LTE-M DEPLOYMENT GUIDE TO BASIC FEATURE SET REQUIREMENTS

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1 Executive Summary

LTE-M (LTE-MTC low power wide area (LPWA)) is a new cellular radio access technology specified by 3GPP in Releases 13 to 15 to address the fast-expanding market for low power wide area connectivity. To achieve global coverage and wide adoption of LTE-M services, MNOs (mobile network operator) must ensure that devices and end-to-end services from various providers will connect to the LTE-M 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 MNOs deploying LTE-M 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 Mobile IoT Forum, based on the survey inputs provided to the GSMA by fifteen MNOs who are deploying LTE-M networks in North America, Canada, Latin America, Europe and Asia.

The following guidelines have been set out in the first release of this guide:

- According to the survey, a minimum of eleven bands: **1, 2, 3, 4, 5, 12, 13, 20, 25, 26 and 28** are required for coverage in all the countries for which the LTE-M 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)
  - High Latency Communication
  - Support for extended coverage
  - LTE-M Half Duplex Mode/Full Duplex
  - Support of Category M1 device
  - VoLTE support
  - SMS
  - Connected Mode Mobility
- VoLTE, SMS, SCEF (Service Capabilities Exposure Function), GTP-IDLE Timer on IPX Firewall and Release 14 and 15 features have not been included among the key minimum features in this edition, although considerations for these features have been provided.

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

2 Introduction

2.1 OVERVIEW

LTE-M is a cellular radio access technology specified by 3GPP in Release 13, 14 and 15. The next step is to further establish LTE-M as a global coverage solution that enables customers, such as enterprise application service providers, to deliver their services globally with the confidence that deployment and operation will be consistent, smooth and predictable. This white paper is a Deployment Guide for the setup and configuration of LTE-M networks and devices, detailing key timer settings and considerations for the deployments.

The recommendations provided in this document are based on the input and deployment plans received from operator members of LTE-M Task Force, who plan to launch LTE-M on a global basis.

2.2 SCOPE

This document provides an overview of the existing deployment plans of the LTE-M key features, and sets out guidelines for mobile MNOs and application service providers on the set up and configurations of key LTE-M features and spectrum bands. These are recommendations to mobile operators deploying the networks globally. They are intended as an aid in the deployment of LTE-M networks and devices globally, to ensure smooth interoperability and roaming.

This guide includes the features standardised in 3GPP Release 10 to 15, focussing on the key features that will be deployed.

Out of scope are non-3GPP LPWA technologies, such as SigFox or LoRa, as well as NB-IoT (Narrow-Band IoT), which is addressed in the separate NB-IoT 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 pure M2M scope. MIoT is a subset of the far bigger IoT concept, for example a bunch of sensors connected together via Wi-Fi or Bluetooth are a part of IoT but not MIoT.
M2M	Machine-to-Machine, a general term referring to any network technology allowing devices 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.
MIoT	Mobile Internet of Things, a GSMA term which refers to the 3GPP standardised LPWA technologies using the licenced band (aka LTE-M, NB-IoT and EC-GSM-IoT). From 3GPP Release 13 and the following Releases, the Category of UEs that support power consumption optimisations, extended coverage and lower complexity are part of MIoT (CAT M1, CAT NB1 from Release 13 and CAT M2, CAT NB2 from Release 14). As this particular term is widely used throughout GSMA, it is utilised also in this document. Not to be confused with the term “mIoT” which means 5G massive IoT in 3GPP terminology.
LTE-M	LTE-M is the simplified industry term for the LTE-MTC low power wide area (LPWA) technology standard published by 3GPP in the Release 13 specification. It specifically refers to LTE Cat M1, suitable for the IoT. LTE-M is a low power wide area technology which supports IoT through lower device complexity and provides extended coverage, while allowing the reuse of the LTE installed base.

2.4 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

2.4 ABBREVIATIONS

TERM	DESCRIPTION
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
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
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.
MIoT	Mobile Internet of Things
MME	Mobile Management Entity
MNO	Mobile Network Operator
MSC	Mobile Switching Centre
MTC	Machine Type Communications
NB-IoT	Narrowband IoT
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

2.4 ABBREVIATIONS

TERM	DESCRIPTION
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
[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]	GSMA IR.92	IMS Profile for Voice and SMS; Section 3.2.1
[8]	GSMA CLP.28	NB-IoT Deployment Guide to Basic Feature Set Requirements
[9]	3GPP TS 36.101	Evolved Universal Terrestrial Radio Access (E-UTRA);

3 GSMA Minimum Baseline for LTE-M Interoperability - Problem Statement

3.1 PROBLEM STATEMENT

3GPP Rel 13 introduced several new features and functions within the new LTE-M technology, which defines Cat M1. Many of these enhanced features and functions are commonly referred to as Power Saving Mode (PSM), eDRX, Coverage Enhancement Mode A and B, etc. 3GPP Rel 14 and Rel 15 have introduced further new features with the LTE-M technology.

There are several existing LTE timers that continue to be utilised, and there are some new timers defined in support of several of these features. It is the intent of the members of the Mobile IoT Forum to deploy a common set of timer configurations so that enterprise application developers have a consistent experience globally. In addition to consistent timer setting configurations, this document will also address common mechanisms for which to handle conditions not previously experienced on legacy cellular networks, such as how to handle Mobile terminated data when a device is in PSM.

There have now been more than 30 LTE-M Networks deployed commercially in over 25 markets. Further details of these launches can be found here.

3.2 MINIMUM BASELINE FOR LTE-M INTEROPERABILITY: RISKS AND BENEFITS

The benefits of a consistent LTE-M deployment configuration settings are to achieve a common deployment experience for enterprise developers globally. Consistent experience is very important to enterprise developers independent of the MNO network being accessed.

In addition, several MNO’s and network providers have gained early insights and experience with these new advanced features, and this document is intended to share that experience and learning with any MNO, network providers and chipset providers who plan to deploy and support LTE-M.

