Massive IoT

TECHNICAL PRODUCT DESCRIPTION

9/221 02-AXB 250 17-V2 Uen HJ

Contents

1 Introduction

This document describes the Massive IoT features for the SGSN-MME.

1.1 Scope

The document covers the following features:

— Low Complexity UE Support

— Extended Coverage-GSM (EC-GSM) IoT Support

— Coverage Extension Support, LTE

— Extended Idle Mode Discontinuous Reception (eDRX)

— Power Saving Mode (PSM) for LTE, NB-IoT, and GSM

— Data over NAS (DoNAS)

— Monitoring Enhancements (MONTE)

— Configurable Battery Saving (CBS)

— Rate Control for CIoT EPS Optimization

1.2 Target Groups

This document is intended as an introduction to Massive IoT features for network operators, network and service planners, as well as system engineers and administrators. It assumes a basic knowledge of data communications and telecommunications.

2 Massive IoT Overview

The features described in this document are applicable for the Massive IoT use case, which requires resource optimizations. The core concept of Massive IoT is to focus on the following:

— Diverse use case requirements

— Many connected devices and low data volumes per device

- Applications are delay tolerant
- Increased battery life
- Extended coverage
- Security
- Two-way communication
- Reduced paging and signaling

2.1 Massive IoT Interfaces

Massive IoT has many applications depending on the various market scenarios. It is for this reason that the mobile market has broken down radio technologies into three distinct classes, which are supported by the SGSN-MME. For an overview of the three classes of radio technologies for IoT and the surrounding nodes, see Figure 1.

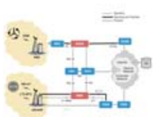

Figure 1 Massive IoT Network Overview

GSM Is applicable to IoT services for all GSM enabled UEs.

LTE for MTC (LTE-MTC)
Is applicable to a range of IoT applications consisting of Cat 1, Cat 0, and Cat-M1 UEs.

Narrowband IoT (NB-IoT)
Is a subset of RAT Type LTE and fulfills the connectivity requirements for massive MTC applications. NB-IoT has the same characteristics and configurations as LTE, unless specifically stated otherwise, and allows for many devices to send small amounts of data in parallel.

NB-IoT is applicable to a range of IoT applications that focus on low cost, extended coverage area, and lower battery consumption.

2.2 Massive IoT in SGSN-MME

The following Massive IoT features are supported in SGSN-MME:

Low Complexity UE Support

This licensed feature enables the MME to notify the eNodeB that the network is dealing with a low-complexity UE as specified by 3GPP.

EC-GSM IoT Support

This licensed feature extends GSM signal coverage in the radio network for Machine-Type Communication (MTC) devices.

Coverage Extension Support, LTE

This licensed feature extends LTE signal coverage in the radio network for Machine-Type Communication (MTC) devices.

eDRX for LTE, NB-IoT, and GSM

This licensed feature enables the SGSN-MME to support devices to enable the eDRX feature, that increases battery life by reducing the time available for paging.

Power Saving Mode for LTE, NB-IoT, and GSM

This licensed feature allows the SGSN-MME to support devices with PSM enabled, reducing the need for frequent recharging or changing batteries.

High Latency Communication

This feature allows the SGSN-MME to synchronize downlink payload delivery from the Application Server to UEs using PSM or eDRX.

PSM & eDRX Interworking

The SGSN-MME allows eDRX to be used during PSM Active Time.

Data over NAS

This licensed feature enables user data to be transported without setting up radio bearers in the RAN.

DoNAS, PDN type Non-IP

This feature allows NB-IoT UEs to use generic or proprietary data protocols, instead of sending an IP header with the data packets.

Monitoring Enhancements

This licensed feature enables monitoring of specific events that are normally internal to the MME and makes these events available to the Application Server (AS) through the Service Capability Exposure Function (SCEF) node.

Configurable Battery Saving

This feature allows local configuration values for PSM and eDRX parameters.

In additional, the SGSN-MME also supports the NB-IoT RAT type.

RAT Type: NB-IoT

Enables the MME to handle RAT type NB-IoT internally and to send the NB-IoT RAT type to the SGW, PGW, and the HSS. This enables full system support for UEs using NB-IoT access.

Table 1 Massive IoT Features Supported in SGSN-MME

Massive IoT Features	RAT TYPE		
	GSM	**LTE**	**NB-IoT**
Low Complexity UE Support	Not Supported	Licensed Feature	
Coverage Extension	Licensed Feature	Licensed Feature	
eDRX	Licensed Feature	Licensed Feature	
UE Power Saving Mode	Licensed Feature	Licensed Feature	
Monitoring Enhancement	Not Supported	Licensed Feature	
Configurable Battery Saving	Not Supported	Supported	Supported
High Latency Communication	Not Supported	Supported	Supported
Data over NAS	Not Supported	Not Supported	Licensed Feature
DoNAS, PDN type Non-IP	Not Supported	Not Supported	Licensed Feature

3 Low Complexity UE Support

The Low Complexity UE Support feature enables the MME to store the UE Radio Capability for Paging information and notify the eNodeB of this information in the `Paging` message. The presence of the UE Radio Capability for Paging information indicates that the network is dealing with a low-complexity UE as specified by 3GPP.

The UE Radio Capability for Paging information, if available, is transferred between the eNodeB and the MME in the following procedures:

— UE Capability Info Indication

  If the Low Complexity UE Support license state is granted, the MME stores the information included in the `UE Radio Capability for Paging` IE of the `UE CAPABILITY INFO INDICATION` message sent from the eNodeB.

  For more information, see S1-MME Interface Description.

— Paging

  If the Low Complexity UE Support feature state is on, the MME includes the `UE Radio Capability for Paging` IE in the `Paging` message sent to the eNodeB. For more information, see LTE Mobility Management.

  For the UE Restoration upon the DDN with the IMSI procedure within Geographically Redundant Pool, the UE Radio Capability for Paging information is handled in the same way in the Paging procedure. For more information, see Geographically Redundant Pool.

The UE Radio Capability for Paging information, if available, is transferred between the MMEs in the following procedures and operations:

— Attach

  If theLow Complexity UE Support feature state is on, the old MME includes the UE Radio Capability for Paging information in the `MM Context` IE of the `Identification Response` message sent to the new MME.

  If the Low Complexity UE Support license state is granted, the new MME stores the UE Radio Capability for Paging information.

  For more information, see LTE Mobility Management.

— Inter-MME TAU

  If Low Complexity UE Support feature state is on, the old MME includes the UE Radio Capability for Paging information in the `MM Context` IE of the `Context Response` message sent to the new MME.

  If the Low Complexity UE Support license state is granted, the new MME stores the UE Radio Capability for Paging information.

  For more information, see LTE Mobility Management.

— Inter-MME Handover

  If the Low Complexity UE Support feature state is on, the source MME includes the UE Radio Capability for Paging information in the `MM Context` IE of the `Forward Relocation Request` message sent to the target MME.

If the Low Complexity UE Support license state is granted, the target MME stores the UE Radio Capability for Paging information.

For more information, see the LTE Mobility Management.

— UE Smooth Move within MME Pool

  If theLow Complexity UE Support feature state is on, the source MME includes the UE Radio Capability for Paging information in the `MM Context` IE of the `Forward Relocation Request` message sent to the target MME.

  If theLow Complexity UE Support license state is granted, the target MME stores the UE Radio Capability for Paging information.

  For more information, see MME Pool.

— UE Geo-Replication within Geographically Redundant Pool

  If the Low Complexity UE Support license state is granted and the UE Radio Capability for Paging information changes, the serving MME immediately updates this information to the replication MME (R-MME).

  For more information, see Geographically Redundant Pool.

The following interfaces are affected if the Low Complexity UE Support feature is enabled:

— S1-MME interface

  The optional `UE Radio Capability for Paging` IE is included in the `Paging` message sent to the eNodeB.

— S10 interface

  The optional UE Radio Capability for Paging information is included in the `MM Context` IE of the following messages sent between the MMEs:

  - `Identification Response`
  - `Context Response`
  - `Forward Relocation Request`

For information about enabling the Low Complexity UE Support feature, see Features and Functions Management.

For more information about configuring the Low Complexity UE Support feature, see Configuring Massive IoT.

4 Paging in IoT

The MME receives RAT type per Tracking Area (TA) in the S1 SETUP REQUEST message and in the ENB CONFIGURATION UPDATE message, sent from the eNodeB. The RAT type is stored per TA in the MME.

Based on the RAT type, the MME includes one of the following IE in the S1 Paging message sent to the eNodeB:

— For LTE, the Extended UE Identity Index Value IE is included. This IE is used by the eNodeB when paging UEs with RAT type LTE.

— For NB-IoT, the NB-IoT UE Identity Index Value IE is included. This IE is used by the eNodeB when paging UEs with RAT type NB-IoT.

For information on paging devices using eDRX, see Extended Idle mode Discontinuous Reception.

4.1 Paging Timer and Adaptive Paging

The paging timer value controls when to resend the paging message, if there is no response from the UE.

When paging NB-IoT UEs using CE and Cat-M1 UEs that support CE Mode B operating in either CE Mode A or CE Mode B, the MME needs additional time before resending the paging message. Therefore, the paging timer is extended.

For paging NB-IoT UEs using CE, the MME uses the value configured by the S1NBT3413PagingTimer parameter.

For paging Cat-M1 UEs that support CE Mode B operating in either CE Mode A or CE Mode B, the MME uses the value configured by the S1T3413WbCeModeBPagingTimer parameter.

If Adaptive Paging is used, the ProfileT3413PagingTimer parameter can be configured in the paging profile table. This timer has a range of 320 -15000 milliseconds. Usually, the upper range limit of 15 seconds for the paging timer is too short for NB-IoT UEs using CE. This range is also too short for Cat-M1 UEs that support CE Mode B operating in either CE Mode A or CE Mode B. If the ProfileT3413PagingTimer is configured, it overrides the S1NBT3413PagingTimer or S1T3413WbCeModeBPagingTimer. If no value is configured for the ProfileT3413PagingTimer, the S1NBT3413PagingTimer with a default value of 30 seconds is used instead for NB-IoT UEs. The S1T3413WbCeModeBPagingTimer with a default value of 15 seconds is used for Cat-M1 UEs that support CE Mode B operating in either CE Mode A or CE Mode B.

Note: If Adaptive Paging is used, Ericsson recommends not to configure the `ProfileT3413PagingTimer` when creating the paging profile for NB-IoT UEs using CE and Cat-M1 UEs that support CE Mode B operating in either CE Mode A or CE Mode B.

5 Coverage Extension Support

Coverage Extension Support in SGSN-MME includes the following features:

— EC-GSM IoT Support

— Coverage Extension Support, LTE

When these features are enabled, the signal coverage is extended through repeated signaling over the radio interface. Coverage Extension Support results in an improved signaling range, and increased signaling quality between connected MTC devices and the radio network.

5.1 EC-GSM IoT Support

The SGSN-MME provides the Extended Coverage-GSM (EC-GSM) IoT Support feature, which extends GSM coverage by the process of repeating the message sent over the air interface. This process allows for an improved coverage, while still maintaining the quality of the signal between MTC devices and the radio network. The number of repetitions performed is defined by the Coverage Class parameter. The radio network informs the SGSN-MME of the Coverage Class being used. During the MS signaling procedures, Coverage Class information is exchanged to extend NAS timers.

