NB-IOT DEPLOYMENT GUIDE TO BASIC FEATURE SET REQUIREMENTS

JUNE 2019

NB-IoT Deployment Guide to Basic Feature set Requirements

This is a White Paper of the GSMA

SECURITY CLASSIFICATION: NON-CONFIDENTIAL

COPYRIGHT NOTICE

DISCLAIMER

ANTITRUST NOTICE

Table of Contents

1 Executive Summary

NB-IoT is a new cellular radio access technology specified by 3GPP in Release 13, Release 14 and Release 15 to address the fast-expanding market for low power wide area connectivity. To achieve global coverage and wide adoption of NB-IoT services, MNOs (mobile network operator) must ensure that devices and end-to-end services from various providers will connect to the NB-IoT systems that have been deployed, and that the data transport capability and connection modes are well understood.

This document contains non-binding guidelines designed to help mobile operators deploying NB-IoT networks and devices globally to ensure interoperability and smooth roaming. It identifies a minimum set of key features, details key configurations and considerations for deployments. The recommendations have been developed by the members of the GSMA NB-IoT Forum, based on the survey inputs provided to the GSMA by 15 mobile operators who are deploying NB-IoT networks in over 40 markets, which include Europe, the Middle East, Africa, South America and Asia-Pacific (APAC).

The following guidelines have been set out in this guide:

- According to the survey, ten bands: 1, 2, 3, 4, 5, 8, 12, 20, 26 and 28 are required for coverage in all markets for which the NB-IoT members have provided input
- The deployment of the following features is included in the key minimum requirements to achieve a balance of roaming service continuity and power optimisation:
    - PSM (Power Save Mode)
    - eDRX (Extended Discontinuous Reception)
    - Paging
    - Cell Reselection
    - Support for extended coverage
    - Power class
    - Rate control mechanisms
    - Home Subscriber Server
    - Multi Frequency Band
- SMS (Short Message Service) and SCEF has not been included among the key minimum features in this edition, although considerations for both features have been provided.

The GSMA plans to update this Deployment Guide after publication, to provide further specific recommendations once mobile network operators have gained more NB-IoT deployment experience.

2 Introduction

2.1 OVERVIEW

NB-IoT is a new cellular radio access technology specified by 3GPP in Release 13, Release 14 and Release 15 to address the fast-expanding market for low power wide area connectivity. The mobile industry is now establishing NB-IoT as a global coverage solution that enables customers, such as application service providers, to deploy and operate their services worldwide. This paper is a guide for the setup of NB-IoT networks and devices, detailing key configurations and considerations for deployments.

The recommendations provided in this document are based on the input and deployment plans shared by operator members of the Mobile IoT Initiative, which are either planning to launch or have already launched a NB-IoT network, in over 50 markets in Europe, Middle East and Africa, South America and APAC, including Japan, China and South Korea.

2.2 SCOPE

This guide provides an overview of the existing deployment plans for key features of NB-IoT. It also sets out guidelines for mobile network operators and application service providers on the set up and configurations of key NB-IoT features and spectrum bands. These are designed to help mobile network operators and service providers deploying NB-IoT networks and devices globally to ensure smooth interoperability and roaming.

This guide includes the features standardised in 3GPP Releases 13-15. Out of scope are non-3GPP LPWA technologies, such as SigFox or LoRa. The LTE-M technology has been covered in the LTE-M Deployment Guide.

2.3 DEFINITIONS

TERM	DESCRIPTION
IoT	Internet of Things, 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. IoT offers functions and services, which go beyond the scope of M2M. MIoT is a subset of the broader IoT concept, for example, a group of sensors connected together via Wi-Fi or Bluetooth are part of IoT, but not MIoT.
M2M	Machine-to-Machine, a general term referring to any network technology enabling devices to communicate with each other. For example, two industrial robots connected to each other via Ethernet in a factory could be described as M2M, but not MIoT.
MIoT	Mobile Internet of Things, a GSMA term that refers to the 3GPP standardised low power wide area technologies using licenced spectrum bands (aka LTE-M, NB-IoT and EC-GSM-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 MIoT (Category M1, Category 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 utilised in this document. It should not 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 Internet of Things (IoT). The technology provides improved indoor coverage, support of massive number of low throughput devices, low delay sensitivity, ultra-low device cost, low device power consumption and 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.

2.4 ABBREVIATIONS

TERM	DESCRIPTION
3GPP	3rd Generation Partnership Project
API	Application Programming Interface
AS	Application Server
BS	Base Station
BTS	Base Transceiver Station

2.4 ABBREVIATIONS

TERM	DESCRIPTION
CDF	Charging Data Function
CGF	Charging Gateway Function
CIoT	Cellular Internet of Things
CMM	Connected Mode Mobility
dB	Decibel
DRX	Discontinuous Reception
DL	Downlink
eDRX	Extended Discontinuous Reception
eNB	Evolved Node B
EPS	Evolved Packet System
FOTA	Firmware Over The Air
GSM	Global System for Mobile Communications
GSMA	GSM Association
GTP	GPRS Tunnelling Protocol
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
IWK-SCEF	InterWorking Service Capabilities Exposure Function
LPWA	Low Power Wide Area

2.4 ABBREVIATIONS

TERM	DESCRIPTION
LTE	Long-Term Evolution
LTE-M	Long-Term Evolution Machine Type Communications
LTE MTC	Long-Term Evolution Machine Type Communications
M2M	Machine-to-Machine.
MFBI	Multi Frequency Band Indicator
MIoT	Mobile Internet of Things
MME	Mobile Management Entity
MNO	Mobile Network Operator
MO	Mobile Originated
MSC	Mobile Switching Centre
MT	Mobile Terminated
MTC	Machine Type Communications
NB-IoT	Narrowband IoT
O&M	Operation and Maintenance
OTA	Over The Air
PDN	Packet Data Network
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

2.4 ABBREVIATIONS

TERM	DESCRIPTION
SGW	Serving Gateway
SI	System Information
SIM	Subscriber Identity Module
SMS SC	Short Message Service Centre
TAU	Tracking Area Updating
TCP	Transmission Control Protocol
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

2.5 REFERENCES

REF	REF DOC NUMBER	TITLE
[1]	IOTTF07_DOC004	MIoT Roaming Whitepaper Draft. GSMA NG working group
[2]	3GPP TS 23.682	TS 23.682 (clause 4.5.4): Architecture enhancements to facilitate communications with packet data networks and applications
[3]	3GPP TS 24.008	Mobile radio interface Layer 3 specification; Core network protocols; Stage 3
[4]	3GPP TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3

REF	REF DOC NUMBER	TITLE
[5]	3GPP TS 23.401	General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access
[6]	3GPP TS 36.201	Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description
[7]	3GPP TS 36.307	Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements on User Equipment's (UEs) supporting a release-independent frequency band
[8]	3GPP TS 36.331	Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification
[9]	3GPP TS 36.101	Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception
[10]	3GPP TS 29.272	Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol
[11]	3GPP TS 29.212	Policy and Charging Control (PCC); Reference points

3 GSMA Minimum Baseline for NB-IoT Roaming and Interconnect

3.1 PROBLEM STATEMENT

NB-IoT is a new technology that has been specified and standardised in a very short timeframe, in response to customer requirements and emerging competition from non-3GPP proprietary technologies.

The Mobile IoT Initiative is accelerating the development of the NB-IoT ecosystem, specifically supporting MNOs, equipment vendors and developer cooperation at the industry level, as per the GSMA's remit.

NB-IoT is now estabilished as a global coverage solution that enables application service providers to deploy and operate their solutions worldwide in a smooth and predictable manner. There have now been more than 80 NB-IoT Networks deployed commercially in over 45 markets. Further details of these launches can be found here.

MNOs must continue to ensure that devices and end-to-end services from various providers will connect to the NB-IoT systems that have been deployed, and that the data transport capability and connection modes are well understood. Individual MNOs will have their own internal processes to ensure that their devices will connect to their systems. MNOs and partners will also establish roaming agreements to expand and improve coverage and connectivity capability. However, beyond business as usual, high-level co-ordination at this stage would accelerate the realisation of the wider benefits of common standards and predictable interconnect. High-level coordination can also help ensure that MNOs' forthcoming decisions relating to deployment architectures are better informed and make the enablement of device interconnect and roaming more straightforward.

Moreover, high-level coordination will help ensure that NB-IoT RAN technology and devices meet the requirements that have shaped the technology's development, to the benefit of both application service providers and MNOs. For example, many NB-IoT devices will need to be low cost to meet the needs of MNOs' customers. One way to lower costs is to limit the number of spectrum bands that will be supported by a particular device. Therefore, customers need to know which bands have been used to deploy NB-IoT by MNOs in territories where they intend to operate. To this end, MNOs can provide details of the bands in which they have deployed, or intend to deploy, NB-IoT carriers.

The same knowledge can be valuable for MNOs that have yet to decide on their NB-IoT deployment band, where there is the scope for flexibility. In geographies where international roaming traffic is likely to be significant, an MNO may decide to align their deployment band with MNOs in adjacent or nearby territories. Such an approach would benefit application service providers deploying NB-IoT-enabled devices. They may wish to deploy their devices across national boundaries, served by a local MNO in each territory. Knowing which approach to deployment and service provision a MNO has taken will help the application service provider to select the best MNO for seamless deployment.

The mobile industry and its customers benefit from the ability for devices to roam and to interconnect to all mobile networks. As it is only feasible for NB-IoT devices to support a limited number of bands and protocols, the industry should not make assumptions based on previous experience, which may not prove to be applicable in this case.

This guide builds up a picture of global deployment architectures, from the roaming and interconnect perspective, to realise the benefits that are available through the development and deployment of a global telecommunications standard.