4 LTE-M Data Architecture

Figure 1 below provides an overview of the architecture for LTE-M (and NB-IoT) in a roaming scenario as described by 3GPP:

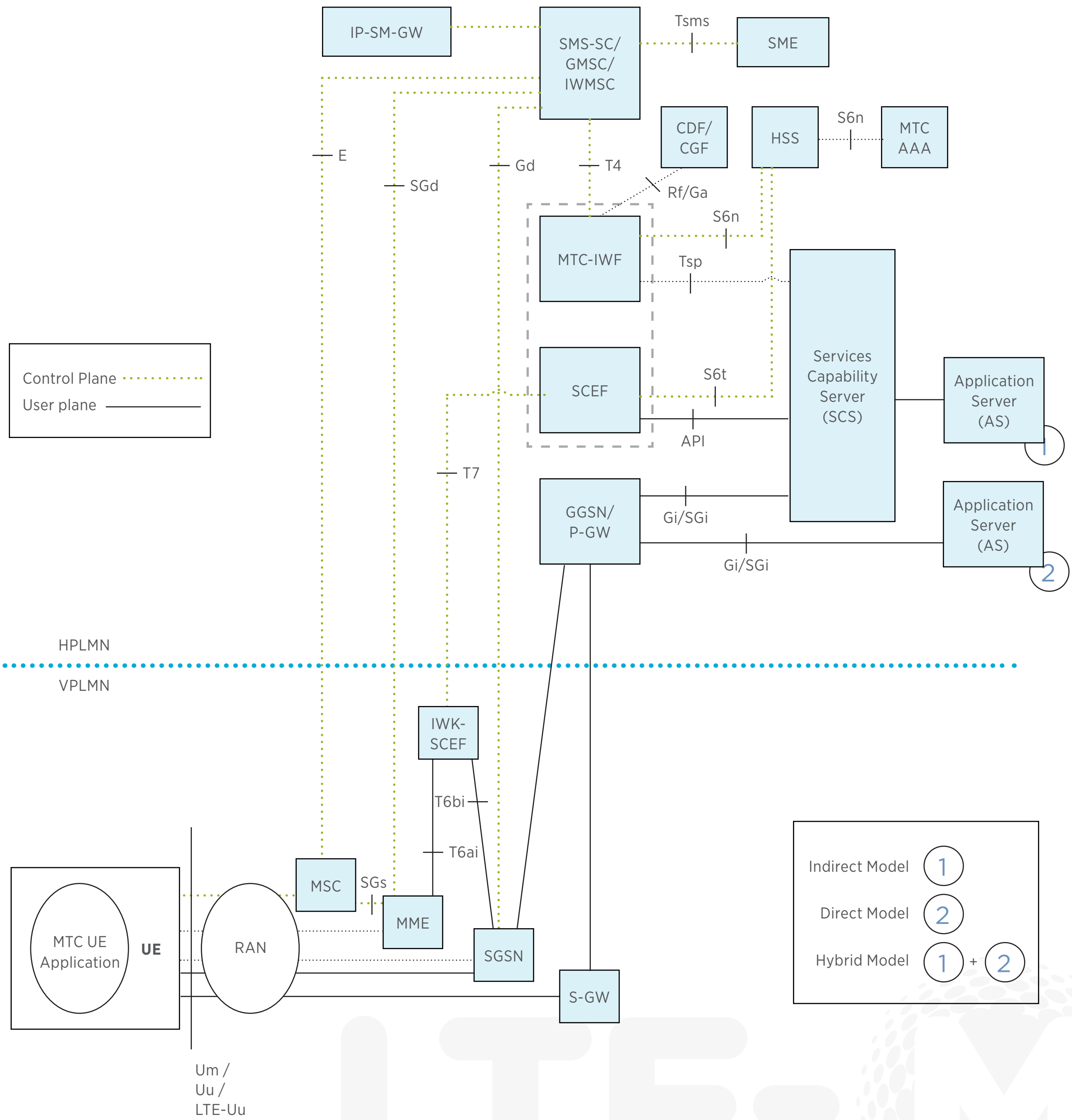


Figure 1: 3GPP Architecture for Machine Type Communication (NB-IoT and LTE-M Roaming)

This chapter provides an overview of the 3GPP options for data. 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 with out 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.

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 Plane (including User Plane Optimisation and User Plane Original), from 3GPP Rel-13 using the User Plane CIoT EPS optimisation with Non-IP PDN type

For Mobile Originating (MO) services, data could be transmitted at any time if needed. For Mobile Terminating (MT) service, data can only be transmitted in accordance with PSM and eDRX timers, which is the only time that the device is reachable by the network. However, for MT services 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/or 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 due to the fact that 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 which will connect to the SCEF of the home network (via the new T7 interface in Figure 1).

RECOMMENDATIONS

It is recommended that MNO's support IP traffic over User Plane as a minimum requirement to start supporting roaming.

All other features an optimisation described above are currently not supported, future releases of this document might provide more details.

5 LTE-M Deployment Bands

According to 3GPP, including Release 14, there is a defined set of frequency bands for which LTE-M can be used. 3GPP specification [9] from Release 13 provides the list of the supported bands: 1, 2, 3, 4, 5, 7, 8, 11, 12, 13, 18, 19, 20, 26, 27, 28, 31, 39, 41 and Release 14 added the bands: 25 and 40.

From the input received by the LTE-M Task Force members so far there are a variety of bands that have been indicated to be used. In order to achieve global roaming support, the following bands will need to be covered in order to produce global modules that cover North America, Latin America, Europe and parts of Asia:

- Bands 1, 2, 3, 4, 5, 12, 13, 20, 25, 26, 28

As indicated above only a subset of the bands supported by 3GPP Release 13 are envisioned to be used, currently 11 frequency bands for a global coverage in all the countries for which the LTE-M members have provided input. As indicated there has been input from 15 MNO groups covering North America, Latin America, Europe and Asia.

6 LTE-M Feature Deployment Guide

This section outlines the following features will affect roaming and/or configurations and are recommended as part of the configuration guide:

LTE-M RELEASE 13	LTE-M RELEASE 14	LTE-M Release 15
PSM Standalone Timers	Positioning: E-CID and OTDOA	LTE-M traffic identifier (RAT Type)
eDRX Standalone	Higher data rate support	Support for higher UE velocity
PSM and eDRX Combined Implementation	Improvements of VoLTE and other real-time services	Power Class 6 (14dBm)
High Latency Communication	Mobility enhancement in Connected Mode	Wake-up signals (WUS)
GTP-IDLE Timer on IPX Firewall	Multicast transmission/Group messaging	Early data transmission (EDT)
Long Periodic TAU	Relaxed monitoring for cell reselection	Reduced system acquisition time
Support of Category M1	Release Assistance Indication	Spectral efficiency improvements
Support of Half Duplex Mode in LTE-M	Coverage improvements	Feedback for early termination
Extension of coverage features (CE Mode A / B)	Downlink channel quality reporting	Improved access control
SCEF		
VoLTE		
Connected Mode Mobility		
SMS Support		
Non-IP Data Delivery (NIDD)		
Connected-Mode (Extended) DRX Support		
Control Plane CIoT Optimisations		
User Plane CIoT Optimisations		
UICC Deactivation During eDRX		

7 LTE-M Release 13 Features

7.1 PSM STANDALONE TIMERS

Power Saving Mode is a feature designed for IoT devices to assist them to 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 but finite amount of energy. The cumulative energy consumption of reattaches can become significant over the lifetime of a device and battery life could be extended if this procedure could be avoided.