For information about enabling the EC-GSM IoT Support feature, see Features and Functions Management.

For more information about configuring the EC-GSM IoT Support feature, see Configuring Massive IoT.

5.2 Coverage Extension Support, LTE

The Coverage Extension Support, LTE feature extends LTE and NB-IoT signal coverage in the radio network for LTE-MTC and NB-IoT devices. The signal coverage is extended through repeated signaling between the UE and the eNodeB, resulting in improved radio coverage over the radio network.

The MME stores the `Cell Identifier and Coverage Enhancement Level` IE, if it is present in the `UE Context Release Complete` message received from the eNodeB during procedures, such as S1 Release or TAU.

If the feature is enabled, the MME uses the stored information in the `Assistance Data for CE capable UEs` IE during the paging procedure. The `Assistance Data for CE capable UEs` IE and the `Paging Attempt Information` IE is included in the `Assistance Data for Paging` IE in the `Paging` message sent from the MME to the eNodeB.

Many UEs in Coverage Extension (CE) mode can increase CPU load.

The S1-MME interface is affected if the Coverage Extension Support, LTE feature is enabled. For more information, see S1-MME Interface Description.

For information about enabling the Coverage Extension Support, LTE feature, see Features and Functions Management.

For more information about configuring this feature, see Configuring Massive IoT.

5.2.1 CE Mode for CAT-M1 UEs

The Coverage Extension (CE) Mode is used by the MME to determine how long the S1-AP-related time-out values, the paging timer, and the NAS timers need to be extended, during UE signaling procedures.

There are two CE modes applicable for Cat-M1 UEs when using Coverage Extension for LTE. The CE modes are CE Mode A and CE Mode B.

When a UE supports CE Mode B, the `CE-mode-B Support Indicator` IE is sent in the `S1 Initial UE` message from the eNodeB to the MME, or in the `Handover Request Acknowledge` message from the target eNodeB to the MME.

The MME detects if a UE supports CE Mode A by reading the `UE Radio Capability` IE sent from the eNodeB to the MME. The supported CE Mode is presented in the get_subscriber CLI command.

5.2.2 CE for CAT-NB UEs

For Cat-NB UEs, it is mandatory to use Coverage Extension (CE). For Cat-NB UEs located in a narrowband TA, the MME expects that CE is used without receiving any indication from the eNodeB.

As for CE Modes A and B, the MME uses the CE information in the `UE Context Release Complete` message received from the eNodeB. The MME then returns it to the eNodeB during the paging procedure.

CE Modes A and B are not applicable for Cat-NB UEs, and are therefore not presented in the get_subscriber CLI command.

5.2.3 Extended Timers

When the Coverage Extension Support, LTE feature is enabled, the S1-AP-related time-out values and the NAS timer are extended, depending on the following:

— For UEs that support CE Mode A, the MME extends the S1-AP-related time-out values to a value of one second less than the NAS timer.

— For Cat-M1 UEs that support CE Mode B and for Cat-NB UEs, the MME extends the NAS timer value in various procedures, for example, during a Service Request procedure. The MME also extends the S1-AP-related time-out values to a value of one second less than the extended NAS timer.

The value that the NAS timer value is extended to depends on RAT Type and follows the values stipulated by 3GPP. For more information, see SoC with 3GPP TS 24.301 and Table 2.

The S1-AP-related time-out values are extended for messages over the S1-MME interface that depend on an answer from the UE, for example the `INITIAL-CONTEXT-SETUP` message.

When a UE is Cat-M1 UE, the `CE-mode-B Support Indicator` IE is sent in the `Handover Request Acknowledge` message from the target eNodeB to the MME. The S1-AP-related timer-out values and the NAS timers are extended according to the timer extension for Cat-M1 UEs that support CE Mode B operating in either CE Mode A or CE Mode B before the UE enters into ECM-IDLE state. See Table 2.

The CPU and memory load of the MME can increase if the timer is extended for the Cat-M1 and Cat-NB UEs. When the Coverage Extension Support, LTE feature is disabled, the S1-AP-related time-out values and the NAS timer value are not extended.

The relationship between CE modes and the timer extension during the procedures, such as Paging, S1 Release, or TAU, is listed in the following table:

Table 2 Timer Extension for UE Using CE Modes

RAT Type and CE Mode	NAS Timer	S1 Timer	Paging Timer T3413
Cat-M1 UEs that support CE Mode A	The NAS timer value is not extended and configured according to 3GPP: • The value for EPS mobility management is 6 seconds. • The value for EPS session management is 8 seconds.	The MME extends the following S1 timers with a default value of 5 seconds: • S1TInitialContextSetup • S1TERabModify • S1TERABReleaseCmd • S1TERABSetupReq • S1TUeContextModification	If Adaptive Paging is used, the ProfileT3413PagingTimer parameter can be configured in paging profile table. If no value is configured for the `ProfileT3413PagingTimer`, the S1T3413PagingTimer parameter is used.

Cat-M1 UEs that support CE Mode B and Operate in CE Mode A or CE Mode B	According to 3GPP TS 24.301.	The MME extends the following S1 timers with a default value: • S1TInitialContextSetup, the default value is 17 seconds. • S1TERabModify, the default value is 15 seconds • S1TERABReleaseCmd, the default value is 15 seconds • S1TERABSetupReq, the default value is 15 seconds • S1TUeContextModification, the default value is 17 seconds	The MME uses the value configured by the S1T3413WbCeModeBPagingTimer parameter. When the Adaptive Paging is used, the paging timer is configured as follows: • If the `ProfileT3413PagingTimer` parameter is configured, it overrides the `S1T3413WbCeModeBPagingTimer` parameter. • If no value is configured for the `ProfileT3413PagingTimer`, the `S1T3413WbCeModeBPagingTimer` with a default value of 15 seconds is used.
Cat-NB UEs	According to 3GPP TS 24.301, the NAS timers are extended with fixed values: • The value for EPS mobility management is 246 seconds. • The value for EPS session management is 188 seconds.	The S1 timer is hard-coded to 245 seconds.	The MME uses the value configured by the S1NBT3413PagingTimer parameter. When the Adaptive Paging is used, the paging timer is configured as follows: • If the `ProfileT3413PagingTimer` parameter is configured, it overrides the `S1NBT3413PagingTimer` parameter. • If no value is configured for the `ProfileT3413PagingTimer`, the `S1NBT3413PagingTimer` with a default value of 30 seconds is used.

6 Extended Idle Mode Discontinuous Reception

The Extended Idle Mode Discontinuous Reception (eDRX) feature improves the battery life of a device by reducing the time available for paging.

The eDRX licensed feature is supported for LTE, NB-IoT, and GSM access type.

For more information on configuring the eDRX feature, see Features and Functions Management.

For more information about configuring this feature, see Configuring Massive IoT.

6.1 Extended Idle Mode Discontinuous Reception for LTE

For LTE and NB-IoT access types, an eDRX enabled device has a Paging Time Window, at regular intervals, where it can be reached by paging requests. When outside the Paging Time Window, the UE cannot be reached by paging requests. For devices that have eDRX enabled, the MME supports delaying paging requests until the device opens the Paging Time Window.

The eDRX feature can be used with CE Mode A or CE Mode B. For more information about Coverage Extension, see Coverage Extension Support, LTE.

Note: A device can request both PSM and eDRX, which allows it to configure PSM and eDRX parameters depending on the requirements of the IoT service or application.

If the Active Timer value is greater than `0` and less than the value of eDRX Cycle + Paging Time Window, the MME adjusts the Active Timer value to the value of eDRX Cycle + Paging Time Window.

In a PSM and eDRX combination, where Active Timer = `0`, the eDRX parameters are accepted but not used, because PSM causes the device to be unreachable during IDLE state, and blocks any Paging Occasion.

Mobile Terminated Location Requests for eDRX enabled UEs are not possible. This is because when the GMLC sends a `Provide Subscriber Location Request` to the SGSN-MME for an eDRX enabled UE, the SGSN-MME rejects the request by returning `DIAMETER_ERROR_UNREACHABLE_USER` result code to the GMLC.

For more information about legacy behavior for Mobile Terminated Location Request, see Control-Plane-Based Positioning.

6.1.1 Attach and TAU Procedures

The UE requests eDRX by including the `Extended DRX Parameters` IE, during an `Attach Request` or a `TAU Request` message procedure.

The `Extended DRX Parameters` IE includes:

- The length of the eDRX cycle, `eDRX cycle, TeDRX` parameter.
- The length of the Paging Time Window, `Paging Time Window` parameter.

If the MME accepts the request, the MME includes the `Extended DRX Parameters` IE in the `Attach Accept` or the `TAU Accept` response. The MME can modify the `Extended DRX Parameters` IE. For more information, see Section 8 on page 27.

If the `Extended DRX Parameters` IE is not included in the `Attach Accept` or the `TAU Accept` response, the UE does not use eDRX mode.

To continue using eDRX, the UE must include the `Extended DRX Parameters` IE in every `Attach` or `TAU` procedure.

If the MME receives a UE `Attach Request` including `Extended DRX Parameters` over the SGs-Lite interface, the MME does not include `Extended DRX Parameters` in the `Attach Accept` response. This means that eDRX over SGs-Lite interface is not possible.

At inter-MME TAU with SGW relocation, pending payload on the source SGW is not forwarded to the target SGW.

For more information on Inter-MME mobility, see LTE Mobility Management.

6.1.2 Paging Procedure

When using eDRX, the Paging Preparation Time is used to specify the time, before the UE opens the next Paging Time Window, when the MME starts the Paging procedure. The Paging Preparation Time is configured with the `PagingPreparationTime` parameter.

A delayed paging procedure to a UE using eDRX is in the pending state until it is executed or discarded by the MME.

6.1.2.1 Paging for EPS Service

Figure 2 shows the Paging procedure for a UE with eDRX enabled because of EPS service.

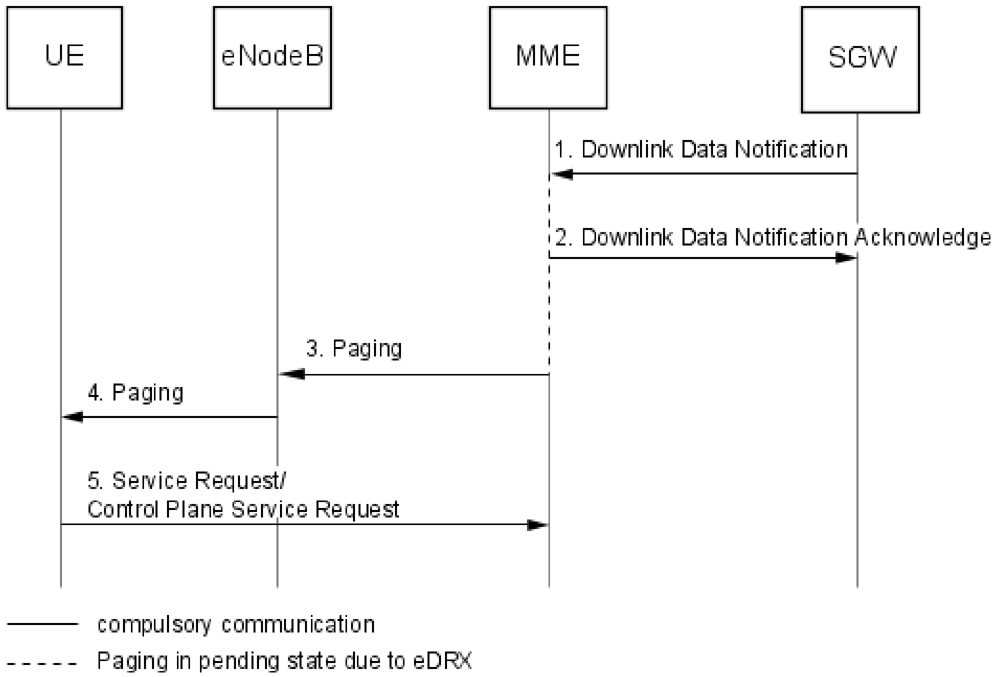

Figure 2 Paging Procedure for a UE with eDRX Enabled Because of EPS Service

The following steps describe the Paging procedure for a UE with eDRX enabled when EPS service is initiated:

1. The SGW sends a `Downlink Data Notification` to the MME. If the UE is not currently reachable for paging, the MME calculates when the UE opens its next Paging Time Window and sets the `Buffered DL Data Waiting Indication` flag.