3.2 MINIMUM DEPLOYMENT FEATURE SET REQUIREMENTS: RISKS AND BENEFITS

The setup of NB-IoT data architecture and key features can affect the performance of a NB-IoT device, its cost and even its ability to roam. Below are some examples of the impact of different feature set-up on NB-IoT device performance:

- If PSM and eDRX timers were set differently in different networks, device and service behaviour would change, impacting their responsiveness to backend-originated commands and the longevity of the battery.
- If some (optional) NB-IoT features are not enabled, there could be negative implications for end-to-end security.
- When a device is set up with Control Plane/SCEF configuration and roams on to a different network that has no connectivity to the visitor's SCEF, it will not be able to communicate with its application server using SCEF-based communication. It may be necessary for the device to use P-GW-based communication to establish communication.
- Roaming devices might need to be certified for all bands, which will have potentially significant cost implications.

Since many chipsets support both NB-IoT and LTE-M, application logic should be as constant as possible regardless of which RAN is used. From the IoT developer perspective, these radios need to work the same way, i.e., if possible, have the same minimum feature sets available. Ideally, the "write once, run in any network" rule should be applied, to avoid adapting the actual application to account for a device switching between NB-IoT and LTE-M, for example, when roaming across Europe.

4 NB-IoT Data Architecture

Figure 1 below provides an overview of the architecture for NB-IoT in a roaming scenario:

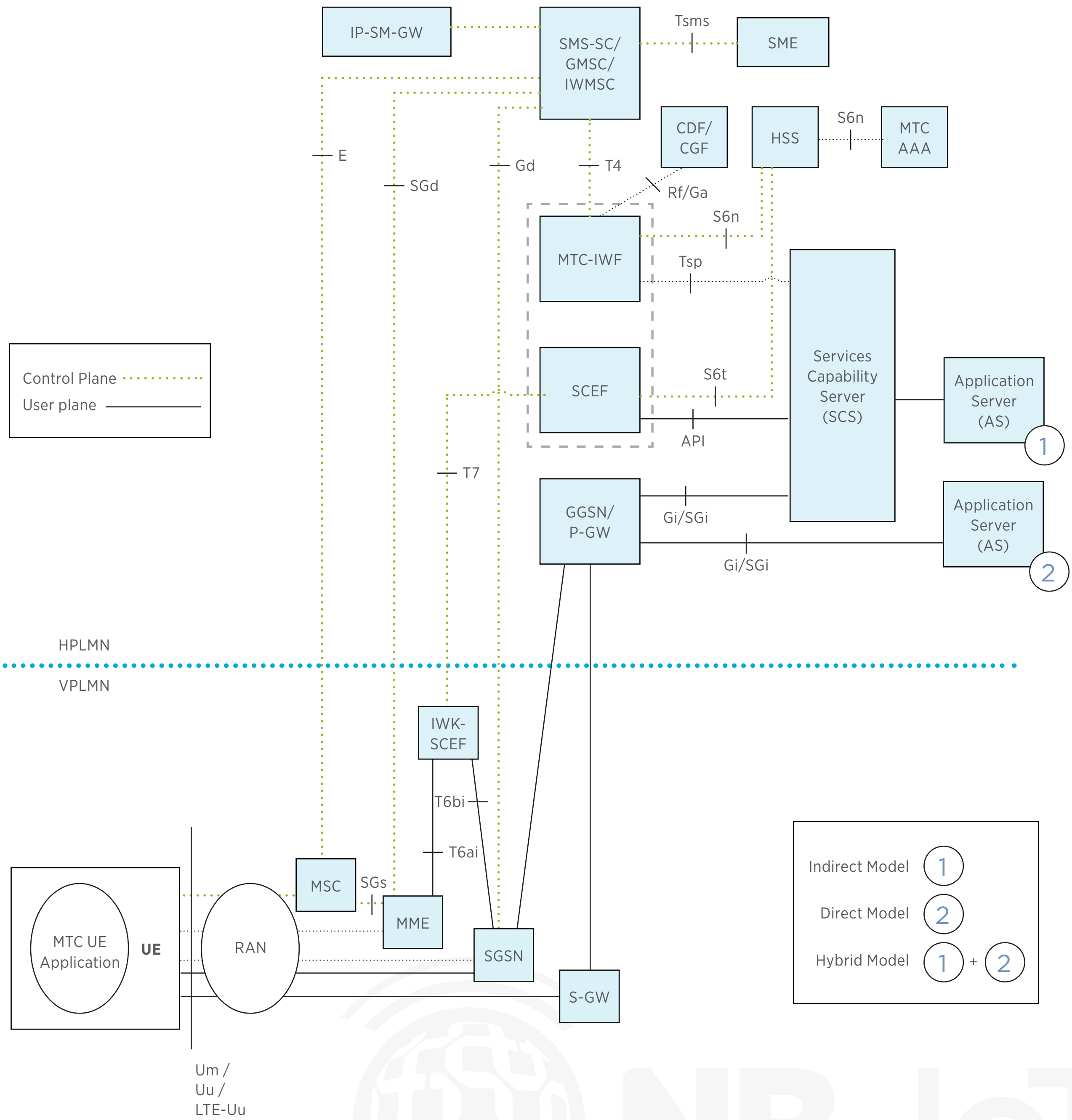

Figure 1: 3GPP Architecture for Machine Type Communication (NB-IoT and LTE-M Roaming)

According to 3GPP specifications, there are two main Network Attach options to support connectivity:

1. Attach with PDN (Packet Data Network) connection: the UE (User Equipment) is required to establish the PDN connection as part of the attach procedure. This has been the case for all 3GPP EPS (Evolved Packet System) releases up to Rel-13.

2. Attach without PDN connection: this is a new capability that has been introduced in Rel-13 to allow UEs supporting CIoT (Cellular Internet of Things) optimisations to remain attached without PDN connection, which may be useful for cases where huge numbers of devices would keep a connection inactive for very long period of time and seldom transmit data over it. When a UE is attached without PDN connection, only SMS service is available for any data transmissions and applications are constrained

There are different data connectivity options for PDN connections available to IoT devices using the EPS:

- IP over Control Plane (both UDP (User Datagram Protocol) and TCP (Transmission Control Protocol), from 3GPP Rel-13 using the Control Plane CIoT EPS optimisation with IP PDN types
- IP over User Plane (both UDP and TCP), including User Plane Optimisation and User Plane Original,available since Rel-8 with IP PDN types
- Non-IP over Control Plane, from 3GPP Rel-13 using the Control Plane CIoT EPS optimisation with Non-IP PDN type
- Non-IP over User Plan, including User Plane Optimisation and User Plane Original,from 3GPP Rel-13 using the User Plane CIoT EPS optimisation with Non-IP PDN type

The device (in accordance with PSM, eDRX) will allow transmission of data in both directions. However, there is also the option to request the device to set up ad-hoc connections (not scheduled by PSM, eDRX) by means of triggering the device either via the interface Tsms or Tsp.

Each of these options has advantages and disadvantages. The traditional mechanism for transporting information over LTE is by means of IP over User Plane (most commonly TCP) and SMS.

Control Plane CIoT EPS Optimisation transports user data or SMS messages via MME by encapsulating them in NAS (Non-Access-Stratum), and reduces the total number of control plane messages when handling a short data transaction.

For services that occasionally transmit reasonably small amounts of data, the utilisation of the Control Plane will optimise the power consumption because the amount of signalling required and the “air time” is reduced. Power consumption can be optimised using non-IP, UDP and TCP. Non-IP allows for the use of protocols that have been optimised for a specific use. UDP is asynchronous, which reduces the time of the connection, while TCP will keep the connection open until an acknowledgment is received. However, supporting a network-originated UDP connection might require the use of either a virtual private network (VPN) or IPv6 due to the need to specifically address the device from the server network.

The services that need to send more information could benefit from User Plane connection, which can be used to send multiple packages. Overall, this approach might consume less power than sending multiple messages over the Control Plane. On the other hand, using non-IP over the User Plane might be unrealistic simply because the benefits of using efficient protocols are nullified by using a user plane connection.

In the case of non-IP communication over the Control Plane, the MNO has two options, either through the PGW (Packet Gateway) (requiring support for the SGi interface to the application server) or by utilising SCEF. For the latter case, the visited network will direct the message to the IWF (Interworking Function) -SCEF that will connect to the SCEF of the home network (via the new T7 interface in Figure 1).

RECOMMENDATIONS

MNOs should consider supporting IP traffic over Control Plane as a minimum requirement to start supporting roaming. This option is the best solution for supporting devices that need to consume as little power as possible. This means that all modules should also support IP/Control Plane.

At this stage, there is no clear consensus about supporting Non-IP traffic. However if Non-IP traffic is supported, the deployment should start by utilising the SGi interface and later on by SCEF, when the appropriate APIs are defined by 3GPP.

5 NB-IoT Deployment Bands

3GPP has defined a set of frequency bands for which NB-IoT can be used. 3GPP TS 36.101 [9] from Release 13 provides the list of the supported bands: 1, 2, 3, 5, 8, 12, 13, 17, 18, 19, 20, 26, 28, 66 and Release 14 added the bands: 11, 25, 31 and 70. Release 15 added further bands: 4, 14 and 71.

The input received by the Mobile IoT Initiative members, so far, indicates a variety of bands have been used. Below is an overview of the frequency bands supported in the different regions:

REGION	BAND
Europe	3, 8, 20
Commonwealth of Independent States	3, 8, 20
North America	2, 4, 5, 12, 66, 71, 26
Asia Pacific	1, 3, 5, 8, 18, 20, 26, 28

REGION	BAND
Sub-Saharan Africa	3, 8
Middle East and North America	8, 20
Latin America	2, 3, 5, 28

This input suggests only a subset of the bands supported by 3GPP Release 13 are likely to be used: a total of thirteen frequency bands (1, 2, 3, 4, 5, 8, 12, 18, 20, 26, 28, 66 and 71). After looking at the minimum overlap of the bands for individual countries, a minimum of ten bands: 1, 2, 3, 4, 5, 8, 12, 20, 26 and 28 are required for coverage in all the countries for which the NB-IoT members have provided input.