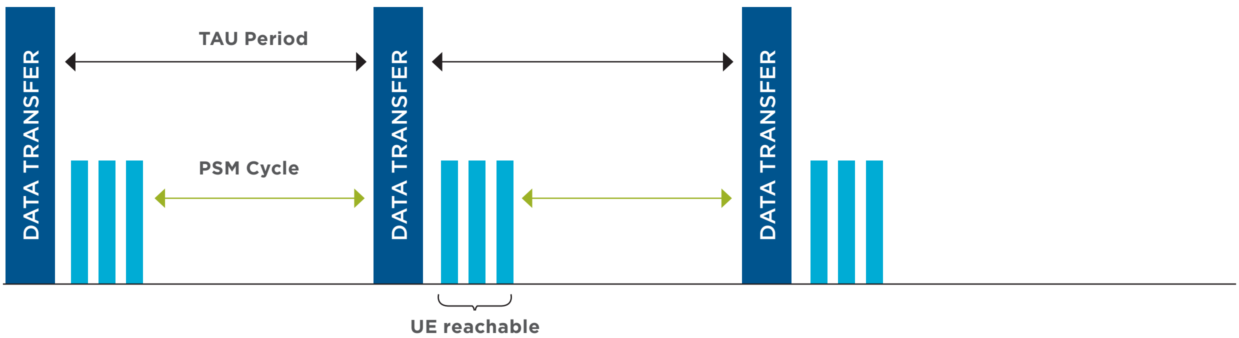


Figure 2: PSM Timers

RECOMMENDATIONS

As a minimum, PSM should be supported for LTE-M deployments.

PSM effectively turns off monitoring of Paging Instances on the device (that occur every 2.56 seconds), and increases time periods of devices sending Periodic Tracking Area Updates (pTAUs) to extended intervals to inform the network of its current registration (otherwise known as 'pTAU Extended Timer'). As a result, the device is able to save battery current drain by decreasing device-to-network signalling. With the introduction of PSM, radio modules can go into a HIBERNATE state (a state of low battery consumption) when not sending data to make the most efficient use of battery life.

PSM has 2 timers, configurable through AT Commands embedded within an enterprise Customer device software, which enables the device to request to the network when it would like to be put into the following PSM states:

1. T3324 Active Timer – Time the User Entity (UE) (otherwise known as "IOT Module") stays in ACTIVE / IDLE mode following a wake-up to Periodic Tracking Area Update or initiate a Mobile Origination event (Mobile Origination means the User Entity sends data or SMS up to the network destined to a back-end Application Server). This timer has a trade-off between lower values and maximum values: Lower values save more battery life by allowing the UE to go into HIBERNATE state quicker, which is the remaining duration of T3412 Extended timer. Higher values of T3324 will allow a longer time for the application server (AS) to respond to UE/MO data (e.g. Acknowledgements, network initiated data). Customers are advised to test out this parameter to come to a value that best fits their Use Case.

It is recommended a Ratio of T3324 Active Timer to T3412 Extended Timer:

(T3412 Extended Timer -T3324 Active Timer)/T3412 Ratio should be > 90% in order to achieve optimum battery savings by use of the PSM feature.

There is no network recommended value but the value cannot be below:

Minimum: 16 Seconds Minimum Allowed Value, calculated from: (2*DRX cycles (MNO LTE DRX cycle value (e.g. 2.56sec)) + 10 seconds (buffer time)) = 2*2.56sec + 10 seconds = 16 seconds.

2. T3412 Timer – Extended T3412 Timer is the value the device informs the network with Periodic Tracking Area Update (pTAU) that it is still registered. The duration after T3324 Timer expiry and the next pTAU instance is the HIBERNATE period.

> **Note:** The UE/Device is not reachable by a Mobile Terminated message/SMS during the PSM/Hibernate state.

It is recommended the following value of 4 Hours for this setting: Minimum: 4 Hours.

> **Note:** Max T3412 Extended = 413 days – as defined by 3GPP (TS 24.008)

Regarding attempts to deliver mobile terminated SMS / Data, it is recommended that the enterprise application implement a "pull" model for MT Data, such that the device initiates MO data transmission to the application server, and the application server responds to the device with the downlink payload.

> **Note:** On Mobile Originations: An Application Processor running on a UE, that controls the UE Module / the Radio, can initiate a Mobile Origination at any time, even if the device is within a PSM state. Therefore, Mobile Originations are not governed by the use of PSM. Furthermore, T3412 resets after MO events.

GENERAL APN RECOMMENDATIONS

There are also specific recommendations to the use of PSM in combination with custom APNs to ensure the APN Idle Timer are set such that they are in-sync with what the Customers PSM timers are set to. APN Idle Timer is a value that upon reaching, IMPLICITLY DETACHES the Context/UE from the network. This timer is typically set to a value of 4 hours. Therefore, if a Customer wants to use the PSM, their T3412 Extended Timer value should not be greater than their APN Idle Timer.

In cases where a customer has an existing APN that now wants to add PSM capable devices which require different (e.g. most likely longer) APN Idle times, it is recommended to use a separate APN for the PSM capable devices if the original APN Idle Time cannot be changed.

In Summary: It is recommended that the following timer T3412 should be supported for an LTE-M deployment:

- ➔ Minimum: 240 minutes (4 hours)
- ➔ Maximum: 3GPP Release 13 Maximum 413 days

Additionally, if the UE requested value is lower than the minimum recommended value the network may override to the minimum value. If the UE requested value is higher than the maximum recommended value, the network will override to the maximum value as set in Release 13.

MT SMS

It is recommended that MT SMS are not be stored by the MNO beyond the existing SMS expiration timer.

As a consequence, to prevent loss of information, devices using PSM and for which MT SMS are expected should not request a PSM Timer of higher value than the standard SMS expiry timer from the SMS Center (Typically 7 days).

MT Data Packets

Currently there is no general store and forward mechanism supported by MNOs, further release of this document might provide more information. With this in mind, it is recommended to not store MT data while a device is in PSM mode and utilise the method defined above by the enterprise application developers to wait until the UE performs a MO data session, then deliver MT data.

7.2 eDRX STANDALONE

Extended Discontinuous Reception 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.

Currently, 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 degradation of service. For example, if called, the smartphone might 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 not to be reachable for a few seconds or longer.

For some applications eDRX may provide a good compromise between device reachability and power consumption.

Every eDRX cycle can be configured with a paging transmission window (PTW) containing a number of paging opportunities. The eDRX cycle determines the fundamental downlink reachability and the PTW determines with what reliability the reachability can be guaranteed under, such as, varying load conditions.