2. The MME sends the `Downlink Data Notification acknowledge` to the SGW, which includes the parameter `DL Buffering Duration`. The `DL Buffering Duration` parameter specifies the amount time the SGW buffers the Downlink Payload and is equal to four times the `eDRX cycle, TeDRX` parameter.

3. Just before the next Paging Time Window opens (Paging Preparation Time), the MME starts the Paging procedure.

4. According to the selected paging profile, and while the Paging Time Window is open, the MME attempts to send `Paging` messages to the UE. The `Paging` message to the UE contains the `Extended DRX Parameters` IE.

5. If Paging is successful, the Service Request or Control Plane Service Request procedure continues.

When a paging procedure is in pending state, and the MME is interrupted by an initial UE message, the paging procedure is discarded, and the user plane is set up during the initial UE message procedure. The measurement VS.M2M.NbrPendingPagingEdrxUe.E is decremented, and because no paging procedure is performed by the MME, the measurements VS.M2M.PagingEdrxUeAtt.E and VS.M2M.PagingEdrxUeSucc.E are not affected.

The Adaptive Paging feature can be used with eDRX for LTE and NB-IoT. The MME does the following if it cannot reach the UE during the Paging Time Window:

1. The MME stores the next applicable paging width in the paging profile.
2. The MME attempts to reach the UE using the updated paging profile.
3. The MME modifies the paging profile to start from the stored paging width.
4. The following EBM events show updated values of the paging profile.
    - PAGING_ATTEMPTS_ENB
    - PAGING_ATTEMPTS_ENB_LIST
    - PAGING_ATTEMPTS_TA
    - PAGING_ATTEMPTS_TA_LIST
5. The MME repeats steps 1–4, as long as there are remaining paging widths in the paging profile. If there are no more paging widths in the paging profile, the MME sends `Downlink Data Failure Indication` to SGW.
6. The stored paging width is cleared if a TAU, Service Request, Attach, or Detach procedure occurs.

For more information on Paging and Service Request procedures, see LTE Mobility Management.

6.1.2.2 Paging for Mobile-Terminated SMS

eDRX is supported for SMS over SGs. This support applies to both NB-IoT and LTE-MTC, Cat-M1 UEs included.

Figure 3 shows the Paging procedure for a UE with eDRX enabled because of MT-SMS.

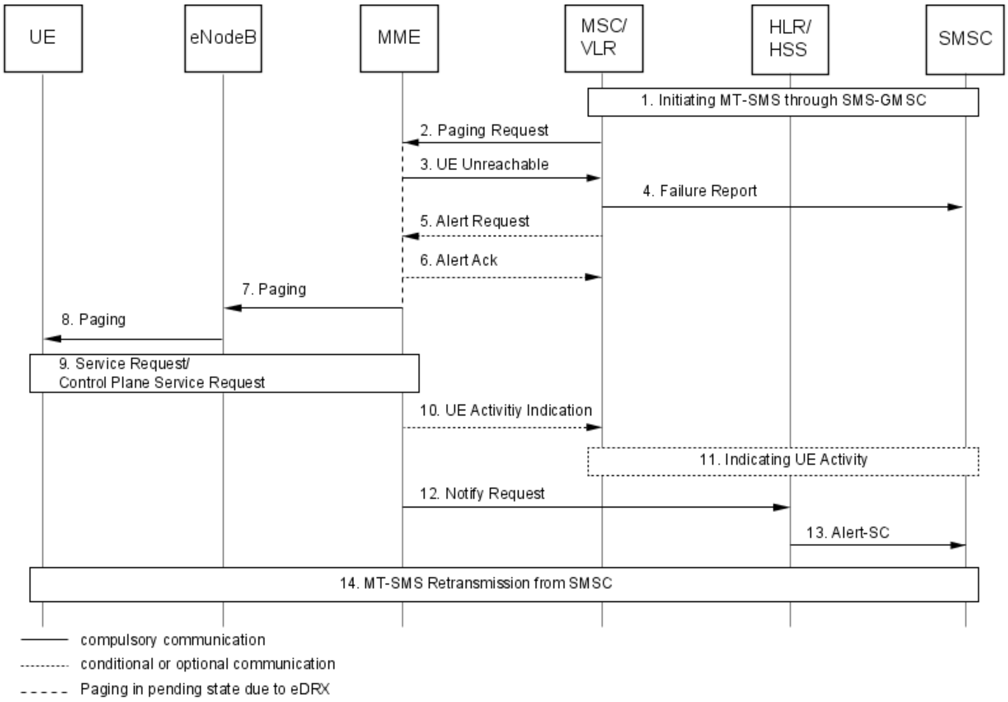

Figure 3 Paging Procedure for a UE with eDRX Enabled Because of MT-SMS

The following steps describe the eDRX Paging procedure for a UE with eDRX enabled when MT-SMS is initiated:

1. The SMSC initiates transfer of MT-SMS. The SMS message is forwarded through the SMS-GMSC to the MSC/VLR where the UE is CS attached.

2. The MSC/VLR sends an SGsAP `Paging Request` message to the MME. The `Service indicator` IE carried in the message is set to `SMS indicator`.

3. If the UE using eDRX is unreachable for paging, the MME sends the MSC/VLR a `UE Unreachable` message with an SGs cause code configurable by the SGsCauseForMtSmsUnderEdrx parameter.

4. The MSC/VLR sends the SMSC a `Failure Report` message.

5. (Optional) The MSC/VLR requests UE activity notice by sending an `Alert Request` message to the MME.

6. (Optional) The MME sends the MSC/VLR an `Alert Ack` message in response.

7. The MME calculates when the UE opens its next Paging Time Window. Just before the next Paging Time Window is opened, the MME starts the Paging procedure by sending the eNodeB a `Paging` message. The `Paging` message carries the following IEs:

   — `Paging eDRX Information` and `Extended UE Identity Index Value` in LTE-MTC cases

— NB-IoT Paging eDRX Information and NB-IoT UE Identity Index value in NB-IoT cases

8. The UE is paged by the eNodeBs.

9. If the paging is successful, the UE sends the MME a Service Request or Control Plane Service Request message. In response to the Control Plane Service Request message, the MME sends the UE a Service Accept message.

10. (Optional) If alert is requested by the MSC/VLR, the MME sends the MSC/VLR a UE Activity Indication message when it learns that the UE becomes active.

11. (Optional) The MSC/VLR indicates UE activity to the SMSC through the HLR and the HSS.

12. The MME notifies the HSS that the UE is now reachable by sending a Notify Request message.

    Note: Whether the MME sends the Notify Request message when it has alerted the MSC/VLR to the UE activity is determined by the dual_notify_for_mt_sms_under_power_saving parameter setting.

13. The HSS sends an Alert-SC message to the SMSC.

14. MT-SMS transmission is initiated again.

    Note: The MSC/VLR needs to send a Paging Request message and wait for an SGsAP Service Request message before the MME handles the SMS message transmitted from the MSC/VLR.

For more information about the MT-SMS procedure, see EPS Support for CS Services.

For more information about SMS transport over NAS for UEs that use the NB-IoT RAT type, see Section 10.3 on page 37.

6.1.3 Resilient eDRX Session at AP Takeover

The SGSN-MME replicates the connection data for eDRX subscribers to a redundant AP. The eDRX data transferred to the AP replica includes:

— Paging Profile Width

— The Buffered DL Data Waiting Indication flag status.

— The time stamp of the next Paging Time Window.

After the AP Takeover:

— For UE initiated signaling:

  - If the `Buffered DL Data Waiting Indication` flag is set, user plane is set up to allow the GW to send payload.

  - If the `Buffered DL Data Waiting Indication` flag is not set, the MME takes no eDRX related action.

— For network initiated signaling, DDN, start a new eDRX paging procedure which can use a saved paging profile width.

— For automatic wake-up one hour after AP Takeover, if the saved time stamp has not passed, the MME starts the paging procedure in the next Paging Time Window.

For more information about AP Takeover, see Resilience.

6.2 Extended Idle Mode Discontinuous Reception for GSM

For GSM, if the MS requests the eDRX, the MS sends the extended DRX parameters to the SGSN during an Attach or RAU procedure. When the eDRX is enabled, the MS can only be paged at the Paging Occasion (PO) in each eDRX cycle.

The eDRX capability is negotiated through the `Extended Feature Bitmap` IE during the BVC-RESET procedure between SGSN and the BSC. Bit 7 `eDRX` of the `Extended Feature Bitmap` IE indicates whether optional feature eDRX is supported by the SGSN and the underlying Network Service Entity (NSE) in the BSC. For more information about BVC-RESET procedure, see Gb Interface Description.

6.2.1 Attach and RAU Procedures

The MS requests eDRX by including the `Extended DRX Parameters` IE in an `Attach Request` or `RAU Request` message.

If the SGSN accepts the request, the SGSN includes the `Extended DRX Parameters` IE in the `Attach Accept` or `RAU Accept` message.

If the MS wants to continue using eDRX, the MS must include the `Extended DRX Parameters` IE in every `Attach Request` or `RAU Request` message.

6.2.2 Paging Procedure

When the SGSN receives the downlink data or signaling and the MS is in eDRX mode, the SGSN performs the Paging procedure based on the Time Until Next Paging Occasion (TUNPO).

Note: The SGSN performs Paging procedure without considering the TUNPO if:

- The MS is using one of the following two shortest eDRX cycles:
  - eDRX cycle value: `0000`; eDRX cycle length: 1.9 seconds
  - eDRX cycle value: `0001`; eDRX cycle length: 3.8 seconds
- The MS is using the eDRX cycle that is shorter than the time configured by the parameter `PagingTimingAdvance`.

For more information on Paging procedure, see GSM Mobility Management.

6.2.2.1 Paging without TUNPO

For an MS in eDRX mode, if the SGSN receives the downlink data or signaling from the GGSN while the TUNPO is not available: the SGSN performs the blind Paging procedure by sending a `Paging PS` message including the `eDRX Parameters` IE to the BSC. This is also used for time synchronization between the SGSN and the BSC.

Figure 4 shows the Paging procedure without TUNPO when the SGSN receives the downlink data or signaling from the GGSN.