Note: The GSMA has received input from 15 MNOs covering a total of 56 countries.

6 NB-IoT Feature Deployment Guide

This section outlines the following features that will affect roaming and/or recommended configurations as part of the basic minimum feature set:

NB-IoT RELEASE 13 FEATURES	NB-IoT RELEASE 14 FEATURES	NB-IoT RELEASE 15 FEATURES
PSM Standalone Timers	Positioning: E-CID and OTDOA	Local RRM Policy Information storage for UE differentiation
eDRX configurations	New Category NB2	BEST
TAU and Periodic TAU	Power Class 6 (14dBm)	NB-IoT TDD Support
IPX firewall timer	Connected Mode Mobility	Wake-up signals (WUS)
Standalone Deployment	Multicast transmission/Group messaging	Early data transmission (EDT)
LTE Guardband Deployment	Paging and random access on non-anchor carrier	Improved access control
LTE In-band Deployment	Relaxed monitoring for cell reselection	Reduced system acquisition time
Paging	Release Assistance Indication	NPRACH range enhancement
SCEF deployment plans		Mixed standalone operation
SMS deployment for NB-IoT-only UEs		Small-cell support

NB-IoT RELEASE 13 FEATURES	NB-IoT RELEASE 14 FEATURES	NB-IoT RELEASE 15 FEATURES
Cell Reselection		RLC UM support
Coverage Extension		Scheduling request (SR)
Power Class		Measurement accuracy improvements
Rate Control		
Home Subscriber Server		
Firmware Upgrade available		
Multi Frequency Band Indicator		
Connected-Mode (Extended) DRX Support		
UICC Deactivation During eDRX		
Non-IP Data Delivery (NIDD)		
User Plane CIoT Optimisations		

7 NB-IoT Release 13 Features

7.1 PSM CONFIGURATIONS

Power Saving Mode (PSM) is designed to help IoT devices conserve battery power and potentially achieve a 10-year battery life.

Whilst it has always been possible for a device's application to turn its radio module off to conserve battery power, the device would subsequently have to reattach to the network when the radio module was turned back on. The reattach procedure consumes a small amount of energy, but the cumulative energy consumption of reattaches can become significant over the lifetime of a device. Therefore, battery life could be extended if this procedure could be avoided.

When a device initiates PSM with the network, it provides two preferred timers (T3324 and T3412); PSM time is the difference between these timers (T3412-T3324). The network may accept these values or set different ones. The network then retains state information and the device remains registered with the network. If a device awakes and sends data before the expiration of the time interval it agreed with the network, a reattach procedure is not required.

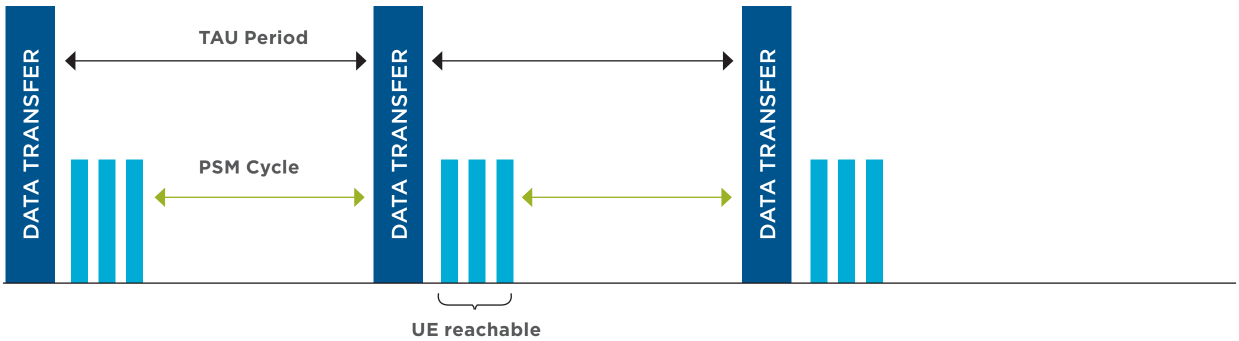

Figure 2: TAU (Tracking Area Updating) period and PSM cycle

For example, for a monitoring application, the radio module in a device might be configured by an application to enable PSM, negotiate a 24-hour time interval with the network and provide a daily status update to a centralised monitoring point. If the device's monitoring application were to detect an alarm condition, irrespective of any agreed sleep interval, the application could wake the radio module instantly and send vital information to the centralised monitoring point without the need to execute a reattach procedure.

In a similar manner to a radio module that has been powered off, a radio module with PSM enabled cannot be contacted by the network whilst it is asleep. The inability to be contacted whilst asleep may preclude the use of PSM for some applications.

Whilst the device is asleep, an operator might choose to store incoming packets or SMS (if supported) to be forwarded to the device once it awakens. This guide recommends the MNO set aside storage for at least the last packet of 100 bytes, to allow the customer to send simple messages to the device, such as an update to the clock. Any storage limitations will need to be communicated to the customer to establish a clear agreement on the operator's store and forward policy for UE utilising PSM. As the packets and SMS are stored in the home network, any limitation on downlink information retention will continue to be applied consistently when the device is roaming.

As is clear from Figure 2 above, the value of the PSM is limited by the utilised tracking area update (TAU). During the attachment procedure, the device can also request a periodic TAU, also by providing a T3412 value.

In the GSMA survey of operators' PSM policies, the majority of MNOs noted that they plan to store and forward at least the last received packet.

For detailed information, refer to:

- TS 23.682 (clause 4.5.4) [2]: Architecture enhancements to facilitate communications with packet data networks and applications.
- TS 24.301[4]: provides the timers used and their default values.
- TS 24.008 [3]: provides the coding detail for the timers (GPRS Timer 2 and 3)

Summary:

- PSM is a UE mechanism to reduce the energy used by the UE.
- The UE reports how often and for how long it needs to be active in order to transmit and receive data. However, the final values are determined by the network.
- PSM mode is similar to power-off, but the UE remains registered with the network. When the UE becomes active, again there is no need to re-attach or re-establish PDN connections.
- The PSM feature was introduced in 3GPP Release 12 and is available for all LTE device categories.
- UE requests the PSM simply by including a timer with the desired value in the attach, TAU or routing area update. The maximum time a device may sleep is approximately 413 days (set by 3GPP Release 13 for T3412). The maximum time a device may be reachable is 186 minutes (an equivalent of the maximum value of the Active timer T3324).

RECOMMENDATIONS

This guide recommends that MNOs and UE should support PSM for NB-IoT deployments.

No further restrictions should be set to timers based on 3GPP Release 13 [2] and [3][4], and the device requested values used wherever possible. If UE requested value is not supported it would be recommended to consider setting an Override function to a maximum value set in Release 13.

It is recommended that a "store and forward" policy should be supported for PSM. The operator should consider storing/forwarding the last received packets or an SMS (whichever is supported) to be sent to the device when it awakens. At a minimum, the last packet of 100 bytes should be sent, to allow the customer to send a simple message. Any store/forward limitations or errors should be communicated to the customer as part of a service level agreement.

7.2 eDRX STANDALONE

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.

Today, many smartphones use discontinuous reception (DRX) to extend battery life between recharges. By momentarily switching off the receive section of the radio module for a fraction of a second, the smartphone is able to save power. The smartphone cannot be contacted by the network whilst it is not listening, but if the period of time is kept to a brief moment, the smartphone user will not experience a noticeable degradation of service. For example, if called, the smartphone might simply ring a fraction of a second later than if DRX was not enabled.

eDRX allows the time interval during which a device is not listening to the network to be greatly extended. For an IoT application, it might be quite acceptable for the device to not be reachable for a few seconds or longer.

Whilst not providing the same levels of power reduction as PSM, for some applications eDRX may provide a good compromise between device reachability and power consumption.

Figure 3: eDRX Cycle

As for PSM, the details of this feature can be found in 3GPP TS 23.682 [2] and 3GPP TS 24.301 [4]. The allowed values for eDRX are listed below in Table 1:

eDRX CYCLE LENGTH
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)

Table 1: eDRX cycle lengths

As with PSM, in the GSMA survey of operators' eDRX policies, the majority of MNOs noted that they plan to store and forward all packets.

Summary:

- eDRX is a mechanism to save device energy, particularly for mobile-terminated traffic.
- Networks and devices negotiate when devices can sleep.
- The device keeps its receiver circuitry switched off for a defined period of time; during this time, the device is not listening for paging or downlink control channels.
- When the UE wakes up, the receiver will listen for the Physical Control Channel.

RECOMMENDATIONS

As a minimum, this guide recommends MNOs support eDRX for NB-IoT deployments.

It is recommended that the MNO should support a "store and forward" policy for eDRX and consider storing/forwarding at least the last received packets or an SMS (whichever is supported) to be sent to the device when it awakens. At a minimum, the last packet of 100 bytes should be sent to allow the customer to send simple messages. Any store/forward limitations should be communicated to the customer a part of a service level agreement.

PSM and eDRX are complementary features and a customer's application might need both. This guide recommends that customers should be informed about the implications of their choice for power consumption versus reachability

Note: The device can request the use of both PSM and eDRX during an attach or TAU procedure, but it is up to the network to decide to enable none, one of them or both (see 3GPP TS 23.682 [2] and 3GPP TS 23.401[5]).

7.3 OTHER TIMERS TO CONSIDER

There are other timers that need to be considered by an MNO when configuring the network to make the best use of PSM and eDRx, such as TAU and Periodic TAU, and IPX firewall timers.

7.3.1 TAU AND PERIODIC TAU

As indicated in the above section 7.1, there is a direct relation between the TAU and PSM. However, devices that are constantly moving, particularly outside of the tracking area, would need to reattach and consequently more signalling would be required. It is good practice to provide a long enough TAU to meet the service need, but the extra signalling will increase power consumption.