MO events can trigger uplink transmissions at any time, regardless of DRX/eDRX settings. MT traffic can be delivered after reaching the UE which is following eDRX.

Figure 3: eDRX Cycle

RECOMMENDATIONS

It is recommended that LTE-M deployments support idle-mode eDRX and to consider accepting the 3GPP Rel13 defined UE requested values of a minimum of 5.12 seconds, and maximum: 43.69 minutes.

7.3 PSM AND EDRX COMBINED IMPLEMENTATION

It is recommended that LTE-M deployments support both PSM and eDRX as these are complementary and a customer's application might need both. A customer needs to be informed regarding the impact on the battery.

In case of combined use of PSM and e-RX, a careful alignment is needed between the different configuration parameters (PSM timers and e-RX paging cycle length) in order to ensure paging success by the network.

Further recommendations will become available which is for further study.

7.4 HIGH LATENCY COMMUNICATION

The High Latency Communications (HLCom) can be used to handle mobile terminated (MT) communication, when the UE is unreachable while using PSM or eDRX. "High latency" refers to the initial response time before normal exchange of packets is established. The feature is described in 3GPP TS 23.682.

Currently, high latency communications may be handled by two main mechanisms:

- an extended buffering to hold downlink data;
- Explicit notification towards the SCS/AS indicating the time a device become reachable again

Extended buffering is done at the Serving-GW (S-GW) and it is controlled by the MME/SGSN, which explicitly inform the S-GW to buffer downlink packets related to a specific UE until it is reconnected.

By using explicit notifications, the S-GW simply discards the downlink packets when the device is not reachable and the MME/SGSN issues a notification towards the SCS/AS once the device becomes available.

RECOMMENDATIONS

Currently there is no support for HLCom feature for LTE-M Deployments. Thus, it means that when an LTE-M device is in either PSM or eDRX, mobile terminating messages, depending on MNO choice the messages will either be buffered or discarded.

7.5 GTP-IDLE TIMER ON IPX FIREWALL

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.

RECOMMENDATIONS

There are no recommendations at this time with regards to the GTP-IDLE Timer on IPX Firewall until more experience obtained.

7.6 LONG PERIODIC TAU

RECOMMENDATIONS

It is recommended that the 3GPP Release 13-defined TAU Requests from the UE are used to support Long Periodic TAU.

7.7 SUPPORT OF CATEGORY M1

The [9] provides the set of features and capabilities that are defined for the UE category M1 which includes:

- Maximum output power: the supported classes are Class 3 (23dBm) and Class 5 (20dBm)
- Half duplex and full duplex for FDD and TDD, however currently supported frequency bands are only operating in FDD.
- Coverage extension.

7.7.1 SUPPORT OF HALF DUPLEX MODE IN LTE-M

The LTE-M standard supports FDD and TDD operation for LTE-M deployment in paired and unpaired bands, respectively. An LTE-M device in FDD operation can either employ full-duplex operation, which means that the device supports simultaneous transmission and reception, or half-duplex operation, which means that the device alternates between transmission and reception. Devices that only support half-duplex operation are associated with a lower peak rate compared to devices that support full-duplex operation, but devices that only support half-duplex operation are less complex and less costly since they may be implemented with fewer and/or less expensive components.

RECOMMENDATIONS

It is recommended that Half Duplex Mode is supported.

7.7.2 EXTENSION OF COVERAGE FEATURES (CE MODE A / B)

The LTE-M standard supports two Coverage Enhancement (CE) Modes: CE Mode A and CE Mode B. Both CE Modes enable coverage enhancement using repetition techniques for both data channels and control channels. For data channels, CE Mode A supports up to 32 times repetition and CE Mode B supports up to 2048 times repetition. CE Mode A is the default mode of operation for LTE-M devices and LTE-M networks, providing efficient operation in coverage scenarios where moderate coverage enhancement is needed. It is designed to maintain the LTE-M advantages of higher data rates, voice call possibility, and connected mode mobility.

CE Mode B is an optional extension providing even further coverage enhancement at the expense of throughout and latency. It was mainly designed to provide coverage deep within buildings. For this reason, Mode B is intended more for stationary or pedestrian speeds applications that require limited data rates and limited volumes of data per month. The maximum coverage Mode B provides is highly configurable by the MNO (from 192 to 2048 repeats).

RECOMMENDATIONS

It is recommended that Coverage Enhancement Mode A is included in the basic LTE-M feature set. CE Mode A is the mandatory coverage extension mode, to be supported by all LTE-M devices. LTE-M advantages of higher data rates, voice call possibility, and connected mode mobility may continue to be supported.

For MNOs considering to add CE Mode B in the future, which provides additional coverage enhancement via increased message repetition, additional testing by MNO is required to understand its effects on data throughput, and other features deployed within the network. It is recommended that MNO's that have deployed mode B, provide this information to its roaming partners to allow them to inform their customers of the availability of the feature. If CE Mode B is not enabled on a visited network, the roaming device will revert to CE Mode A and revert to the coverage benefits offered by CE Mode A.

7.8 SCEF

The Service Capability Exposure Function (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]).

RECOMMENDATIONS

Currently there is no support for SCEF. Some MNOs surveyed by the GSMA plan to support SCEF from 2018, others have not yet decided. Some will be implementing it in phases, others going directly to full SCEF deployment. Those who will be deploying both NB-IoT and LTE-M networks might benefit from deploying SCEF, but it is an optional feature for LTE-M. Therefore, SCEF is not part of the minimum feature set required for the short-term deployment and this edition of the 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 LTE-M Deployment Guide:

- Messaging and Wake-Up notifications features
- APIs monitoring the UE
- Device Triggers: Device states, etc.,
- Location/ Presence
- QoS

7.9 VOLTE

RECOMMENDATIONS

VoLTE is not a mandatory recommendation for global LTE-M deployments, however if operator does deploy VoLTE the following recommendations should apply:

- The device and then network must support GSMA PRD NG.108 “IMS Profile for Voice and SMS for UE category M1” to support voice and SMS for UE category M1.

7.10 CONNECTED MODE MOBILITY

There are two main mobility modes: Idle Mode Mobility and Connected Mode Mobility. In Idle Mode the UE has the decision to perform cell reselection. While In the Connected Mode, the network controls UE mobility, the network decides when the UE shall move, to which cell and triggers the handover procedure.

Connected Mode Mobility (CMM) is important especially for VoLTE in combination with mobility. Stationary VoLTE use cases will not require CMM. However, VoLTE use cases requiring mobility (i.e.: Wearables) will want to combine VoLTE with CMM to retain the session during movement between eNB's.