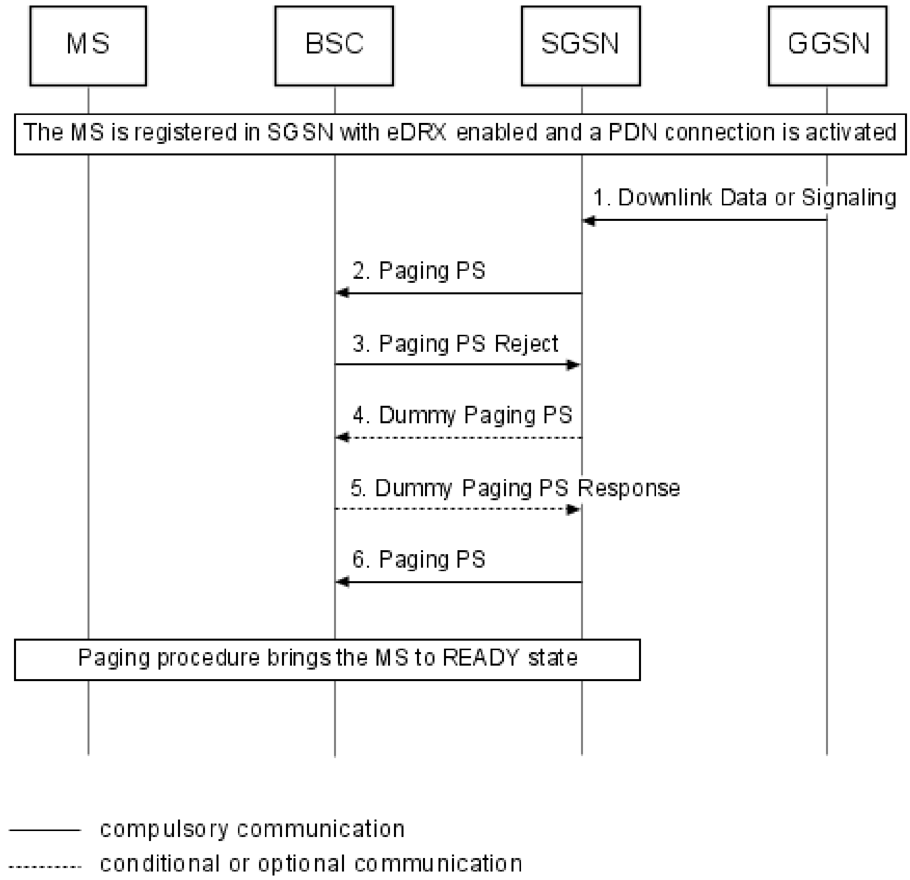

Figure 4 Paging without TUNPO When SGSN Receives the Downlink Data or Signaling

The following steps describe the Paging procedure without TUNPO when the SGSN receives the downlink data or signaling from the GGSN:

1. The GGSN sends the downlink data or signaling to the SGSN.

2. If the TUNPO is not available for the MS, the SGSN sends a `Paging PS` message including the `eDRX Parameters` IE to the BSC immediately.

3. If the BSC cannot page the MS, the BSC responds to the SGSN with a `Paging PS Reject` message including the TUNPO for this MS. After the SGSN receives the `Paging PS Reject` message, the measurement VS.M2M.PagingEdrxUeRej.G is incremented.

   Note: If the UE Tracer feature is activated for the MS in eDRX mode, the `Paging PS Reject` message is traced over the Gb interface and recorded in the UE tracer log for the MS. For information on UE Tracer, see UE Tracer and UE Tracer Log.

4. If the eDRX cycle value the SGSN sent in `Paging PS` message in Step 2 is not the maximum eDRX cycle value, the SGSN sends a `Dummy Paging PS`

message with the maximum eDRX cycle value to the BSC. The maximum eDRX cycle value: `1011`, eDRX cycle length: 52 minutes.

5. The BSC responds to the SGSN with a `Dummy Paging PS Response` message including the TUNPO.

   Note: The SGSN can use the TUNPO received in this step to calculate the TUNPO for any other MS within the same RA.

6. The SGSN sends a `Paging PS` message to the BSC based on the TUNPO for this MS in Step 3.

   The SGSN sends the `Paging PS` message to the BSC before the PO. The advanced time is configured by the parameter `PagingTimingAdvance`.

6.2.2.2 Paging with TUNPO When Receiving Downlink Data

For an MS in eDRX mode, if the SGSN receives the downlink data from the GGSN and the TUNPO is available, the SGSN performs Paging procedure based on the TUNPO.

Figure 5 shows the Paging procedure with TUNPO when the SGSN receives the downlink data from the GGSN. This procedure is performed when the SGSN is already time-synchronized with the BSC.

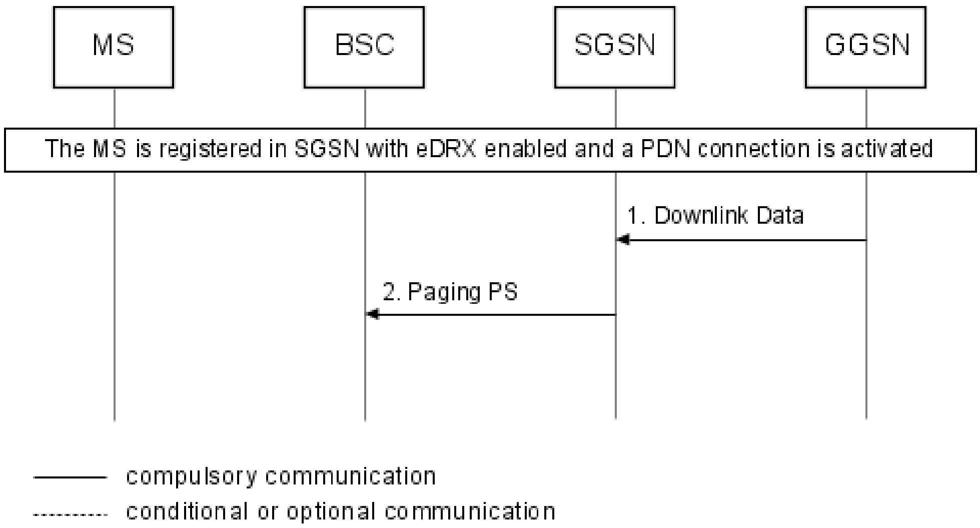

Figure 5 Paging with TUNPO When SGSN Receives the Downlink Data

The following steps describe the Paging procedure with TUNPO when the SGSN receives the downlink data from the GGSN:

1. The GGSN sends the downlink data to the SGSN.

2. The SGSN waits until next PO to send a `Paging PS` message including the `eDRX Parameters` IE to the BSC.

If no response is received from the MS, after the `T3313` timer expires, the SGSN reattempts the Paging procedure according to the `N3313` number at next PO.

Note: The SGSN sends each `Paging PS` message to the BSC before the PO. The advanced time is configured by the parameter `PagingTimingAdvance`.

6.2.2.3 Paging with TUNPO When Receiving Downlink Signaling

For an MS in eDRX mode, if the SGSN receives the downlink signaling from the GGSN and the TUNPO is available, the SGSN performs Paging procedure based on the TUNPO.

Figure 6 shows the Paging procedure with TUNPO when the SGSN receives the downlink signaling from the GGSN during the Network-Requested Secondary PDP Context Activation (NRSPCA) and GGSN-Initiated PDP Context Modification procedures.

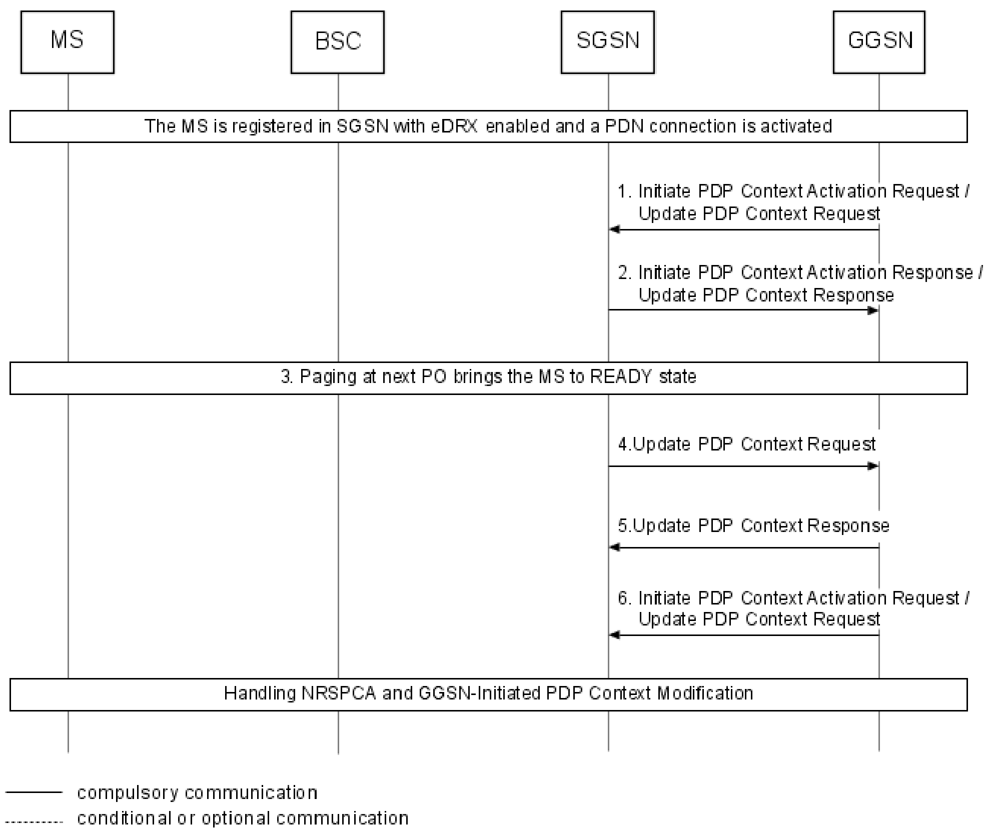

Figure 6 Paging with TUNPO When SGSN Receives the Downlink Signaling

The following steps describe the Paging procedure with TUNPO when the SGSN receives the downlink signaling from the GGSN:

1. The GGSN sends an `Initiate PDP Context Activation Request` or `Update PDP Context Request` message to the SGSN.

Note: During the PDP Activation procedure, if the SGSN receives a Create PDP Context Response message including a Delay Tolerant Connection Indication (DTCI) flag is set to 1, this indicates that the PDN connection is delay tolerant.

2. If the PDN connection is delay tolerant, the SGSN does the following:

   — Sets the internal Pending Network Initiated PDN Connection Signaling (PNSI) flag to 1, and

   — Responds to the GGSN with a cause code UE is temporarily not reachable due to power saving in the Initiate PDP Context Activation Response or Update PDP Context Response message.

3. The SGSN waits until next PO to page the MS based on the TUNPO. The MS enters the READY state when the SGSN receives an uplink LLC PDU for user data, signaling, or any valid LLC frame serving as a paging response.

4. If the internal PNSI flag is set to 1, the SGSN sends the GGSN an Update PDP Context Request message with the UE available for Signaling Indication (UASI) flag set to 1.

5. The GGSN responds to the SGSN with an Update PDP Context Response message.

6. The GGSN resends the Initiate PDP Context Activation Request or Update PDP Context Request to the SGSN.

Note:

If the GGSN initiates the PDP Context Deactivation procedure by sending a Delete PDP Context Request message to the SGSN for an MS using eDRX, the SGSN does the following:

— Deletes the PDP Context locally, and

— Responds to the GGSN with the cause code Request Accepted in the Delete PDP Context Response message.