7.3.2 IPX FIREWALL TIMER

Some MNOs employ a firewall on the 3GPP S8 interface towards IPX (Internetwork Packet Exchange) network in order to protect their network. These firewalls are not part of the 3GPP standards, but some of the settings could have an impact on the performance of the service. These firewalls usually supervise the GPRS Tunneling Protocol (GTP) tunnel (session) of each SIM that is roaming on the network. To clean up the firewall from unused GTP sessions, an idle timer is used, meaning that, if no traffic is transferred by a SIM, this GTP Tunnel is deleted.

In PSM, the device will sleep for very long periods of time and hence not send any data. If the firewall deletes the GTP session, this could lead to a new registration of the UE once it wakes up (if it is using Attach with PDN connection) or to the need to re-establish the PDN connection. This process will reduce battery lifetime.

RECOMMENDATIONS

To maximise the performance of the selected PSM cycle, the GTP idle timer needs to be longer than the PSM.

7.4 DEPLOYMENT MODE

MNOs surveyed by the GSMA plan to deploy NB-IoT in all three deployment modes specified by 3GPP – standalone deployment, LTE guardband deployment and LTE in-band deployment.

RECOMMENDATIONS

In order to fully support roaming, any NB-IoT device should be able to attach to the visited NB-IoT network regardless of the deployment mode.

7.4.1 STANDALONE DEPLOYMENT

Standalone deployment is a deployment scenario in which operators deploy NB-IoT using existing idle spectrum resources. These resources can be the operator's spectrum fragments with non-standard bandwidths or spared from other radio access technologies (RATs) by refarming.

7.4.2 LTE GUARDBAND DEPLOYMENT

Guardband deployment is a deployment scenario in which operators deploy NB-IoT in guard bands within existing LTE spectrum resources.

7.4.3 LTE IN-BAND DEPLOYMENT

Guardband deployment is a deployment scenario in which operators deploy NB-IoT in guard bands within existing LTE spectrum resources.

7.4.3.1 PRB CONFIGURATIONS

NB-IoT technology occupies a frequency band of 180 kHz bandwidth [6], which corresponds to one resource block in LTE transmission.

For in-band deployment, not all frequencies, i.e. resource blocks within the LTE carrier, can be used for NB-IoT cell connection. For the UE to synchronise and acquire the NB-IoT cell, for an in-band downlink anchor carrier, the PRB is restricted to the values set out in Table 2 below. For uplink carrier and non-anchor, there is no limitation. For standalone and guard-band operation mode, the downlink and uplink carrier should be set symmetrically.

LTE system bandwidth	3 MHz	5MHz	10MHz	15MHz	20MHz
LTE PRB indices for NB-IoT synchronisation	2, 12	2, 7, 17, 22	4, 9, 14, 19, 30, 35, 40, 45	2, 7, 12, 17, 22, 27, 32, 42, 47, 52, 57, 62, 67, 72	4, 9, 14, 19, 24, 29, 34, 39, 44, 55, 60, 65, 70, 75, 80, 85, 90, 95

Table 1: Allowed LTE PRB indices for cell connection in NB-IoT in-band operation

Source: https://cdn.rohdeschwarz.com/pws/dl_downloads/dl_application/application_notes/1ma266/1MA266_0e_NB_IoT.pdf

Note: Indices are from low to high frequencies

RECOMMENDATIONS

This guide recommends that PRB should be aligned on all cells. A majority of operators surveyed by the GSMA are planning this set-up.

7.5 PAGING

In a paging procedure, paging messages are sent to a particular UE in RRC_IDLE mode, or to inform all UEs in RRC_IDLE mode of SI updates.

RECOMMENDATIONS

This guide recommends MNOs support paging, subject to PSM/eDRX activation, as it is necessary for downlink-initiated service.

7.6 SCEF DEPLOYMENT PLANS

The SCEF provides a means to securely expose and discover the services and capabilities provided by 3GPP network interfaces. The SCEF provides access to network capabilities through homogenous network APIs (see 3GPP TS 23.682 [2]).

The majority of MNOs surveyed by the GSMA plan to support SCEF, some are implementing it in phases; others are going directly to full SCEF deployment. As SCEF is not part of the minimum feature set required for the short-term deployment, the edition of this guide does not make recommendations for the SCEF functions to be exposed through network APIs.

The following points will be considered for the next edition of the Deployment Guide:

- In order to support an NB-IoT device with SCEF function in a visited network, at a minimum, the visited network would need to support interworking SCEF. Alternatively, the NB-IoT device would need to use a SGi interface, as per the recommendation in section 3.
- Due to the planned timing of SCEF introduction by the MNOs surveyed by the GSMA, the list of priority SCEF functions needs to be further reviewed. A minimum set of functions of the SCEF could include the following feature groups, ordered according to their priority to support business and roaming requirements:
  - MME-SCEF interface: allows roaming of visiting devices using non-IP over the control plane. Networks should prioritise the deployment or enablement of T6a interface on the MME side.
  - Abstraction: hides the underlying 3GPP network interfaces and protocols to allow full net work integration. The following functions are among those that may be supported:
    - Underlying protocol connectivity, routing and traffic control.
    - Mapping specific APIs on to appropriate network interfaces.
    - Protocol translation.
  - Monitoring Events: The Monitoring Events feature is intended for monitoring of specific events in the 3GPP system and making such monitoring events information available via the SCEF. It allows for the identification of the 3GPP network element suitable for configuring the specific events, the event detection, and the event reporting to the authorised users. Configuration and reporting of the following monitoring events should at least be supported:
    - UE reachability.
    - Location of the UE, and change in location of the UE.
    - Loss of connectivity.
    - Communication failure.
    - Roaming status (i.e. Roaming or No Roaming) of the UE, and change in roaming status of the UE and
    - Change of IMSI-IMEI(SV) Association.
    - Availability after DDN failure.
    - SCEF support for Reporting of Monitoring Events from the HSS or the MME for roaming scenarios.

- Network Parameter Configuration: The Network Parameter Configuration feature is de signed to set parameter values via the SCEF that may be used for:
  - Maximum Detection Time.
  - Maximum Latency.
  - Maximum Response Time.
- Assurance:
  - Integration with O&M systems.

7.7 SMS DEPLOYMENT FOR NB-IoT-ONLY UEs

A mobile terminated SMS is one mechanism – along with a UDP packet – that can be used to trigger the device. An NB-IoT device could also send alerts directly to a mobile phone via SMS (mobile originated SMS); to do so, the NB-IoT device would need to be programmed to send SMS to a specific phone.

According to the GSMA survey, only some of the operators deploying NB-IoT will support SMS, thus no clear deployment recommendation can be provided at this time. The following will be considered for the next edition of the Deployment Guide:

- In some cases, operators and their customers may decide to "port" old IoT solutions to NB-IoT technologies. However, in such cases, customers will not be able to use all the optimisations offered by the network.
- There is currently no implementation of SMS over IP. Supporting SMS over IP might increase the cost of the module by increasing implementation complexity. The operators not providing initial support for SMS are doing so to keep the cost of NB-IoT to a minimum.
- Attach without PDN connectivity using SMS triggers. The deployment plans for this option have not yet been confirmed.
- Some providers might be planning to launch NB-IoT SMS-only devices. The plans for this option have not yet been confirmed.
- Some providers might be using SMS for the OTA provisioning or configuration of SIM (HTTPS/CAT_TP session triggering, RFM, RAM etc.).

7.8 CELL RESELECTION

This guide recommends that MNOs should support cell reselection: the majority of the surveyed MNOs plan to support this feature.

7.9 COVERAGE EXTENSION

Some IoT applications require devices to be positioned in areas that are not readily accessible by radio coverage, such as underground parking garages and in ground pits. The 3GPP Enhanced Coverage feature 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 3GPP Enhanced Coverage 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.

The trade-off is that repeating signal transmissions consumes additional power and the time between battery recharge or replacement may be reduced.

3GPP Release 13 has defined three modes EC0 for 0dB, EC1 for 10dB and EC2 for 20dB.

RECOMMENDATIONS

To support the majority of the devices and all different type of settings, MNOs need to support all three modes.

7.10 POWER CLASS

Some IoT applications are particularly sensitive to power consumption. To minimise the impact of connectivity on the device battery life, for release 13 UEs two power class options could be used. One is the traditional mobile LTE device power level of 23dBm (Power Class 3) and a new one, with less power output, at 20dBm (Power Class 5). 3GPP Release 14 adds an even lower power output class at 14dBm (Power Class 6).

The main benefit with the lower power classes is that they facilitate integration of the power amplifier (PA) in a single-chip implementation and in addition, especially for the 14-dBm power class, that it may be more compatible with simpler battery technologies that can only sustain a low battery discharge power. These lower power classes are primarily intended for devices with stringest requirements on manufacturing cost and device form factor, but with less stringent requirements on battery life and coverage.

The introduction of lower power output UEs presents a challenge for operators to effectively communicate to end customers that not all NB-IoT devices will deliver the same performance for coverage and battery life, and challenge existing operator network designs.

Operators need to carefully consider their situation if they are to support lower power class devices in their networks. LTE cellular networks are likely to have been planned assuming the UE can transmit up to 23dBm. A reduction in power output from a UE will lead to a reduction in coverage. Depending on how an operator has performed their cell planning, a 3 dB or 9 dB reduction in UE power output may introduce areas of the network where the lower power devices may go out of coverage that didn't previously exist or limit the ability for a UE to operate below ground in parking garages or the like. Operators with extended range NB-IoT cells providing coverage at up to 100 km range may find that distance is no longer achievable. Where an operator presents maps for end customers to self assess coverage at a specific location, operators may need to provide multiple coverage maps to reflect the different coverage levels available from each power class.