RECOMMENDATIONS

There is clear support for the Connected Mode Mobility for VoLTE. It is also recommended that Connected Mode Mobility also be supported for all data traffic at this stage. More details will be provided in future releases of this document.

7.11 SMS SUPPORT

RECOMMENDATIONS

At this stage there is clear consensus that SMS will be deployed for global LTE-M deployments. Currently the majority of deployments support the MME SGs interface. The following 3GPP features are available however are not yet widely deployed:

- Support of Rel 12 Feature SMS without Combined attach relies on implementation of SMS over MME. It has some limitation in term of support of services offered on current M2M such as "No Wake ON".
- Support of Rel 11 Feature SMS over MME relies on a new interface "SGd".

However, if the MNO does deploy SMS the following recommendations apply:

- For deployments supporting also VoLTE, consider to support SMS over IMS
- Devices supporting 2G, 3G and/or 4G, as well as LTE-M, the MNO should deploy and support LTE-M SMS in the manner consistent with the MNO's existing implementation of SMS over legacy LTE networks
- If a service is deployed which utilises SMS and international roaming is required, the MNO will need to advise the customer where this will be and where this is not available.

Note: Timers for SMS in the case of EPS CIoT optimisation need to be evaluated in the next revision of this Deployment Guide for CE Mode A as described in section 10 of 3GPP TS 24.011

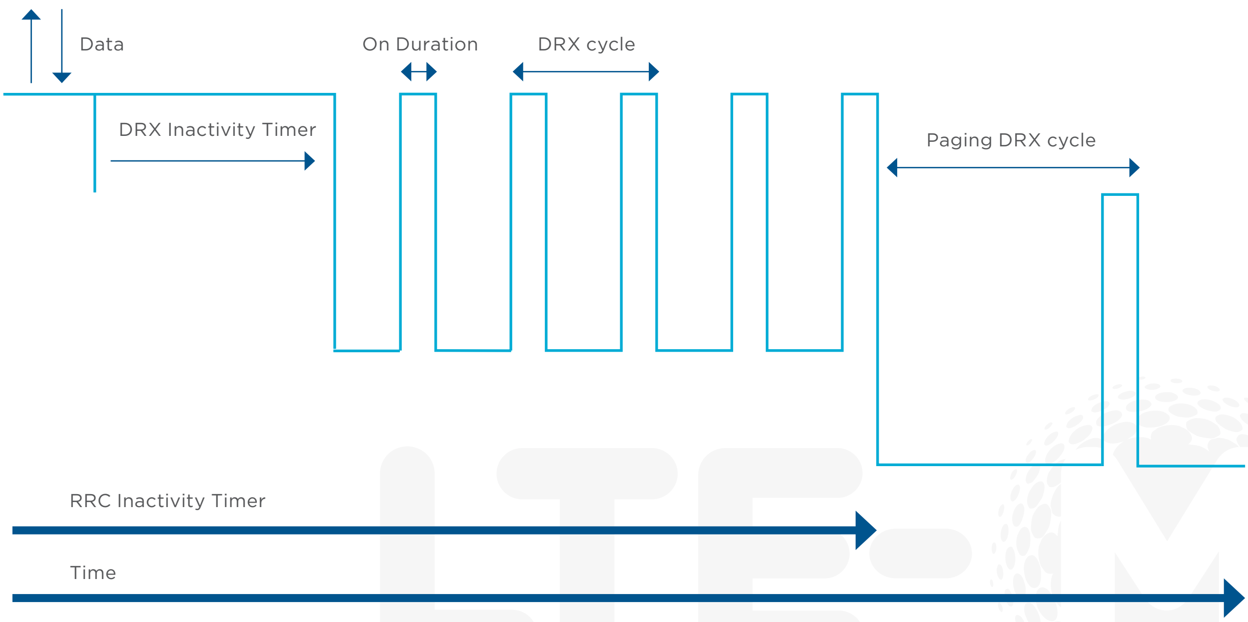
7.12 NON-IP DATA DELIVERY (NIDD)

Non-IP PDN type is an optional LTE-M 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

7.13 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 10.24sec. 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:



RECOMMENDATIONS

- 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

7.14 CONTROL PLANE CIoT OPTIMISATIONS

Control Plane CIoT EPS optimisation is an optional LTE-M feature that allows to transport user data (IP, Non-IP) via control plane signalling to the MME (called also Data over NAS (DoNAS)). This feature reduces the signalling overhead by approximately half for moving from idle to connected mode which improves network efficiency and improves UE battery life. This procedure is suited for UDP where only a few packets are sent per connection.

7.15 USER PLANE CIOT OPTIMISATIONS

User Plane CIoT EPS optimisation is an optional LTE-M 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. Since the UE ends up in normal connected mode, the only difference compared to ordinary connection establishment is during state transition which is more efficient from signalling (and power) point of view, and therefore there is no limit on packet size or number of transactions per connection so this procedure is well suited for TCP and UDP.

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 eDRX. 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 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).

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 introduced in Release 15, 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 LTE-M 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 LTE-M 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 LTE-M device enters Coverage Enhancement levels Mode A or Mode B 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 repetitions required to deliver a message. This early onset of signal repetitions may lead to LTE-M 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 23dBm 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.

8 LTE-M Release 14 Features

The following sections describe the new LTE-M features in Release 14. All features are optional for the UE and can be supported by Cat-M1 and Cat-M2 and by normal LTE UEs with coverage enhancement (CE) mode support unless otherwise stated. All features are applicable to both CE modes (A and B) in all duplex modes (HD-FDD, FD-FDD, and TDD) 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 used as the positioning protocol for LTE-M. 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. Signalling for the LTE positioning methods E-CID and OTDOA is supported already in Release 13 for Cat-M1 and other UEs in coverage enhancement (CE) mode. However, Release 14 introduces full standard support by also including measurement performance requirements and additional OTDOA enhancements.

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

For OTDOA, LTE's positioning reference signal (PRS) is re-used. PRS are configured to occur periodically in the time domain. The UE measures the reference signal time difference (RSTD) between PRS signals transmitted from three or more synchronised eNBs and reports the result to a positioning server which uses this information to estimate the location.

Furthermore, additional OTDOA enhancements are introduced in Release 14 in order to take into account the limited UE bandwidth of Cat-M UEs and the low signal-to-noise ratio (SNR) operating point of UEs in CE mode. Each cell and UE can be configured with up to three positioning reference signals (PRS) instead of just one, each PRS with its own configured transmission interval, duration and bandwidth, with or without frequency hopping. Although these OTDOA enhancements have been designed with Cat-M and other UEs in CE mode in mind, they can be supported by LTE UEs that do not support CE mode.