7 Power Saving Mode

The SGSN-MME supports Power Saving Mode (PSM) enabled devices, for instance M2M and IoT devices, which require longer battery life than conventional UEs. For information on configuring the PSM for GSM feature or the PSM for LTE feature, see Features and Functions Management.

7.1 PSM for GSM

PSM for GSM allows a device, at Attach and RAU, to request an Active Timer with a T3324 value and optionally a Periodic RAU Timer with aT3312 extended value to enable PSM. PSM can also be enabled with an Active Timer value that equals zero. Timer values can be adjusted by SGSN-MME. If the requested Active Timer value is greater than zero and less than two DRX cycles +10 s, the SGSN-MME adjusts the value to two DRX cycles +10 s. If eDRX is enabled in the device and the requested Active Timer value is greater than zero and less than two eDRX cycles +10 s, the SGSN-MME adjusts the value to two eDRX cycles +10 s. The Periodic RAU Time is greater than the Active Time. PSM for GSM is granted for home subscribers only.

In the SGSN-MME, the Active Timer and the Mobile Reachable Timer are started when the device goes to MM state STANDBY_REACHABLE. During the Active Time, the device can be reached by paging. When the Active Timer expires, the device enters PSM and does not listen to paging. The MM state is set to STANDBY_NOT_REACHABLE and PPF flag is cleared. Until the next signaling from the device, for example periodic RAU, the SGSN-MME does not attempt to page the device. For more information on MM states, see GSM Mobility Management.

The number of devices currently in PSM is measured using the VS.MM.NbrAttachedPsm.G gauge. Active Time and Periodic RAU Time are shown using the get_subscriber CLI command, and recorded in EBM. The time a device is in PSM is recorded through the EXIT_PSM EBM event.

GSM payload packets being transferred in the downlink direction can be temporarily stored by the scheduling function while waiting to be transmitted to the device. When the device is in PSM, the payload buffer timer can expire and the payload is discarded.
The number of IP packets buffered or discarded because of suspended Logical Link Control (LLC) between the device and the SGSN for the device in PSM is measured using the bssgpDownlinkPacketsBuffLlcSuspendedPsm and the bssgpDownlinkPacketsDiscardLlcSuspendedPsm counters respectively. For more information on SGSN-MME payload flow control, see Payload Handling and Quality of Service.

For more information about configuring the PSM for GSM feature, see Configuring Massive IoT.

7.2 PSM for LTE

PSM for LTE allows a device, at Attach and TAU, to request an Active Timer with aT3324 value and optionally a Periodic TAU Timer T3412 extended value to enable PSM. PSM can also be enabled with and Active Timer value that equals zero. Timer values can be configured and adjusted by the SGSN-MME. For more information on timer value configuration, see Section 8 on page 27. If the Active Timer value is greater than zero and less than “2 x DRX-cycle + 10 s”, the SGSN-MME adjusts the value to “2 x DRX-cycle + 10 s” or accepts the value regardless of the DRX cycle length, depending on the configuration of the parameter MinActiveTimeBasedOnDrxLte.

The Periodic TAU Timer value is selected in the following order:

1. The `T3412 extended` value requested by the device in Attach or TAU request

2. The `Subscribed-Periodic-RAU-TAU-Timer` value received in the subscription data from the HSS, if the SubscribedMobileReachableTimerAllowed parameter is set to `true`

3. The `S1MobileReachableTimer` value minus 4 minutes

The Periodic TAU Timer value is greater than the Active Timer value. To avoid signaling storms, the SGSN-MME adds a random value between 1–3240 seconds to the Periodic TAU Timer by default. An operator can disable the addition of a random value to the Periodic TAU timer value for PSM devices with the node function psm_add_random_value_to_ptau_timer by using the modify_node_function CLI command.

Note: Because of numerical representation on the S1-MME interface, the Periodic TAU timer value sent to the UE can differ from the Periodic TAU timer value stored in the SGSN-MME.

PSM for NB-IoT is based on PSM for LTE, except for the minimum allowed Active Timer. If the configuration of parameter MinActiveTimeBasedOnDrxNb does not allow the Active Timer value to be greater than zero and less than two DRX cycle + 10 s, the SGSN-MME adjusts the value to "2 x DRX-cycle + 10 s". For NB-IoT, there is no DRX value received from the device. To get the minimum Active Timer value for NB-IoT, the maximum NB-IoT DRX value that the eNodeB can send is used, which gives a minimum Active Timer value of 32 s. If the configuration of parameter MinActiveTimeBasedOnDrxNb allows the Active timer value to be greater than zero and less than "2 x DRX-cycle + 10 s", the SGSN-MME accepts the value regardless of the DRX cycle length.

In the SGSN-MME, the Active Timer and the Mobile Reachable Timer are started when the device goes to the ECM-IDLE state. During the Active Time, the device can be reached by paging. When the Active Timer expires, the device enters PSM and does not listen for paging. If the Active Timer value is set to zero, the device enters PSM immediately when the device goes to the ECM-IDLE state. Until the next signaling from the device, for example periodic TAU, the SGSN-MME does not attempt to page the device.

Note: A device can request both PSM and eDRX, which allows it to configure PSM and eDRX parameters depending on the requirements of the IoT service or application.

If the Active Timer value is greater than `0` and less than the value of eDRX Cycle + Paging Time Window, the MME adjusts the Active Timer value to the value of eDRX Cycle + Paging Time Window.

In a PSM and eDRX combination, where Active Timer = `0`, the eDRX parameters are accepted but not used, because PSM causes the device to be unreachable during IDLE state, and blocks any Paging Occasion.

Avoided paging attempts are counted using the counter VS.MM.pagingAvoidedDueToUeInPsm.E. The number of devices currently in PSM is measured using the VS.MM.NbrAttachedPsm.E gauge, while the time a device is in PSM is recorded through EBM.

If the SGW sends a `Downlink Data Notification` message to the SGSN-MME during PSM, the SGSN-MME responds by sending a `Downlink Data Notification Acknowledge` message to the SGW. The `Downlink Data Notification Acknowledge` message includes the Cause IE set to `Request accepted`, and the `DL Buffering Duration` IE set to the remaining time until the Periodic TAU Timer expires. This signals the SGW to do the following:

- Buffer the DL data for the current UE until the user-plane bearers are set up, and
- Not send any new `Downlink Data Notification` for the current UE, until the Periodic TAU Timer expires.

PSM is supported for SMS over SGs. This support applies to both NB-IoT and LTE-MTC, Cat-M1 UEs included.

If the SMSC initiates MT-SMS for a UE in PSM, the MSC initiates a Paging procedure. The Paging procedure is the same as that described in Section 6.1.2.2 on page 16 except that Step 7, Step 8, and Step 9 are not performed. Instead, the MME waits until the UE performs Periodic TAU before notifying the MSC/VLR or HSS of UE activity. The SGs cause code carried in the `UE Unreachable` message is configurable by the SGsCauseForMtSmsUnderPsm parameter.

For more information about configuring the PSM for LTE feature, see Configuring Massive IoT.

8 Configurable Battery Saving

The SGSN-MME allows local configuration values for PSM and eDRX to be allocated instead of the values requested by the device. With this feature, an operator can control the allocated battery saving parameters of the device. The operator can also control if PSM, eDRX, or both functionalities are allowed or blocked. Different configuration profiles can be selected for different device groups, and a node level configuration can be applied to all other devices. The configuration profile selection is based on APN-NI, IMSINS, or both. A selection on node level is possible when using a default battery saving selection list and a default battery saving profile.

CBS is used for a device only if a battery saving selection list exists, either by configuration on IMSINS, or as a default battery saving selection list. The profile selection is then made in the following order:

1. The battery saving selection list includes a battery saving selection with APN-NI matching the default APN-NI of the device.

2. The battery saving selection list includes a battery saving selection with APN-NI = '*'.

3. A default battery saving profile.

If no profile is found, CBS is not used for the device.

If a battery saving profile exists for the device, and if a parameter is configured in the profile, the value of the configured parameter replaces the parameter value requested by the device. However, if a battery saving profile exists for the device and if a parameter is not configured in the profile (NULL), the parameter value requested by the device is used.
For more information, see Battery Saving (CLI).

For more information about configuring the CBS feature, see Configuring Massive IoT.

9 High Latency Communication

High Latency Communication (HLcom) is developed to achieve full synchronization between the Application Server and UEs using PSM or eDRX. HLcom optimizes signaling between the MME and the SGW when downlink payloads are buffered.

9.1 Extended DL Data Buffering of Downlink Packets in the SGW

For IoT devices, when a DDN message is received from the SGW and the UE is in the ECM-IDLE mode because of eDRX or PSM, the MME first checks the local configuration in the CBS profile. Then the MME checks the subscription data in the related messages to determine it must start extended DL data buffering in the SGW.

If the MME configures the `DlBufferingSuggestedPacketCountLte` or the `DlBufferingSuggestedPacketCountNb` parameter in the CBS profile, the MME requests the extended DL data buffering in the SGW based only on the local configuration. For more information, refer to the DlBufferingSuggestedPacketCountLte and DlBufferingSuggestedPacketCountNb parameters.

If the MME does not configure the `DlBufferingSuggestedPacketCountLte` or the `DlBufferingSuggestedPacketCountNb` parameter in the CBS profile, the MME checks the subscription data in the following messages:

- `Update Location Answer`
- `Insert Subscriber Data Request`

If the value of the `Dl-Buffering-Suggested-Packet-Count` AVP contained in the subscriber data is `0`, the extended DL data buffering in the SGW is not requested. The MME sends DDN ACK message to SGW with cause `unable to page UE`, paging is not started.

If the value of the `Dl-Buffering-Suggested-Packet-Count` AVP contained in the subscriber data is `-1`, the extended DL data buffering in the SGW is requested without a suggested number of packets to be buffered. The MME includes the `DL Buffering Duration` in the DDN ACK message.

If the value of the `Dl-Buffering-Suggested-Packet-Count` AVP contained in the subscriber data is `>0`, then the extended DL data buffering in the SGW is requested. The MME includes the `DL Buffering Duration` and the `DL Buffering Suggested Packet Count` in the DDN ACK message. This message specifies the maximum number of downlink data packets to be buffered in the SGW for this UE.

If the MME does not configure the `DlBufferingSuggestedPacketCountLte` or the `DlBufferingSuggestedPacketCountNb` parameter in the CBS profile, and the `Dl-Buffering-Suggested-Packet-Count` AVP is not included in the subscription data, the MME includes the `DL Buffering Duration` in the DDN ACK message to specify the time for which the SGW must refrain from sending any additional Downlink Data Notification.

9.2 Downlink Payload Synchronization

When a `Downlink Data Notification` is received from the SGW, the UE is in ECM-IDLE mode, and if the UE is not available for paging, because of eDRX or PSM, the MME includes the `DL Buffering Duration` timer in the `Downlink Data Notification Acknowledge` response. The `DL Buffering Duration` timer is used to synchronize the MME and the SGW. While the `DL Buffering Duration` timer has not expired, the SGW buffers downlink payload.

After the MME sends a `Downlink Data Notification Acknowledge` response to the SGW, the following procedures can occur:

- PSM and eDRX - when the UE initiates a periodic TAU procedure or an intra-MME TAU procedure and the SGW is buffering downlink payload, the MME sets up user plane, and downlink payload is delivered to the UE.

