LTE carrier’s guard-band, or “standalone” for deployments in dedicated spectrum

6. Abbreviations

Term	Description
3GPP	3rd Generation Partnership Project
API	Application Programming Interface
AS	Application Server
BS	Base Station
BTS	Base Transceiver Station
Cat M1	Category Machine 1
CDF	Charging Data Function
CGF	Charging Gateway Function
CIoT	Cellular Internet of Things
CMM	Connected Mode Mobility
dB	Decibel
DRX	Discontinuous Reception
A-GNSS	Assisted GNSS
E-CID	Enhanced Cell ID
DL	Downlink
eDRX	Extended Discontinuous Reception
eNB	Evolved Node B
EPS	Evolved Packet System
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile Communications
GSMA	GSM Association
GTP	GPRS Tunnelling Protocol
HLCom	High Latency Communication
HPLMN	Home Public Land Mobile Network
HSS	Home Subscriber Server
IoT	Internet of Things
IP	Internet Protocol
IP-SM-GW	Internet Protocol Short Message Gateway
IPX	Internetwork Packet Exchange
IWF	Interworking Function

Term	Description
IWK-SCEF	Interworking Service Capabilities Exposure Function
LPWA	Low Power Wide Area
LTE	Long-Term Evolution
M2M	Machine-to-Machine.
MIoT	Mobile Internet of Things
MME	Mobile Management Entity
MOBILE OPERATOR	Mobile Network Operator
MSC	Mobile Switching Centre
MTC	Machine Type Communications
NB-IoT	Narrowband IoT
OTDOA	Observed Time Difference Of Arrival
PGW	Packet Gateway
PRB	Physical Resource Block
PSM	Power Saving Mode
RAN	Radio Access Network
SCEF	Service Capabilities Exposure Function
SCS	Services Capabilities Server
SGSN	Serving GPRS Support Node
SGW	Serving Gateway
SIM	Subscriber Identity Module
SMS	Short Message Service
SMS SC	Short Message Service Centre
TAU	Tracking Area Updating
UDP	User Datagram Protocol
UE	User Equipment (User Device)
UICC	Universal Integrated Circuit Card (sometimes known as the SIM card)
UL	Uplink
VPLMN	Visited Public Land Mobile Network