8.2 HIGHER DATA RATE SUPPORT

The low-complexity UE category introduced in LTE Release 13 (Cat-M1) has a UE bandwidth of 1.4 MHz and a peak rate of 1 Mbps in DL and UL. Coverage enhancement (CE) modes A and B, which are applicable to both Cat-M UEs and normal LTE UEs, are also restricted to 1.4 MHz in Release 13. This work item introduces the following data rate improvements in order to be able to address a wider range of use cases.

- **New UE category M2:** A new UE category (Cat-M2) is introduced with a UE bandwidth of 5 MHz and peak rates of approximately 4 Mbps in DL and 7 Mbps in UL. These peak rates apply for UEs supporting full-duplex FDD operation – the peak rates for UEs supporting half-duplex FDD are approximately half of these numbers and the peak rates for UEs supporting TDD depend on the DL/UL subframe configuration.
- **Wider bandwidth in CE mode:** CE modes A and B are improved to support maximum data channel bandwidths of 5 or 20 MHz in DL, and CE mode A is improved to support a maximum data channel bandwidth of 5 MHz in UL. The control signaling (MPDCCH, system information, etc.) is still restricted to 1.4 MHz in order to re-use as much as possible of the Release 13 design.
- **Higher UL peak rate for Cat-M1:** Support for a larger transport block size (TBS) of 2984 bits instead of 1000 bits is introduced in order to increase the UL peak rate for Cat-M1. Increasing the UL TBS is not expected to increase the UE complexity significantly but will provide an UL peak rate boost which may be particularly useful in DL-heavy TDD configurations.
- **10 DL HARQ processes in FDD:** In order to enable UEs that support full-duplex FDD operation to do continuous DL data transmission, the number of DL HARQ processes is increased from 8 to 10, increasing the DL peak rate with 25%. This will also benefit half-duplex FDD UEs configured with HARQ-ACK bundling.
- **HARQ-ACK bundling in HD-FDD:** In half-duplex FDD operation, the DL peak rate is limited by the fact that the UE needs to switch to UL in order to transmit HARQ-ACK feedback. This work item introduces HARQ-ACK bundling, where the UE transmits a single HARQ-ACK feedback for multiple DL transport blocks, thereby enabling the UE to incease the portion of subframes that can be used for DL data transmission from 30% to 53% (or to 59% using 10 DL HARQ processes).
- **Faster frequency retuning:** Since the UE bandwidth of Cat-M UEs can be smaller than the system bandwidth, a guard period of 2 OFDM symbols is applied in CE mode to allow these UEs to do frequency retuning within the system bandwidth. This work item introduces support for shorter guard periods of 1 symbol (for Cat-M) and 0 symbols (for normal LTE UEs in CE mode), allowing for somewhat improved link performance.

These features can be supported by Cat-M2 and normal LTE UEs supporting CE mode. All features except the wider bandwidth can also be supported by Cat-M1.

8.3 IMPROVEMENTS OF VOLTE AND OTHER REAL-TIME SERVICES

Cat-M1 and other UEs in CE mode A support VoLTE already in Release 13 but this work item introduces optimisations to improve the coverage for VoLTE and other delay sensitive services in particular in half-duplex FDD and TDD where the number of available DL/UL subframes is limited.

- **New PUSCH repetition factors:** For the uplink data channel (PUSCH), two new subframe repetition factors (12, 24) were included in the existing range (1, 2, 4, 8, 16, 32) in order to allow more efficient use of available subframes.
- **Modulation scheme restriction:** A possibility for eNB to restrict the modulation scheme for the data channels (PDSCH/PUSCH) to QPSK is introduced. This can improve the link performance when repetition is used. In the uplink case, it can also help reduce peak-to-average power ratio (PAPR), improving power consumption and coverage.
- **Dynamic HARQ-ACK delays:** A field indicating a HARQ-ACK delay was introduced in the downlink control information (DCI) to allow more flexible scheduling of the HARQ-ACK feed back for DL data transmissions.

These features are not limited to VoLTE but can be used with any service for Cat-M or other UE in CE mode A.

8.4 MOBILITY ENHANCEMENT IN CONNECTED MODE

Release 13 supports intra-frequency RSRP measurements in idle and connected mode for Cat-M1 and other UEs in CE mode and similar mobility procedures as LTE. Release 14 introduces full mobility support in idle and connected mode including both intra- and inter-frequency RSRP/RSRQ measurements.

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 Cat-M UEs and enhanced coverage of UEs operating in CE mode.

Similar to LTE, SIB20 configures the transmission of the single multicast control channel (SC-MCCH) per cell which in turn configures up to 128 multicast traffic channels (SC-MTCHs). Each SC-MTCH can be configured to support up to 1 Mbps over 1.4 MHz or 4 Mbps over 5 MHz, with or without frequency hopping. The modification and repetition periods of SC-MCCH are extended to account for the repetitions used for coverage extension on MPDCCH and PDSCH.

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 RELAXED MONITORING FOR CELL RESELECTION

When this feature is enabled and the criteria for relaxed monitoring are fulfilled, the UE can reduce its neighbor cell measurements to as seldom as every 24 hours. This can reduce the power consumption substantially especially for stationary UEs in challenging coverage conditions. This feature is specified in Release 15 but is early implementable in Release 14.

8.7 RELEASE ASSISTANCE INDICATION

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

8.8 COVERAGE IMPROVEMENTS

Various minor coverage improvements are introduced for CE mode A and B in Release 14.

- **New PUCCH repetition factors:** Large repetition factors (64 and 128) for transmission of HARQ-ACK feedback over PUCCH is introduced to improve coverage for UEs in the worse coverage in CE mode B.
- **UE transmit antenna selection:** A possibility is introduced for eNB to control the UE transmit antenna selection for LTE UEs that happen to support two transmit antennas instead of just one in CE mode A.
- **SRS coverage enhancement:** Support for sounding reference signal (SRS) repetition in the special subframe in TDD was introduced in order to enable improved link adaptation.

The SRS coverage enhancement can furthermore be supported also by LTE UEs that do not support CE mode.

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 optimizing the transmission parameters for NPDCCH and NPDSCH.

9 LTE-M Release 15 Features

The following sections describe the new LTE-M features in Release 15. All features are optional for the UE and can be supported by Cat-M1 and Cat-M2 and by normal LTE UEs with coverage enhancement (CE) mode support unless otherwise stated. All features are applicable to both CE modes (A and B) in all duplex modes (HD-FDD, FD-FDD, and TDD) 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 LTE-M TRAFFIC IDENTIFIER (RAT TYPE)

LTE-M is a newly defined 3GPP RAT type Identifier used in the Core Network only, which is a sub-type E-UTRAN (LTE) RAT type, and defined to identify in the Core Network the E-UTRAN when used by a UE indicating LTE-M in its UE radio capability. The sub-type definition is TBD.