A reduction in coverage may mean a NB-IoT device enters Coverage Enhancement levels CE1 or CE2 sooner than a power class 3 device. The impact may mean for some UEs, any energy savings gained through reduced power output are lost or exceeded by the signal repititions required to deliver a message. This early onset of signal repetitions may lead to NB-IoT cell congestion as the number of power class 5 and power class 6 devices increase within a single reduced size cell.

The introduction of lower power output UEs shifts the burden of understanding the intracies of their chosen UE to the customer, further complicating an already complex decision process.

RECOMMENDATIONS

MNOs should, at a minimum, support 23dBm in Release 13. Power levels of less than 23 dBm should be considered where it makes sense for an operator and their local market. For roaming, MNOs should expect to negotiate support for lower power output levels as part of their IoT roaming agreement.

7.11 RATE CONTROL

In normal scenarios, NB-IoT-enabled UE send data packets infrequently. However, in abnormal scenarios (such as when data is retransmitted due to timeout or malicious software implanted in UEs), UE can send data packets frequently during a short period. This may cause network congestion and affect services. Air-interface resources of NB-IoT are precious. Therefore, 3GPP specifications introduce the following two mechanisms for rate control when UEs send data packets:

- Serving PLMN Rate Control
- APN Rate Control

RECOMMENDATIONS

This guide recommends MNOs should support both rate control mechanisms.

7.12 HOME SUBSCRIBER SERVER

Since NB-IoT is a new technology introduced in 3GPP Release 13, the HSS requires a profile to support it. The interface S6a to the HSS is described in 3GPP TS 29.272 [11]; one of the mandatory parameters is the RAT type, which is already present in previous version of the interface. However, for NB-IoT, a new value for the RAT Type has been defined: EUTRAN-NB-IoT (1005), see 3GPP TS 29.212 [10]. In addition, there is a correlated change for disallowed access in the parameter Access-Restriction-Data, where bit '6' is for "NB-IoT Not Allowed".

Thus, the HSS requires a software upgrade to support NB-IoT.

7.13 FIRMWARE UPGRADE AVAILABLE

RECOMMENDATIONS

It is recommended that firmware upgrades (FOTA) are supported initially by means of IP based data communication. At this stage there is no support for FOTA operation over non-IP communication.

7.14 MULTI FREQUENCY BAND INDICATOR

MFBI indicates the support of multiple bands in one radio frequency cell. There are several overlapping bands, as indicated in 3GPP TS 36.307 [7] and displayed in the table below:

E-UTRA OPERATING BAND	OVERLAPPING E-UTRA OPERATING BANDS	DUPLEX MODE
2	25	FDD
3	9	FDD
4	10, 66	FDD
5	18, 19, 26	FDD
9	3	FDD
10	4, 66	FDD
12	17	FDD

E-UTRA OPERATING BAND	OVERLAPPING E-UTRA OPERATING BANDS	DUPLEX MODE
17	12	FDD
18	5, 26, 27	FDD
19	5, 26	FDD
25	2	FDD
26	5, 18, 19, 27	FDD
27	18, 26	FDD
33	39	FDD
38	41	FDD
39	33	FDD
41	38	FDD
66	4, 10	FDD

Table 3: Overlapping bands (multi-band environments) for each E-UTRA band

For NB-IoT the MFBI parameter is present, as defined in 3GPP TS 36.331 [8] (Section 6.7.3.4).

RECOMMENDATIONS

It is recommended to support MFBI for NB-IoT Deployment.

7.15 CONNECTED-MODE (EXTENDED) DRX SUPPORT

Configuration of C-DRX has a dramatically large effect on UE battery consumption.Connected DRX (C-DRX) was added in Release 8 and connected-mode extended DRX (C-eDRX) was added in Release 13. Both C-DRX and C-eDRX operate similarly where the UE can periodically enter a low power state except the maximum DRX cycle for C-DRX is 2.54sec and for C-eDRX it is 10.24 sec. C-DRX and C-eDRX have a configurable “ON duration” which set the amount of time the UE will listen to the DL control channel each cycle and a configurable “DRX Inactivity time” which set the amount of time without data before UE enter C-DRX/C-eDRX. The time the UE must stay in C-DRX/C-eDRX before being release to idle mode is called the “RRC inactivity Timer”. The following diagram ilistrates this mechanism and the above C-DRX/C-eDRX parameters:

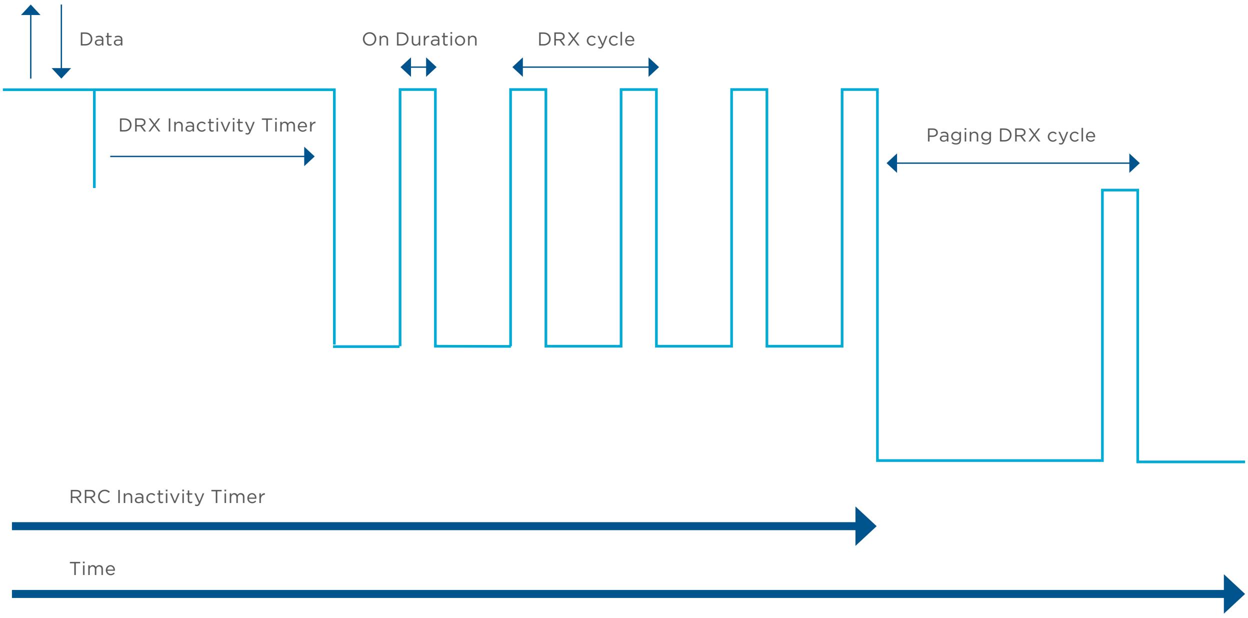

Table 4: Connected-Mode (Extended) DRX Support

The following recommedations are made:

- Network should support C-DRX or C-eDRX (where C-DRX is a subset of C-eDRX)
- To maximise battery life for latency tolerant applications, the maximum C-DRX or C-eDRX cycle and minimum onDurationTimer should be configured

7.16 UICC DEACTIVATION DURING eDRX

In order to reduce power consumption when the UE uses idle mode eDRX, the UE may deactivate the UICC during idle e-DRX. The UE may only deactivate the UICC if the UICC is configured to allow deactivation. UICC configuration requires elementary files (EF's) within the UICC to be set (e.g. the Administrative Data EF) (see section 4.2.18 in TS 31.102).

RECOMMENDATIONS

- The UICC should be configured to allow the UE to deactive the UICC while in idle mode eDRX mode.

7.17 NON-IP DATA DELIVERY (NIDD)

Non-IP PDN type is an optional feature that allows an EPS UE to transfer data without adding an IP header or transport header and without the need to operate an IP stack and obtaining an IP address. “Non-IP” transport is specifically requested by the UE in a PDN Connectivity Request (as part of an Attach Request or separately), by selecting “PDN-type = Non-IP” (possible values are IPv4, IPv4v6, IPv6 or Non-IP). Two mechanisms (provisioned in HSS) are currently defined for the delivery of Non-IP data to the Service Capability Server / Application Server (SCS/AS):

- Delivery using SCEF;
- Delivery using a Point-to-Point (PtP) SGi tunnel

7.18 USER PLANE CIOT OPTIMISATIONS

User Plane CIoT EPS optimisation is an optional feature that allows to transfer of the user plane data without the need for using the Service Request procedure to establish the Access Stratum (AS) when the user is in ECM-IDLE mode (also called RRC Suspend/Resume procedure). This feature significantly reduces the signalling overhead by approximately [75%] to go from idle to connected mode which improves network efficiency and improves UE battery life. There is no limit on packet size or number of transactions per connection so this procedure is well suited for TCP and UDP.

8 NB-IoT Release 14 Features

The following sections describe the new NB-IoT features in Release 14. All features are optional for the UE and can be supported by Cat-NB1 and Cat-NB2 unless otherwise stated. This release of this document presents feature descriptions without recommendations. Recommendations will be provided in a future release of this document.

8.1 POSITIONING: E-CID AND OTDOA

LPP (Location and Positioning Protocol) signalling is introduced as the positioning protocol for NB-IoT. LPP supports several positioning methods, and among these methods, *observed time difference of arrival* (OTDOA) and *enhanced cell identity* (E-CID) are specified in 3GPP.

For OTDOA, a new narrowband positioning reference signal (NPRS) is introduced, based on LTE's PRS in one PRB. NPRS are configured to occur periodically in the time domain. The UE measures the reference signal time difference (RSTD) between NPRS signals transmitted from three or more synchronized eNBs and reports the result to a positioning server which uses this information to estimate the location.

For E-CID, the positioning is based on narrowband reference signal received power and quality (NRSRP/NRSRQ) measurements by the UE and Rx-Tx time difference measurements by eNB along with the cell identity (CID).