  For UE using DoNAS, NAS signaling is kept, an S11-U connection is established, and downlink payload is delivered to UE in NAS PDUs, without setting up user plane data radio bearers in the RAN. For more information about DoNAS, see Section 10 on page 31.

- eDRX - when the UE opens its next Paging Time Window, the MME starts the eDRX paging procedure.

For more information on paging UEs using eDRX, see Extended Idle Mode Discontinuous Reception.

9.3 Inter-MME Mobility without SGW Relocation

When a UE using eDRX or PSM moves between Tracking Areas, which result in an inter-MME TAU procedure without SGW relocation, HLcom allows seamless delivery of pending payload.

The following events happen at an inter-MME TAU procedure when the SGW is buffering downlink payload because eDRX or PSM:

1. The UE sends `TAU request` message to the new MME.

2. The new MME sends a `Context Request` to the old MME.

3. The old MME sends a `Context Response` including the `Buffered DL Data Waiting Indication` flag.

4. The new MME establishes a user plane to allow for buffered DL data transfer.

   For UE using DoNAS, NAS signaling is kept, an S11-U connection is established, and downlink payload is delivered to UE in NAS PDUs, without setting up user plane data radio bearers in the RAN. For more information about DoNAS, see Section 10 on page 31.

5. For UEs using eDRX, the pending paging procedure in the old MME is discarded. The VS.M2M.NbrPendingPagingEdrxUe.E is decremented. The counters VS.M2M.PagingEdrxUeAtt.E and VS.M2M.PagingEdrxUeSucc.E are not updated.

For more information on Inter-MME Mobility, see LTE Mobility Management.

9.4 HLcom Support for Coverage Extension Support, LTE

Coverage Extension (CE) introduces tolerance for longer response times from CE enabled UEs to MME Paging procedures.

Because the response from the UE is delayed, the SGW can send additional DDN signaling to the MME.

HLcom prevents additional DDN signaling from SGW to MME by implementing the following behavior:

1. When the SGW sends DDN, the MME starts Paging procedure toward the UE.

2. To prevent further DDN signaling from the SGW, the MME includes the `DL Buffering Duration` timer set to infinity, in the DDN ACK.

3. When a user plane is set up, the DL data is delivered to the UE. If the Paging procedure fails, a DDN failure is sent to the SGW.

For more information on Coverage Extension, see Coverage Extension Support, LTE.

10 Data over NAS

In 3GPP technical specifications, the Data over NAS feature or Data Transport over NAS feature is referred to as Control Plane Cellular IoT (CIoT) EPS optimization or Data Transport in Control Plane CIoT EPS optimization.

The DoNAS feature is only supported for RAT type NB-IoT.

The DoNAS feature also supports the SMS transport over NAS.

If both the UE and the MME use DoNAS the user data is transported by encapsulating the data in NAS PDUs, without setting up user plane data radio bearers in the RAN. GTP-U tunnels are used for data transport between the MME and the SGW.

The UE requests to use DoNAS in the Attach procedure by indicating Control Plane CIoT EPS optimization as supported in the `UE network capability` IE included in the `Attach Request` message sent to the MME. If the MME confirms the requested behavior in the `Attach Accept` message sent to the UE, then the UE can initiate Mobile Originated data transfer using the control plane.

The UE requests to use DoNAS in the TAU procedure by indicating Control Plane CIoT EPS optimization as supported in the `UE network capability` IE included in the `TAU Request` message sent to the MME. If the MME confirms the requested behavior in the `TAU Accept` message sent to the UE, then the UE can initiate Mobile Originated data transfer using the control plane.

If the `Release Assistance Indication` IE is included in the `ESM Data Transport` message contained in the `Control Plane Service Request` or `Uplink NAS Transport` message from the UE using DoNAS, the MME initiates the S1 Release procedure according to the value of this IE when both of the following conditions are met:

— There is no pending downlink data buffered in the SGW because of the PSM or eDRX.

— There is no ongoing LCS or SGs related procedures such as MT-SMS.

— The UE is not using the Robust Header Compression (ROHC) function.

The `Release Assistance Indication` IE value is `1`, indicating no further uplink or downlink data transmission is expected by the UE. The MME initiates S1 Release procedure immediately after this uplink data is transferred to the SGW.

The `Release Assistance Indication` IE value is `2`, indicating only a single downlink data transmission, for example acknowledgment or response to uplink data is expected by the UE. No further uplink data transmission after this uplink data transmission is expected by the UE. The MME initiates the S1 Release procedure after a single DL data is transferred to the UE.

During an Attach or TAU procedure, for example, the first TAU following GSM or WCDMA Attach, or inter-MME TAU, the MME obtains the UE Radio Capability information by sending an S1AP `Downlink NAS Transport` message without UE Radio Capability information to the eNodeB. This triggers the eNodeB to request the UE Radio Capability information from the UE and upload it to the MME in the S1AP `UE CAPABILITY INFO INDICATION` message. In subsequent ECM connections, the MME sends the UE Radio Capability information to the eNodeB in the first S1AP `Downlink NAS Transport` message. For example, during the Control Plane Service Request or the intra-MME TAU procedure, including the Periodic TAU, the MME includes the UE Radio Capability information in the first S1AP `Downlink NAS Transport` message, if the UE is using DoNAS and this information is received in a previous S1AP `UE CAPABILITY INFO INDICATION` message from the eNodeB.

The rate of user data sent to and from a UE using DoNAS can be controlled. For more information, see Section 13 on page 59.

For information on limitations for DoNAS, see Section 14.3 on page 62.

For information on configuring the DoNAS feature, see Features and Functions Management.

For information on establishing an S11-U connection for DoNAS, see LTE Session Management.

For more information on how to configure the DoNAS feature, see Configuring Massive IoT.

For information on the security aspects, see Security.

10.1 Mobile Originated Data Transfer for DoNAS

A UE using EPS services with DoNAS initiates transport of user data through the control plane. A UE in ECM-IDLE mode can initiate the Control Plane Service Request procedure and include the `ESM data transport` message. For a UE in ECM-CONNECTED mode, the data is transferred in the `ESM data transport` message.

For a UE in the EMM-REGISTERED state without PDN connection, the control plane service request procedure contains only steps 1, step 2, and step 6 as shown in Figure 7. When the control plane service request procedure completes, the UE is in the ECM-CONNECTED mode.

Note: If the UE is in ECM-CONNECTED mode, steps 1–6 are skipped.

Figure 7 shows the Control Plane Service Request procedure for Mobile Originated EPS data transfer with DoNAS.

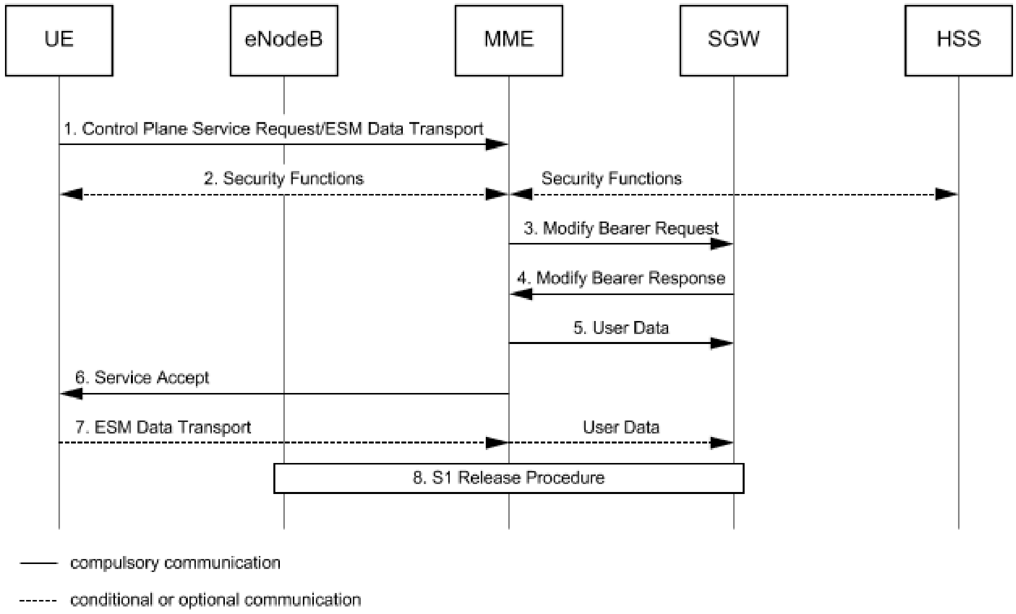

Figure 7 Control Plane Service Request Procedure for Mobile Originated EPS Data Transfer with DoNAS

The following steps describe the Control Plane Service Request procedure for Mobile Originated EPS data transfer with DoNAS:

1. The Mobile Originated procedure is initiated when the UE sends a `Control Plane Service Request` message containing an `ESM Data Transport` message through the eNodeB to the MME.

   If the `Release Assistance Indication` IE is included in the `ESM Data Transport` message indicating the value `1` or `2`, the MME initiates S1 Release procedure after step 6 according to the value of this IE. For more information, see Section 10 on page 31.

2. Optionally, the security functions are performed and the subscriber is authenticated. A security context is established after the ciphering and integrity protection are negotiated. For more information about the integrity check and selective authentication, see Security.

3. The MME allocates a GTP-U F-TEID and includes it in the `Modify Bearer Request` message.

4. The SGW acknowledges the request by sending the `Modify Bearer Response` message containing the SGW GTP-U F-TEID.

5. The MME forwards the user data in a `GTP-U` message to the SGW.

6. The MME sends a `Service Accept` message to the UE.

7. If the UE needs to send more uplink data, the UE sends another `ESM Data Transport` message to the MME. Then the MME validates the message and forwards the user data included in the message to the SGW.

   When the ROHC function is enabled, based on the negotiated header compression configuration, the MME decompresses the uplink data in the ESM messages container if the PDN type is IPv4, IPv6, or IPv4v6. See Section 10.6 on page 40 for more information about ROHC negotiation.

   If the `Release Assistance Indication` IE is included in the `ESM Data Transport` message, the value of this IE is `1` or `2`. Meanwhile, if there is no pending downlink data buffered in the SGW because of the PSM or eDRX, and no ongoing LCS or SGs related procedures such as MT-SMS, the MME initiates the S1 Release procedure according to the value of this IE.

   For more information, see Section 10 on page 31.

8. If the S1 Release procedure is not initiated by the MME in the previous step, the eNodeB initiates this procedure when detecting inactivity of the UE.

10.2 Mobile Terminated Data Transfer for DoNAS

The Mobile Terminated Data Transfer procedure for DoNAS is initiated by the SGW sending a `Downlink Data Notification` message to the MME. For a UE in ECM-IDLE mode using DoNAS, the MME must page the UE.

Note: If the UE is in ECM-CONNECTED mode, steps 1–9 are skipped.

Figure 8 shows the Mobile Terminated EPS data transfer with DoNAS.