9.2 BEST (BATTERY EFFICIENT 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 + integrity)

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

EAS: Enterprise Application Server **HSE:** Home Security Endpoint

Table 1: 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 POWER CLASS 6 (14DBM)

To enable support of use cases associated with small device form factor and low power consumption (e.g. wearables), a new lower UE power class with a maximum transmission power of 14 dBm is introduced for Cat-M1 and Cat-M2, together with signaling support for the lower maximum transmit power with appropriate coverage relaxations.

As previously outlined in section 7.17, introducing lower power class devices may present some challenges for operators.

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 MPDCCH 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 MPDCCH and PDSCH 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 preamble 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.
- **Resynchronisation Signal (RSS):** The new Resynchronisation Signal (RSS) is a dense synchronisation signal of 2 PRBs wide and up to 40 ms long which can be transmitted any where within the system bandwidth. The RSS is transmitted much less frequently than PSS/SSS, but each RSS transmission contains more energy as it is much longer. Given the large energy density in the RSS, the UE may be able to acquire synchronisation for even the deepest coverage conditions with a single attempt (i.e. acquisition time is <= 40 ms) where if the PSS/SSS is used, many more PSS/SSS attempts are often needed taking >1 second. The RSS also communicates the new flag for unchanged SI (see below).
- **Improved MIB demodulation performance:** Reduced MIB acquisition time is enabled by enhanced CGI (i.e. cell global identity) reading delay requirements based on accumulation of transmissions within two 40-ms MIB periods.
- **Improved SIB demodulation performance:** Reduced SIB1/SIB2 acquisition time is enabled by enhanced CGI reading delay requirements based on accumulation of transmissions within one modification period.
- **Flag for unchanged system information (SI):** In previous releases, after long sleep periods, the UE must decode the SIB1 to determine if any system information (SI) has changed before it can send data. In Release 15, an SI Unchanged flag bit is introduced in MIB to let the UE know whether the SIB information has been updated during the last N hours (where N is the system information validity time, which is 3 or 24 hours). This typically means that the UE can save time and energy since it does not need to re-acquire SIB1 as often. The SI update indication is also replicated in RSS, implying that the UE may also be able to re-acquire MIB less often.

9.7 SPECTRAL EFFICIENCY IMPROVEMENTS

Increased spectral efficiency is achieved through higher order modulation, more efficient resource allocation and reduced inter-cell interference by the features listed in this section.

- **Flexible starting PRB:** To facilitate efficient scheduling of MTC-related data transmissions side by side with other transmissions (e.g. MBB-related PDSCH transmissions in downlink and PUCCH/PRACH in uplink), PDSCH/PUSCH resource allocation with a more flexible starting PRB (not restricted by 6-PRB narrowbands) is introduced for UEs that are configured in CE mode with max 1.4 MHz PDSCH/PUSCH channel bandwidth.
- **Downlink 64QAM support:** Support for 64QAM modulation is introduced for PDSCH unicast transmission without repetition in CE mode A to increase the downlink spectral efficiency. The UE peak rate is not increased.

- **CQI table with large range:** An alternative downlink channel quality information (CQI) table spanning a larger range is introduced. The new CQI table can be used by UEs configured with or without 64QAM support and even by UEs not supporting 64QAM. In the latter case, the large range of the CQI table can help reduce the need for RRC reconfigurations when the UE experiences varying channel conditions.
- **Uplink sub-PRB allocation:** Uplink spectral efficiency is improved by the introduction of PUSCH sub-PRB resource allocation in connected mode. New allocation sizes are 1/2 PRB (6 subcarriers) or 1/4 PRB (3 subcarriers). In the latter case, a new π/2-BPSK modulation using 1 at a time out of 2 of the 3 allocated subcarriers can be used to achieve near 0 dB baseband peak-to-average power ratio (PAPR), which may be beneficial for uplink data coverage and for UE power consumption.
- **Frequency-domain CRS muting:** Cat-M1 and Cat-M2 UEs can indicate support of CRS muting outside their 6-PRB narrowband or 24-PRB wideband, respectively, so that the network can take this information into account when deciding whether and how to perform CRS muting to reduce downlink inter-cell interference in the network.

9.8 FEEDBACK FOR EARLY TERMINATION

A possibility to carry a positive HARQ-ACK in an UL DCI over MPDCCH is introduced, primarily for UE power consumption improvement. This allows eNB to indicate to a UE that UL data has been successfully received and may enable early termination of downlink (MPDCCH) monitoring and/or (in case of FD-FDD or TDD but not HD-FDD) early termination of uplink (PUSCH) transmission.

9.9 IMPROVED ACCESS CONTROL

The legacy access barring mechanisms (ACB and EAB) do not distinguish between different coverage enhancement (CE) levels. In high load situations, it may be desired to temporarily bar access e.g. to the highest CE levels, since UEs in high CE levels may be associated with higher resource consumption due to dozens, hundreds or even thousands of repetitions.

A new mechanism for CE-level-based access barring is introduced in Release 15, which enables eNB to bar access per CE level. Note that if access is barred to a CE level, then access is also barred to all higher CE levels. The legacy barring mechanisms (ACB and EAB) are not affected by the new mechanism and they can be configured independently.

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;

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

- PSM (Power Save Mode)
- eDRX (Extended Discontinuous Reception)
- Support for extended coverage mode A
- LTE-M Half Duplex Mode
- CMM
- SMS
- Cat M1

For other features, such as VoLTE and HLCom MNOs don’t yet have consistent deployment plans. Therefore, VoLTE and HLCom are not key features for the short term deployment, and no related recommendations can be provided in this edition of the Deployment Guide.

SCEF is also not included in the key minimum requirements of this edition of the Deployment Guide as some MNOs surveyed by the GSMA plan to support SCEF but others have not yet decided. Some implementing it in phases, others going directly to full SCEF deployment. Those who will be deploying both NB-IoT and LTE-M networks might benefit from deploying SCEF, but it is an optional feature for LTE-M. Therefore, SCEF is not part of the minimum feature set required for the short-term deployment and this edition of the guide does not make recommendations for the SCEF functions to be exposed through network APIs.

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 explanation for each of these features.