8.2 NEW CATEGORY NB2

To reduce the time and UE power required to transfer larger messages in more favourable coverage, the range of transport block sizes (TBS) the NB-IoT UE can support is increased from a maximum of 680 bits DL and 1000 bits UL to 2536 bits on both links.
This establishes a Category NB2 UE. The Cat NB2 UE may optionally have 2 HARQ processes for UL and DL (compared to 1 each in Release 13), allowing further peak rate increases, in which case the time spacing between transmissions is reduced on the assumption the UE decoding capability has been increased.

8.3 POWER CLASS 6 (14dBM)

As previously outlined in section 7.10, introducing lower power class devices may present some challenges for operators.

RF requirements synchronised for a UE with a maximum transmit power of 14 dBm (which can be compared with 20 or 23 dBm in Release 13). The intention is to allow the use of small form-factor batteries which provide a low peak current. Signalling is introduced to allow the network to control if and how these UEs can access a cell. Additional repetitions for control and data are not provided to account for the power class reduction, as these UEs are assumed to be in normal or extended (rather than extreme) coverage, but the UE selection of a coverage level for NPRACH transmission is adjusted according to the UE's maximum power.

8.4 CONNECTED MODE MOBILITY

For the Control Plane CIoT EPS optimisations, RRC Connection Re-establishment and S1 eNB CP Relocation Indication procedures are introduced, to allow the S1 connection to be maintained and retransmissions of the NAS PDUs by MME and UE NAS in case of radio rink failure. Since AS security is not supported by these UEs, a security token based on NAS security is included in the RRC Connection Re-establishment Request and RRC Connection Re-establishment messages to allow authentication of the UE by the MME and authentication of the eNB by the UE. If the UE is successfully authenticated, the MME initiates a newly introduced S1 UE Context Release procedure to release the UE's S1-connection in the old eNB. The MME may initiate MME CP Relocation procedure before the release procedure in order to trigger the old eNB to return non-delivered NAS PDUs to the MME.

For User Plane CIoT EPS optimisations, the legacy handover procedure of data forwarding at handover is used at radio link failure.

8.5 MULTICAST TRANSMISSION/GROUP MESSAGING

Multicast is introduced based on LTE's SC-PTM (Single Cell Point to Multipoint) feature with modifications to suit the low complexity of NB-IoT UEs and enhanced coverage.

Similar to LTE, SIB20-NB configures the transmission of the single multicast control channel (SC-MCCH) per cell which in turn configures up to 64 multicast traffic channels (SC-MTCHs). The modification and repetition periods of SC-MCCH are extended to account for the repetitions used for coverage extension on NPDCCH and NPDSCH.

To keep UE complexity low, the UE is only required to receive SC-PTM in RRC_IDLE mode, and it is not required to process SC-MCCH at the same time as SC-MTCH, nor is it required to process any SC-PTM transmission at the same time as paging or random access.

8.6 PAGING AND RANDOM ACCESS ON NON-ANCHOR CARRIER

Use of non-anchor carriers for paging and random access is introduced. There can be up to 15 DL and UL non-anchor carriers configured in a new NB-IoT SIB, used by paging, RAR, or SC-PTM, each identified by its centre frequency.

For paging purposes, paging occasions (POs) are distributed across the non-anchor carriers in a configurable uneven manner so that the eNB can decide what paging load each carrier should have.

For random access, each non-anchor UL carrier has a probability with which the UE may randomly select it for random access related UL transmissions (Msg1&3), and corresponds to a DL carrier for random access related DL transmissions (Msg2&4). For ordered random access the carrier for Msg1&3 is indicated by DCI. Contention free random access is supported for NPDCCH ordered random access.

On non-anchor carriers for receiving paging and random access response (RAR), the subframes which the UE can assume contain NRS are reduced, to benefit network power consumption and co-existence with LTE and NR in future. In addition to spanning a few valid subframes either side of the NPDSCH carrying paging or RAR, the NRS are reduced to start a few valid subframes before the paging NPDCCH search space or RAR window, and continue until a few valid subframes after the NPDCCH candidate that contains the paging DCI, or after the RAR window respectively.

8.7 RELAXED MONITORING FOR CELL RESELECTION

This feature allows much of the RRM monitoring to be avoided in cases where an NB-IoT UE is stationary and/or the network topology is not changing, and UE battery life can be correspondingly extended. The network configures the UE with a 'NRSRP delta' threshold, and while the change in RSRP its current cell is less than the threshold, the UE does not need to monitor neighboring cells for 24 hours.

8.8 RELEASE ASSISTANCE INDICATION

When the UE has no more data to transmit, it waits for the network to release the connection to enter Idle mode. In order for the network to release the UE to Idle mode quickly to save power, release assistance indication (RAI) is introduced in Release 13 for Control Plane CIoT EPS optimisation, where UE may include RAI in non-access stratum (NAS) signaling to indicate that no further uplink or downlink data transmission and no further uplink data transmission subsequent to the uplink data transmission is expected, thus helping the network to decide if the connection can be released.

Release 14 introduces RAI for access stratum (AS) for both Control and User Plane CIoT EPS optimisation. When AS RAI is configured, UE may trigger a buffer status report (BSR) with zero byte size, indicating to eNB that no further data is expected in UL or DL in the near future and the connection may be released.

8.9 DOWNLINK CHANNEL QUALITY REPORTING

This feature allows the UE to measure the downlink quality of the anchor carrier and report it in Msg3 during the random access procedure. The quality is expressed in terms of required amount of repetition in order to achieve robust NPDCCH performance. The report can be used by eNB for optimising the transmission parameters for NPDCCH and NPDSCH.

9 NB-IoT Release 15 Features

The following sections describe the new NB-IoT features in Release 15. All features are optional for the UE and can be supported by Cat-NB1 and Cat-NB2 unless otherwise stated. This release of this document presents feature descriptions without recommendations. Recommendations will be provided in a future release of this document.

9.1 LOCAL RRM POLICY INFORMATION STORAGE FOR UE DIFFERENTIATION

The network is able to collect and store in the MME information about the UE and its traffic profile. This can be used to improve the scheduling of the UE according to e.g. its battery life or power supply, mobility, and when it tends to have traffic to transmit.

9.2 BEST (BATTERY EFFICIENCY SECURITY FOR LOW THROUGHPUT)

Network based end to middle or end to end (depends on the customer requirement) security solution for payload encryption with very low overhead which is an important requirement for battery driven devices.

This solution can be used on the control plane (DONAS) and use the symmetrical cryptography based on 3GPP AKA run. The solution needs to be implemented on the core (HSE) and device side (chipset/module). The operators have full control on the tunnel establishment and payload encryption (for the countries that payload encryption is not allowed by government)

BEST allows 3 different approaches:

- Key agreement only (just delivering the keys that can be used for the other type of cryptographies e.g. TLS)
- User plane integrity (traffic is not encrypted but integrity is protected
- User plane confidentiality (encryption + injtegrity)

BEST SERVICES		
Key agreement only	User plane integrity	User plane confidentiality
→ derivation of keys in USIM to protect application layer between UE ⇔ HSE or UE ⇔ EAS → BEST not specifying application layer protocol → Key usage up to customer	→ Includes key agreement → Integrity protected user data via NAS → Between UE ⇔ HSE or UE ⇔ EAS → BEST control plane terminates on HSE	→ Includes key agreement → Confidentiality protected user data over NAS → Between UE ⇔ HSE or UE ⇔ EAS → BEST control plane terminates on HSE

Table 5: BEST Services

The key agreement is based on the USIM and doesn't require additional feature or applet on the SIM card. It uses the core functionlaity of the SIM (secret key K)

Customer has control on the frequency of the new key generation. This time/volume based parameter shall be defined on the network (core) by the operators. Key generation algorithm has one fixed parameter (K secret key) and different variable parameters calculated during AKA run on device and network side.

End to middle : Interface between the customer and the network is not defined by BEST. Proposed HTTPS protocols and REST API can be used.

By end to end approach only the customer can decrypt the data and in no part of the transmission the data is plain text.

The key generation algorithm use Milenage or TUAK. (Key length : 128bit for Milenage and up to 256bit for TUAK).

9.3 NB-IoT TDD SUPPORT

Support for TDD is introduced, incorporating the Release 13 NB-IoT feature together with the following Release 14/15 features:

- **Release 14 features:**
  - OTDOA positioning
  - Release assistance indication
  - Paging and random access on non-anchor carrier
  - UE category NB2 with optional support for 2 UL/DL HARQ processes
  - Relaxed monitoring for cell reselection
- **Release 15 features:**
  - Local RRM policy information storage for UE differentiation
  - Improved access control
  - o Small-cell support
  - o RLC UM support

All LTE UL/DL subframe configurations are supported, except for configurations 0 and 6, and all LTE special subframe configurations are supported.

UPLINK-DOWNLINK CONFIGURATION	DOWNLINK-TO-UPLINK SWITCH-POINT PERIODICITY	SUBFRAME NUMBER									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

(Grey cells: not supported)

9.4 WAKE-UP SIGNALS (WUS)

When a UE is in DRX or eDRX, it must regularly check if a paging message is arriving from the core network. At most possible occasions for paging, no message arrives for the UE and the power the UE consumed could have been saved. This feature allows the eNB to send the UE a ‘wake-up signal’ (WUS) to instruct the UE that it must monitor NPDCCH for paging, and otherwise allows the UE to skip the paging procedures. This allows the UE to potentially keep parts of its hardware switched off for more of the time, and save the power of decoding NPDCCH and NPDSCH for paging. Depending on how long the network allows for the UE to ‘wake up’ after receiving a WUS, the UE may be able to keep switched on only a receiver dedicated to WUS detection, allowing much of the UE’s conventional hardware to remain in a very low-power state.