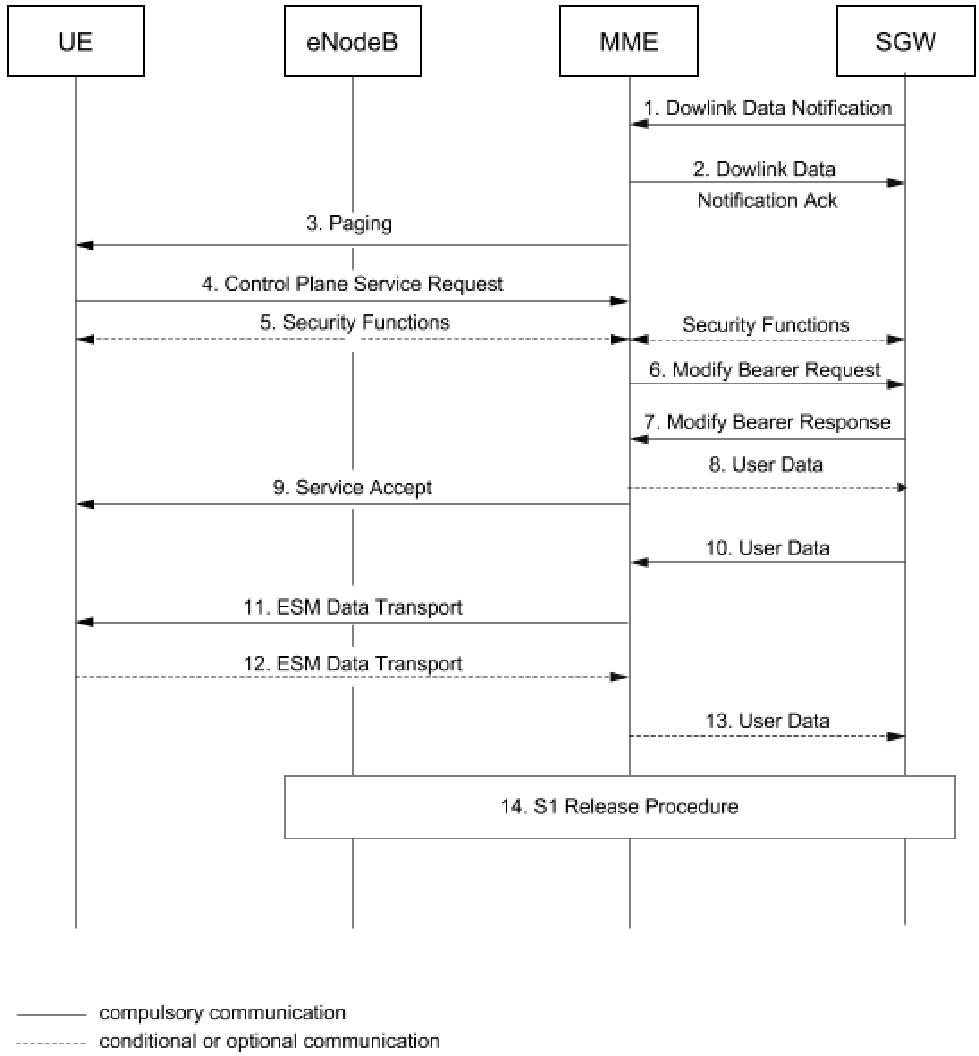

Figure 8 Mobile Terminated EPS Data Transfer with DoNAS

The following steps describe the Mobile Terminated EPS data transfer with DoNAS:

1. The SGW sends a `Downlink Data Notification` message to the MME for the UE.

2. The MME responds to the SGW with a `Downlink Data Notification Ack` message.

3. If the UE is registered in the MME and considered reachable, the MME sends a `Paging` message to each eNodeB belonging to the TAs in which the UE is registered.

4. The UE sends a `Control Plane Service Request` message, with or without user data in an `Initial UE Message`.

5. Optionally, the security functions are performed and the subscriber is authenticated. A security context is established after the ciphering and integrity protection are negotiated. For more information about the integrity check and selective authentication, see Security.

6. The MME allocates a GTP-U F-TEID and includes it in the `Modify Bearer Request` message.

7. The SGW responds to the `Modify Bearer Request` message by sending the `Modify Bearer Response` message containing the SGW GTP-U F-TEID. The SGW is now able to transmit downlink data to the UE.

8. If the MME received user data in the `Control Plane Service Request` message, the MME forwards the user data to the SGW.

9. The MME sends a `Service Accept` message to the UE.

10. The SGW transmits downlink user data to the MME.

11. The MME forwards the user data to the eNodeB in an `ESM Data Transport` message.

12. Optionally, the UE sends user data in an `ESM Data Transport` message.

13. If applicable, the MME sends the received user data to the SGW.

    If the `Release assistance indication` IE is included in the `ESM Data Transport` message, the value of this IE is `1` or `2` in step 12. Meanwhile, if there is no pending downlink data buffered in the SGW because of the PSM or eDRX, and no ongoing LCS or SGs related procedures such as MT-SMS, the MME initiates S1 Release procedure according to the value of this IE.

    For more information, see Section 10 on page 31.

14. If the S1 Release procedure is not initiated by the MME in previous step, the eNodeB initiates this procedure when detecting the inactivity of the UE.

When the ROHC function is enabled, based on the negotiated header compression configuration, the MME compresses the downlink data in Step 11. The MME also decompresses the uplink data in Step 12 found in the ESM messages container if the PDN type is IPv4, IPv6, or IPv4v6.

See Section 10.6 on page 40 for more information about ROHC negotiation.

10.3 Support for SMS Service over SGs Interface

The MME supports SMS transport over NAS for UEs in Tracking Areas with RAT type NB-IoT.

SMS service is the only CS service applicable for UEs using NB-IoT.

SMS messages are transmitted over the SGs interface without requiring NB-IoT UEs to perform a combined procedure. NB-IoT—only UEs can perform EPS Attach or TAU with `SMS Only`. `SMS Only` indicates that SMS is the only non-EPS service. Non-NB-IoT UEs can also perform a combined procedure with `SMS Only` and EPS Attach or TAU with `SMS Only`.

For MO-SMS with DoNAS, a UE in ECM-IDLE mode initiates the Control Plane Service Request procedure instead of the normal Service Request procedure. The SMS message is carried in the `NAS Message Container` IE of the `Control Plane Service Request` message. If the UE is in ECM-CONNECTED mode, the SMS message is carried in an `Uplink NAS Transport` message.

For MT-SMS with DoNAS, a UE in ECM-IDLE mode sends a `Control Plane Service Request` message in response to the paging. If the UE is in ECM-CONNECTED mode, the MME directly sends an SGsAP `Service Request` message in response to the paging by the MSC/VLR.

After receiving a `Control Plane Service Request` message from a UE in ECM-IDLE mode, the MME initiates a bearer modification procedure with the SGW and sends the UE a `Service Accept` message. Then, the MME relays the SMS message to and from the MSC/VLR.

SMS transport over NAS is supported for UEs with eDRX, PSM, or both enabled. For details, see Section 6.1.2.2 on page 16 and Section 7.2 on page 25.

For more information about normal SMS procedures, see MO-SMS and MT-SMS.

For more information about the Attach and TAU procedures, see LTE Mobility Management.

For information about how to configure DoNAS Support for SMS Service over SGs Interface, see Configuring Massive IoT.

10.4 TAU Requests for UEs Using DoNAS

The MME handles specific Intra-MME TAU and Inter-MME TAU requests for UEs using DoNAS.

The MME accepts the following requests:

— Periodic TAU requests.

— Intra-MME TAU requests and inter-MME TAU requests without `active` flag or `signalling active` flag.

— Intra-MME TAU requests and inter-MME TAU requests with `signalling active` flag.

  For information about `signalling active` flag, see LTE Mobility Management.

The MME rejects the following requests, prompting the UE to perform a reattach procedure:

- Intra-MME TAU requests and inter-MME TAU requests with `active` flag.
- Intra-MME TAU requests where the UE is attached without DoNAS enabled, requesting TAU with DoNAS.
- Intra-MME TAU requests where the UE is attached with DoNAS enabled, requesting TAU without DoNAS.
- ISC TAU requests.

10.5 DoNAS, PDN Type Non-IP

The DoNAS, PDN Type Non-IP feature allows the NB-IoT UEs to use generic or proprietary data protocols to deliver Non-IP data, instead of sending an IP header with the data packages.

The MME supports the following two mechanisms to transport non-IP data between the Enterprises (AS) and the Core Network (CN).

- Non-IP Data Delivery over SGi, which is controlled by the `donas_non_ip_over_sgi` feature parameter.
- Non-IP Data Delivery over SCEF, which is controlled by the `donas_non_ip_over_scef` feature parameter.

10.5.1 Non-IP Data Delivery over SGi

The Non-IP Data Delivery over SGi function enables handling of the PDN Type Non-IP over the S11-U interface and the SGi interface. For more information about Data over NAS, see Section 10 on page 31.

The DoNAS-requesting UE sets the PDN Type to Non-IP during the Attach procedure. The MME indicates support for PDN type Non-IP in the `Update Location Request` message to the HSS. The HSS then includes APN configurations with PDN type Non-IP in the `Update Location Answer` message. PDN Type Non-IP can be allowed even if Non-IP is not supported by the HSS. This is done by configuring the `NonIpAccess` parameter.

For information about how to configure the Non-IP data delivery over SGi function, see Configuring Massive IoT.

10.5.2 Non-IP Data Delivery over SCEF

The Non-IP Data Delivery over SCEF function enables handling of the PDN Type Non-IP over the SCEF. For more information, see Non-IP Data Delivery over SCEF.

For information about how to configure the Non-IP data delivery over SCEF function, see Configuring Non-IP Data Delivery over SCEF.

10.6 DoNAS with ROHC

In streaming applications, the overhead of internet packets is excessive for wireless systems where bandwidth is scarce. To optimize the using of radio capacity of PDN connections, IP header compression is used. Robust Header Compression (ROHC) is a standard method to compress the headers of the internet packets and performs well over wireless links.

When Control Plane CIoT EPS optimization is used for IP PDN connections, the MME supports the IP header compression for the supported ROHC profiles based on the ROHC framework.

During the UE requested PDN connectivity in the attach procedure, ROHC configuration is negotiated. The negotiated ROHC configuration is transferred and synchronized between MMEs during TAU procedures.

After ROHC configuration negotiation is complete, the MME supports header compression for the downlink data and decompression for the uplink data based on the negotiation.

For more information about how to configure DoNAS with ROHC, see Configuring Massive IoT.

10.6.1 ROHC Profile

There are multiple header compression algorithms, which are called ROHC profiles defined for the ROHC framework.

Each ROHC profile is specific to the particular network layer: transport layer, or upper layer protocol combination. For example, TCP/IP, RTP, UDP, and IP.

Table 3 shows the ROHC profiles and the reference Request for Comments (RFCs) that include detailed definition for each profile.

Table 3 ROHC Profiles

ROHC Version	ROHC Profile Identifier	Usage	Reference
ROHC V1	`0x0000`	No compression	RFC 5795
	`0x0001`	RTP/UDP/IP	RFC 3095, RFC 4815
	`0x0002`	UDP/IP	RFC 3095, RFC 4815
	`0x0003`	ESP/IP	RFC 3095, RFC 4815
	`0x0004`	IP	RFC 3843, RFC 4815
	`0x0006`	TCP/IP	RFC 6846
ROHC V2	`0x0101`	RTP/UDP/IP	RFC 5225
	`0x0102`	UDP/IP	RFC 5225
	`0x0103`	ESP/IP	RFC 5225
	`0x0104`	IP	RFC 5225

Note: Only IP profile (`0x0004`) is supported in this release.