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

Annex A 3GPP Standardised 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 to be considered with 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 it. 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. A solution 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 feature to limit Attach procedure impact in case of PLMN reselection (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 of 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 growth of number of MTC devices in the next years will induce a shortage of phone numbers (i.e. MSISDN). Operations without MSISDN in 2/3G PS core networks will be allowed. Some services are not supported at operation without MSISDN, like 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 to attach 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
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
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 sub frames, 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 UE becomes reachable again TS 23.682 § 4.5.7

REF no.	MIoT FEATURE	BENEFITS
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))
18	User plane CIoT Optimisations	User plane 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
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 Archi-tecture option for CIoT (C-SGN)	An EPS optimised for CIoT can be enabled by having 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 for Mobility and Attach procedures 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 Expo-sure Function (SCEF)	The Service Capability Exposure Function (SCEF) provides a means to securely expose service and network capabilities like resource management, communication patterns, 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 the 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 subscribers (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
24	Service Capability Expo-sure Function (SCEF)	The Service Capability Exposure Function (SCEF) provides a means to securely expose service and network capabilities like resource management, communication patterns, 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)

Annex B LTE-M Task Force Questionnaire – Release 1

The recommendations in this paper are based on the responses collected from the LTE-M Task Force mobile network operator members.

Below is the questionnaire that was used for gathering the deployment information. All responses to the questionnaire were anonymised and aggregated, to analyse operator plans for deploying LTE-M with PSM to ensure smooth interoperability and roaming treatment.

1. Deployment Bands: In which bands are you planning to deploy LTE-M in each of your markets?
2. What other cellular network (Type, Frequency band) may be used for back-up in area not covered by LTE-M (in order of priority)?

Example

- GSM 900 – E-GPRS
- GSM 1800

3. LTE-M Features: Which features are you planning to deploy that will affect roaming and/or configurations and should be agreed as part of the PSM/eDRX/TAU timer configuration settings?

  a. PSM (please select "yes" if you consider PSM a key feature, and provide the explanation to questions ii –v, or put "haven't decided yet" if this decision hasn't been made yet.
    i. yes/no
    ii. If yes, which configurations (e.g. timer limits) should be agreed and what is the maximum limits to the e-T3412 and T3324 timers (if different from limits fixed by the protocols?)?
    iii. If yes, which policy on packets is going to the device when it's in PSM (Ex: discard, store and forward all of them, store and forward last packet(s), store and forwards first packets(s))
    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?
    vi. Do you plan to offer customers visibility or management of PSM configuration in their devices?
      1. If Yes to "v.", and yes to "ii." – will Carrier perform an Override function if UE requests a value not supported by network?
      2. If Yes, what are Override Value Maximum for T3412 and T3324?

b. eDRX **(please select "yes" if you consider e-IDRX and e-CDRX a key feature, and provide the explanation to questions ii –v, or put "haven't decided yet" if this decision hasn't been made yet.)**
   i. yes/no
   ii. If yes, which configurations (e.g. timer limits) should be agreed, and will you set limits for the e-IDRX & e-CDRX value (if different from limits fixed by the protocols?)?
   iii. If yes, which policy on packets is going to the device when it's in e-IDRX & e-CDRX (e.g. Ex: discard, store and forward all of them, store and forward last packet(s), store and forwards first packets(s))
   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 e-IDRX & e-CDRX configuration in their devices?

c. GTP-IDLE Timer on IPX Firewall used:
   i. Yes/no
   ii. If yes which value:
   iii. If yes, which traffic separator do you support

d. Long Periodic TAU supported
   i. Yes/no
   ii. If yes, which configurations (e.g. timer limits) should be agreed?

ADDITIONAL LTE-M PLANNED FEATURE SET QUESTIONNAIRE:

1. Support of Cat M1

a. Half Duplex Mode
a. Yes / No
b. Full Duplex Mode
a. Yes / No
c. UE Class +23 dBm
a. Yes / No
d. UE Class +20 dBm
a. Yes / No

2. Extension of coverage features

a. Extension coverage Mode A
a. yes/no
b. Extension coverage Mode B
a. yes/no
c. Do you intend to limit the use of Mode A or Mode B to some range of device / use case
a. yes/no
b. if yes, what mechanism to limit the usage

3. 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?

4. Do you plan to deploy VoLTE calls in the future?

a. yes/no

b. VoLTE yes/no (only from 3GPP Rel 14)

5. Do you plan to provide SMS on LTE-M?

a. Yes / No

b. If yes: how?

c. If Yes – do you plan to provide SMS transfer without combined attach?

Annex C LTE-M Task Force Questionnaire – Release 2

This questionnaire is part of the study conducted by the GSMA as part of the production of the LTE-M Deployment Guide. All responses will be anonymised and aggregated, to analyse operator plans for deploying LTE-M ensure smooth interoperability and roaming treatment.

1. Deployment Bands: In which bands are you planning to deploy LTE-M in each of your markets?

(Currently in the LTE-M Deployment Guide: 1, 2, 3, 4, 5, 12, 13, 20, 26 and 28)

LTE Deployment Band	REGIONS

2. **Are you planning to deploy eDRX? (please select "yes" if you consider e-IDRX and e-CDRX a key feature, and provide the explanation to questions ii –v, or put "haven't decided yet" if this decision hasn't been made yet.)**
   i. yes / no
      a) If yes, which configurations (e.g. timer limits) should be agreed, and will you set limits for the e-IDRX & e-CDRX value (if different from limits fixed by the protocols?)?
      b) If yes, which policy on packets is going to the device when it's in e-IDRX & e-CDRX (e.g. Ex: discard, store and forward all of them, store and forward last packet(s), store and forwards first packets(s))
   i. If yes, will you set a limit to the amount or type of downwards information?
   ii. Do you plan to offer customers visibility or management of e-IDRX & e-CDRX con figuration in their devices?
   iii. Which policy, if any, are you recommending for e-IDRX and e-CDRX in combination with PSM?

3. **Do you plan to deploy VoLTE calls in the future?**
   i. yes/no
   ii. VoLTE yes/no (only from 3GPP Rel 14)
   iii. If yes, will you support VoLTE for Half-duplex, full-duplex or both?
   iv. If yes, will you support VoLTE for Mode A only or also Mode B?

4. **Do you plan to support the connected mode mobility**
   i. Yes for VoLTE calls only
   ii. Yes for VoLTE and other type of data traffic
   iii. No

5. **Do you plan to provide a continuity of service by complementing LTE-M to a backup 3GPP solutions**
   i. Yes / No
   ii. If yes: how?
   iii. If yes - do you plan to use SMS for SIM provisioning (Network originated)
   iv. If yes - do you plan to use SMS for SIM tools KIT application (SIM originated)
   v. If Yes – do you plan to provide SMS transfer without combined attach?
   vi. If yes, are you planning to support SMS over IMS? (Either long term or short term, if long term what would be the intermediate solution?)

7. Do you plan to deploy SCEF?
   i. Yes / No
   ii. 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, fol lowed by new SCEF based architecture, or SCEF from the start)
   iii. If Yes – which features are you planning to expose via APIs?