9.5 EARLY DATA TRANSMISSION (EDT)

An idle mode UE is able to transmit data in Msg3 of the random access procedure, carrying between 328 and 1000 bits. After successful reception by eNB, the random access procedure terminates and the UE does not transition to connected mode unless the MME or the eNB decides to move the UE to connected mode. The UE requests a grant for EDT if its pending data is smaller than a maximum permitted size configured by eNB, by using a pre-configured set of NPRACH resources for its pre-amble transmission. The eNB can allow the UE to transmit a smaller amount of data than the maximum permitted size, in order to reduce the power spent transmitting padding bits. If needed, eNB can order fallback to legacy random-access procedure during the EDT procedure.

9.6 REDUCED SYSTEM ACQUISITION TIME

Reduced latency and power consumption is achieved by the improvements for reduced system acquisition time listed in this section.

- **EARFCN pre-provisioning:** Initial cell search can be speeded up by pre-provisioning the UE with the E-UTRA absolute radio frequency channel number (EARFCN) and the geographical area where the EARFCN pre-provisioning configuration is applicable.
- **Additional SIB1-NB repetition:** In FDD, when SIB1-NB is being transmitted with 16 repetitions (the maximum supported), eNB can transmit additional subframes containing SIB1-NB repetitions on anchor carriers and non-anchor carriers to allow faster decoding of SIB1-NB and reduce the UE's power consumption during cell access. Compared to Release 13 which supports up to 8 SIB1-NB repetitions, Release 15 allows 16 repetitions.

9.7 NPRACH RANGE ENHANCEMENT

NB-IoT is sometimes deployed in cells with radius of up to around 100 km. Release 13 NPRACH supports cell radii up to 40 km with unambiguous determination of UE range. Beyond that distance, because NPRACH is a pure sine wave transmission, there can be ambiguities for the eNB to determine the UE's range. A new NPRACH format is introduced with a subcarrier spacing of 1.25 kHz and a cyclic prefix of 800 μs, together with frequency hopping, which is sufficient to allow unambiguous range determination up to 120 km.

9.8 MIXED STANDALONE OPERATION

In Release 13, a standalone anchor or non-anchor NB-IoT carrier can only be configured together with another standalone carrier. This feature allows configuration of standalone anchor carriers with in-band and guard-band non-anchor carriers, and of in-band and guard-band anchor carriers with standalone non-anchor carriers. This allows small slices of non-LTE spectrum to be used as a standalone NB-IoT carrier and be linked with NB-IoT carriers associated to LTE spectrum.

9.9 SMALL-CELL SUPPORT

eNB power classes are defined in NB-IoT to allow deployment of eNBs as microcells, picocells and femtocells, which use lower maximum transmit power than macro eNBs.

9.10 RLC UM SUPPORT

Release 15 adds support for RLC unacknowledged mode (UM) to complement the acknowledged mode (AM) and transparent mode (TM) introduced in Release 13. This reduces the need to send RLC signalling over the air for IoT traffic which may be latency and/or loss tolerant, or recoverable by the application layer.

9.11 SCHEDULING REQUEST (SR)

In Release 13/14 NB-IoT, scheduling request (SR) exists only as a higher-layer procedure, which triggers a random access procedure to request sufficient UL resource to send a buffer status report (BSR). Release 15 has added new, more resource and power efficient, ways to achieve this goal which can be configured by the eNB.

For a connected mode UE, eNB is able to configure by RRC periodic NPUSCH resources for the UE to send BSR, so the eNB is informed when pending traffic has arrived in the UE's Page 33 of 43 buffer. The resources are activated and de-activated ('released') by dynamic signalling on NPDCCH.

A connected mode UE is able to send, in the physical layer, a request to the eNB to be granted NPUSCH resources to send a BSR. This can be done either by a dedicated signal using a pre-configured NPRACH transmission, or via 'piggybacking' the request onto HARQ ACK or NACK transmission from the UE if one is available, by applying a cover code to the ACK or NACK symbols.

9.12 MEASUREMENT ACCURACY IMPROVEMENTS

Improved accuracy of downlink and uplink measurements are achieved by the Release 15 features listed in this section.

- **Narrowband measurement accuracy improvement:** The narrowband secondary synchronization signal (NSSS) or, on the serving cell, transmissions of MIB-NB on the narrow band physical broadcast channel (NPBCH) can be used for making NRSRP measurements, as alternatives to using narrowband reference signals (NRS). NSSS and NPBCH use more re source elements for their transmission than NRS, and this should reduce the amount of sub frames the UE needs to process to achieve a given measurement.
- **Power headroom reporting enhancement:** In Release 13, power headroom reports (PHR) are made by the UE from one of two tables depending on coverage, each containing four entries. This feature improves the granularity of PHR transmitted in Msg3 to have 16 levels.

10 Conclusions

The recommendations provided in this guide aim to achieve the following:

- An accelerated realisation of the wider benefits of common standards and predictable interconnect, while ensuring that forthcoming decisions about deployment architectures are well informed, making it more straightforward to enable device interconnect and roaming;
- Power optimisation, based on an informed compromise between device reachability and power consumption.

Having reviewed the NB-IoT data architecture, this guide recommends that MNOs enable IP traffic over Control Plane to support roaming and maximise the reduction in the power consumption. This means that all modules should also support IP/Control Plane.

The guide also advises that MNOs support the following key minimum features to achieve a balance of roaming service continuity and power optimisation:

- PSM
- eDRX
- Paging
- Cell Reselection
- Support for extended coverage
- Power class
- Rate control mechanisms
- Home Subscriber Server
- Multi Frequency Band Indicator

For other features, such as SMS, MNOs do not yet have consistent deployment plans. Therefore, SMS is not a key feature for the short-term deployment, and no related recommendations can be provided in this first edition of the Deployment Guide.

SCEF is also not included in the key minimum requirements of this edition of the Deployment Guide. Once SCEF is deployed, a NB-IoT device should be set up with SCEF configurations that enable it to interact with a visited network and connect to its application server. An agreement on a specific interface required to achieve this is out of the scope of this paper.

The features standardised in 3GPP Release 14 and Release 15 were added to this Deployment Guide as part of Version 3 of this document. Currently operators and the GSMA are not in a position to provide recommendations for these features but have provided clear explanations for each of thes features The GSMA plans to update this Deployment Guide regularly, to provide recommendations that are more specific once network operators have further NB-IoT deployment experience.

The GSMA plans to update this Deployment Guide regularly to provide more specific recommendations once network operators have futher LTE-M deployment experience.

Annex A 3GPP Standardized MIoT Features

A.1 3GPP RELEASE 10 FEATURES

REF no.	MIoT FEATURE	BENEFITS
1	UE low access priority indicator (LAPI)	A UE can be configured to be low access priority, meaning that it accepts being considered a lower priority by the network (access and core parts). This information is sent within UE requests to the network. The latter uses it in case of congestion, to first drop/reject requests with low priority.
2	AS-level congestion control	In congestion situations, the access node can bar some UEs belonging to a certain class and configured for EAB (Extended Access Barring) TS 22.011 § 4.3.1
3	MME/SGSN control of overload	SGSN and MME may request the access nodes to reduce the load they are generating on the network. Congestion control can be applied per APN for Session management or Mobility management.
4	Congestion control at the PGW / GGSN	The PDN GW detects APN congestion based on criteria (manufacturer dependent) such as: Maximum number of active bearers per APN; and/or maximum rate of bearer activation requests per APN.
5	Optimising the periodic LAU/RAU/TAU Signalling	Network load could be generated by signalling traffic of M2M devices caused by periodic mobility management procedures or RAT/PLMN change due to network problems. One way to limit that load is to extend the value of the periodic LAU/RAU/TAU timer and the Mobile Reachable timer.
6	Protection in case of PLMN reselection	Various features to limit Attach procedure impact in case of PLMN rese-lection (Attach with IMSI at PLMN change, long minimum periodic PLMN search time limit, invalid SIM/USIM states or forbidden PLMN lists, ...)

A.2 3GPP RELEASE 11 FEATURES

REF no.	MIoT FEATURE	BENEFITS
7	External Identifier	The growth in the number of MTC devices in the next years will induce a shortage of phone numbers (i.e. MSISDN). The 3GPP solution is to define a new identifier as part of the subscription data and allow for operations whereby a MSISDN is not allocated but a new identifier is used instead. This new identifier is named External Identifier (<Local Identifier>@<Domain Identifier) TS 23.682 § 4.6, TS 23.003 § 19.7.2
8	Operations without MSISDN	The ongoing growth in the number of MTC devices will induce a shortage of phone numbers (i.e. MSISDN). Operations without MSISDN in 2G/3G PS core networks will be allowed. Some services are not supported at operation without MSISDN, such as the CAMEL ones. Moreover, there may be additional problems with the following services: I-WLAN, IMS, Location services, Mobile Number Portability, Presence Services, MBMS, Generic User Profile, Charging, Remote Device Management and Over-the-Air configuration. This evolution does not concern EPC because MSISDN is already optional in EPC since Rel-8 TS 23.060 [5] § 5.3.17, TS 23.008 § 2.1.2, 5.1, 5.2
9	Device Triggering	The solution is based on the MTC InterWorking Function (MTC-IWF). The SMS message presents an indicator allowing the UE and the network to distinguish an MT message-carrying device triggering information from any other type of message. In addition, useful device trigger information named Trigger payload may be inserted in the SMS message.
10	SMS in MME	SMS in MME enables support of MO and MT SMS over LTE without requiring deployment of MSCs. Instead of delivering MT-SMS via the MSC (which would require the UE to be registered in the CS domain), the Short Messages pass directly between the MME and the SMSC using a new Diameter-based interface SGd.
11	PS Only Service Provision	For M2M applications/devices that only require PS data, avoiding attaching to the CS domain is trivial. However, for other applications/devices, attachment to the CS domain can be avoided only when the following conditions are satisfied: (a) The UE only needs PS domain services and SMS. (b) The SGSN supports SMS. (c) The HLR/HSS supports SMS via SGSN. (d) For roaming cases, the roaming agreement allows SMS via SGSN
12	Extension of Release 10 features on congestion control	Includes - Permission to override “low access priority” and “extended access barring” - Additional Load/Overload Control

A.3 3GPP RELEASE 12 FEATURESS

REF no.	MIoT FEATURE	BENEFITS
	LTE Category 0 UE	This is a new LTE Category specifically for 4G M2M modules called "Category 0". It especially allows simpler and cheaper solutions based on native LTE networks. Indeed, the expected cost is estimated around \$10 vs. \$20 for Category 1 LTE. The cost saving comes from reducing the complexity of the modem: • There is no spatial multiplexing (MIMO). Only a single reception/transmission antenna is used (vs. 2 for Cat. 1); • It works in Half-Duplex operation (HD-FDD), i.e. it sends/receives information in both directions, but only one direction can be utilised at a time. Only one oscillator and no duplexer are needed. • Data rate is limited to 1 Mbps (vs. 10 Mbps for Cat. 1) implying reduction of the transport block size. In case of HD-FDD, this rate is limited to 375 kbps TS 36.300 §18, 23.7
13	Power Saving Mode	Some particular MTC Devices infrequently send/receive mobile originating/terminating small data. In order to lower the power consumption of MTC Devices, Power Saving Mode (PSM) mechanism has been introduced. It refers to a particular UE state applicable in the PS domain where the UE is considered as powered-off, but remains registered with the network and there is no need to re-attach or re-establish PDN connections when exiting this state. TS 22.368 § 7.1.1 TS 23.682 § 4.5.4

A.4 3GPP RELEASE 13 FEATURES

REF no.	MIoT FEATURE	BENEFITS
	LTE Category M1 UE (LTE-M)	This is an evolution of 4G M2M modules “Category 0 “. Called “Category M1” (previously “Category -1”), they have up to 15 dB coverage extension and work in a narrower bandwidth of 1.4 MHz. TS 36.300 § 23.7a
14	Extended DRX Cycles	Extended discontinuous reception (eDRX) is a mechanism used by the UE and network to reduce UE power consumption by extending its sleeping cycle in idle mode. It may be used instead of, or in addition to, PSM (Power Saving Mode) defined in Release 12 TS 23.682 § 4.5.13.1
	Extended Coverage GSM (EC-GSM-IoT)	Extended Coverage GSM IoT (EC-GSM-IoT) is an evolution of the GSM standard (2G) that provides 10 to 20 dB coverage extension. It allows deep indoor coverage (basements…), full rural coverage (agriculture) and allows cheaper modules than classical GSM (reduced Tx power). Extended Coverage GSM IoT can be activated as a new service thanks to software upgrades in BSS and SGSN. In addition, EC-GSM-IoT can use PSM and eDRX to support device battery lifetimes of 10 years. The coverage extension is achieved by the repetition of messages at the physical layer between the UE and the BSC, to provide necessary robustness.
15	LTE Coverage Enhancement (CE)	UE uses enhanced coverage functionality to access the cell. This is a RAN feature based on the repetition of messages between the UE and the eNB. A single transport block is transmitted over multiple subframes, thereby providing higher transmit energy per information bit for a given transmit power TS 36.300 § 23.7b
16	High Latency Communication	High latency communication is a feature used for devices using PSM and/or eDRX. It allows an extended buffering of downlink data packets based on network awareness of UE power saving cycle until the UE becomes reachable again TS 23.682 § 4.5.7
	Narrowband IoT (NB-IoT)	Narrowband-IoT (NB-IoT) is a new 3GPP Radio Access Technology introduced in Rel-13 that forms part of Cellular IoT. It allows access to network services via E-UTRA with a channel bandwidth limited to 180 kHz.
17	Control Plane CIoT Optimisations	Control Plane CIoT EPS optimisation allows to transport user data (IP, Non-IP) within signalling on the access network until the MME (called also Data over NAS (DoNAS))

REF no.	MIoT FEATURE	BENEFITS
18	User Plane CIoT Optimisations	User CIoT EPS optimisation allows to transfer on the user Plane data without the need for using the Service Request procedure to establish the Access Stratum (AS) when the user is in ECM-IDLE mode
19	Attach without PDN Connection	Attach without PDN connection establishment allows the UE to be attached without having a Default PDN connection established. SMS is available to UE that has attached without PDN connection
20	SMS without combined attach	SMS transfer without combined attach allows an NB-IoT UE to request SMS service by launching an EPS Attach procedure instead of a combined attach procedure
21	Non-IP Data Delivery (NIDD)	Non-IP PDN type allows an EPS UE to transfer data without operating an IP stack and obtaining an IP address. “Non-IP” transport is specifically requested by the UE in a PDN Connectivity Request (as part of an Attach Request or separately), by selecting “PDN-type = Non-IP” (possible values are IPv4, IPv4v6, IPv6 or Non-IP). Two mechanisms (provisioned in HSS) are currently defined for the delivery of Non-IP data to the Service Capability Server / Application Server (SCS/AS): • Delivery using SCEF; • Delivery using a Point-to-Point (PtP) SGi tunnel TS 23.401 § 4.3.17.8. TS 23.682 § 5.13.
22	Optimised EPS Architecture option for CIoT (C-SGN)	An EPS optimised for CIoT can be enabled by having a sub-set of functionalities implemented in a single logical entity C-SGN (CIoT Serving Gateway Node) described below. C-SGN is a deployment option using the existing external interfaces of MME + S-GW + P-GW all together, and it does not create new system requirements. C-SGN supports Mobility and Attach procedures for the MME, S-GW and P-GW
23	Monitoring Enhancements	The network detects and reports events that M2M Application Servers / Services Capability Server have configured, related to their devices: association of the UE and UICC, UE reachability, Availability after DDN failure, Current Location, Loss of connectivity, Roaming status, ... The support of monitoring features in roaming scenarios implies a roaming agreement between the HPLMN and the VPLMN. TS 23.682 § 4.5.6
24	Service Capability Exposure Function (SCEF)	The Service Capability Exposure Function (SCEF) provides a means to securely expose service and network capabilities, such as resource management, communication patterns and QoS to third parties through network application programming interfaces (API). For NIDD, the SCEF is enhanced with the capability to support Control Plane CIoT EPS Optimisation. In the roaming case, the Interworking SCEF (IWK-SCEF) serves for interconnection with the SCEF of the Home PLMN and is located in the Visited PLMN TS 23.682 § 4.4.8 (SCEF) TS 23.682 § 4.4.9 (IWK-SCEF)

REF no.	MIoT FEATURE	BENEFITS
25	Group Message Delivery Using MBMS	Group message delivery using MBMS is intended to efficiently distribute the same content to the members of a group that are located in a particular geographical area on request of the SCS/AS via SCEF. Multimedia Broadcast / Multicast Service (MBMS) is a point-to-multipoint service in which data is transmitted from a single source entity to multiple recipients. Transmitting the same data to multiple recipients allows network resources to be shared. TS 23.682 § 4.5.5 and § 5.5.1 TS 23.246
26	Dedicated Core Network	A Dedicated Core Network (DCN, aka DECOR) provides specific characteristics and/or functions dedicated for specific types of subscrib-ers (such as IoT subscribers). The main architecture enhancements are to route and maintain UEs in their respective DCN. An operator may choose to deploy one or more DCNs within a PLMN with each DCN for specific types of subscribers. TS 23.401 [8] § 4.3.25 and § 5.19

Annex B NB-IoT Forum Questionnaire

The recommendations in this paper are based on the responses collected from the NB-IoT Forum mobile network operator members.

Below is the questionnaire that was used for gathering the deployment information.

1. **Data architecture:**

    a. What is your planned / preferred deployment configuration:
        i. IP/User Plane
        ii. IP/Control Plane
        iii. Non-IP/Control Plane

    b. In case of IP traffic do you plan to offer:
        i. TCP device originated: yes/no
        ii. TCP network originated: yes/no
        iii. UDP device originated: yes/no
        iv. UDP network originated: yes/no

2. **Deployment Bands: which bands are you planning to deploy in each of your markets**

3. **MIoT Features: Which features will affect roaming and/or configurations and should be agreed as part of the basic minimum feature set:**

    a. PSM
        i. yes/no
        ii. If yes, which configurations (e.g. timer limits) should be agreed?
        iii. If yes, policy on packets going to the device when it's in PSM
        iv. If yes, will you set a limit to the amount or type of downwards information?
        v. Do you plan to offer customers visibility or management of PSM configuration in their devices?

    b. eDRX
        i. yes / no
        ii. If yes, which configurations (e.g. timer limits) should be agreed?
        iii. If yes, policy on packets going to the device when it's in eDRX
        iv. If yes, will you set a limit to the amount or type of downwards information?
        v. Do you plan to offer customers visibility or management of eDRX configuration in their devices?

    c. Default PRB
        i. Which PRB do you plan to use?

4. Do you plan to deploy SCEF?

a. Yes / No
b. If Yes – please clarify when you plan to deploy it (3Q 2017? 4Q 2017, or later?) Please also clarify whether you plan to deploy it in phases, e.g. “traditional” PGW initially, followed by new SCEF based architecture, or SCEF from the start)
c. If Yes – which features are you planning to expose via APIs?
   i. IP/User Plane
   ii. IP/Control Plane
   iii. Non-IP/Control Plane

5. Do you plan to support CIoT EPS attach without PDN connectivity optimisation?

i. Yes / No

6. Do you plan to provide SMS on NB-IoT?

i. Yes / No
ii. If Yes – do you plan to provide SMS transfer without combined attach?

Other: Please add any other features you consider a key requirement in the short term. Please refer to the list of features from Releases 10-13 in the attachment Excerpt from MIoT Roaming Whitepaper.