10.6.2 ROHC Negotiation during Attach

During the attach procedure, the MME performs ROHC negotiation when receiving the `Attach Request` message indicating the followings:

— The UE includes the header compression configuration in the `PDN Connectivity Request` IE.

— The UE indicates support of Control Plane CIoT EPS optimization in the `UE Network Capability` IE.

— The UE includes the ESM message container, and the PDN type is IPv4, IPv6, or IPv4v6.

— The UE supports header compression.

If there are common head compression configurations supported by both the UE and the MME, the MME completes the ROHC configuration and indicates the followings in the `Attach Accept` message:

— The MME indicates support of Control Plane CIoT EPS optimization and head compression.

— The MME includes the common head configuration parameters in the `Activate Default EPS Bearer Context Request` IE.

10.6.3 ROHC Configuration Status Synchronization during TAU

In the inter-TAU procedure, when the UE indicates its support of header compression for control plane CIoT EPS optimization in the `UE Network Capability` IE in the `TAU Request` message, the header compression configuration is transferred and synchronized based on the following steps:

1. If the new MME supports ROHC, it sets the `IP Header Compression Support (IHCSI)` flag to `1` in the `CIoT Optimization Support Indication` IE in the `Context Request` message.

2. The old MME includes the negotiated header compression configuration in the `PDN Connection` IE in the `Context Response` message.

3. After receiving the negotiated header compression configuration, the new MME synchronizes the header compression configuration status with the UE in the `TAU Accept` message.

In the intra-MME TAU or periodic TAU procedure, the MME synchronizes with the UE the latest status of the header compression configuration. That is, only Step 3 takes place.

10.6.4 Characteristic Impact

The DoNAS with ROHC feature has impact on AP memory usage. The memory usage increases gradually when the feature is activated and decreases gradually when the feature is deactivated. It takes some time for the memory usage to increase or decrease and reach a stable state when the feature state changes. The length of time and memory increase depends on the traffic model.

10.7 Moving UEs Using DoNAS between MMEs in an MME Pool

The LTE 3GPP standard move operation must be used to move UEs using DoNAS between MMEs in an MME pool.

Note: For a UE that is about to be moved, any user data or SMS message included in a `Control Plane Service Request` message is ignored.

For more information on the LTE 3GPP standard move operation, see MME Pool.

10.8 Control Plane and User Plane Data Transport Switch

The Control Plane and User Plane Date Transport Switch function allows the UE data transport is switched from Control Plane (CP) using DoNAS on the S11-U interface to User Plane (UP) on the S1-U interface. This function makes the transfer of data more efficient for transferring large amounts of data over the User Plane (UP) and small amounts of data over the Control Plane (CP).

For more information about the configuration of control plane and user plane data transport switch, see Configuring Massive IoT.

10.8.1 UE-Initiated Control Plane to User Plane Data Transport Switch

This section describes Control Plane to User Plane Data Transport Switch that is initiated by the UE in ECM_CONNECTED. The UE initiates the switch by sending a `Control Plane Service Request` with an active flag.

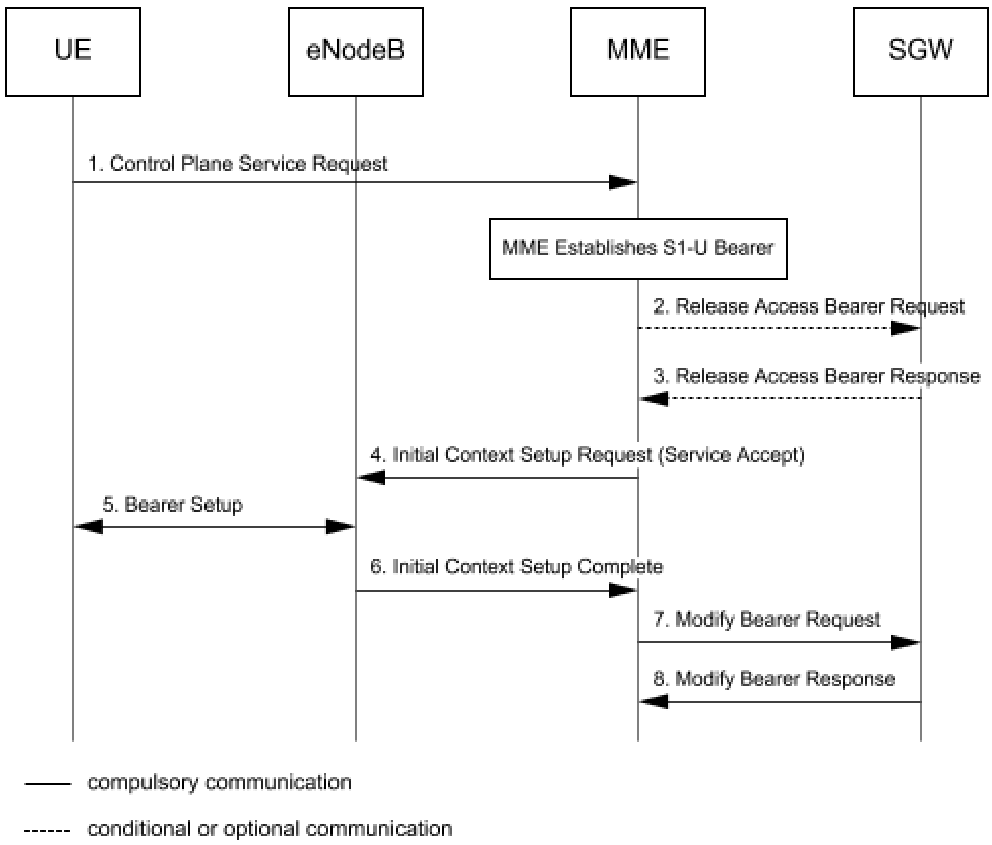

Figure 9 UE-Initiated Control Plane to User Plane Data Transport Switch

The following steps describe the UE-Initiated Control Plane to User Plane Data Transport switch:

1. The UE sends the `Control Plane Service Request` message with active flag that is included in an `Uplink NAS Transport` message to the MME.

2. If the UE is in ECM-CONNECTED mode, the MME sends a `Release Access Bearer Request` message to the SGW to release S11-U tunnel.

3. The MME responses by sending a `Release Access Bearer Response` message to the MME.

4. The MME sends an S1-AP `Initial Context Setup Request` message with the S1-U SGW F-TEID to the eNodeB, and responds to the UE with a `Service Accept` message.

   If the S1-U and S11-U IP address spaces are separated in the network, the MME uses the S1-U SGW F-TEID. If the S1-U and S11-U IP address spaces are not separated in the network, the MME uses the S11-U SGW F-TEID as the S1-U SGW F-TEID.

   For cases where the UE and MME support User Plane CIoT Optimization, the MME sets the `UE User Plane CIoT Support Indicator` IE to `supported`.

5. The Bearer Setup is performed. The user plane radio bearer is set up.

6. The eNodeB sends an `Initial Context Setup Complete` message with the S1-U eNodeB F-TEID to the MME.

7. The MME sends a `Modify Bearer Request` message with the S1-U eNodeB F-TEID to the SGW.

8. The SGW responds by sending a `Modify Bearer Response` message with the S1-U SGW F-TEID to the MME.

For the UE in ECM-IDLE mode, the UE sends a `Control Plane Service Request` message with active flag to set up the user plane data transport. The setup procedure performs the same steps as the preceding descriptions except steps 2–3.

10.9 S1-U and S11-U Separation

When Control Plane CIoT EPS Optimization is used, the IP address spaces for S1-U and S11-U can be different based on the operator deployment.

During an Attach procedure, when the MME sends a `Create Session Request` message to the SGW, if the `Control Plane Only PDN Connection Indication` flag is not set in this message and the SGW supports S1-U and S11-U separation, the SGW responds to the MME with a `Create Session Response` message containing the S11-U SGW F-TEID and S1-U SGW F-TEID. After receiving this message, the MME saves both S11-U SGW F-TEID and S1-U SGW F-TEID.

When a UE moves to another MME using TAU procedure, the MME sends both S1-U SGW F-TEID and S11-U SGW F-TEID included in the `Context Response` message to the new MME.

11 Monitoring Enhancements

The Monitoring Enhancements (MONTE) feature allows for information on specific events that are normally internal to the MME to be made available to the Service Capability Exposure Function (SCEF) node. The licensed feature MONTE is supported for the LTE access type. This feature supports configuration and reporting of the following Monitoring Events:

- UE Reachability
- Loss of Connectivity
- Communication Failure
- Location Reporting

For more information on configuring the MONTE feature, see Features and Functions Management.

11.1 UE Reachability

The UE Reachability event indicates when a UE becomes reachable for sending data or SMS. A PSM UE is considered reachable when it is not in PSM or if it transitions into connected mode.

3GPP defines two types of reachability requests: UE Reachability for Data and UE Reachability for SMS.

11.1.1 UE Reachability for Data

11.1.1.1 Report Triggered by a PSM UE for one-time Reporting

Figure 10 shows the reporting procedure triggered by a PSM UE for one-time reporting.

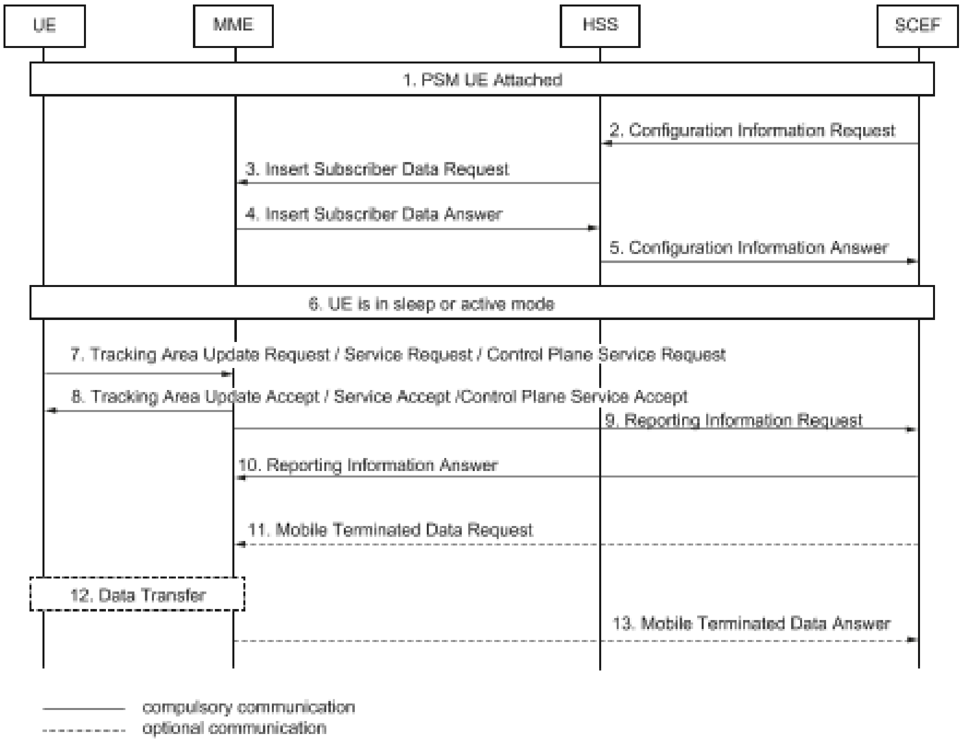

Figure 10 Report Triggered by a PSM UE for one-time Reporting

The following steps describe the reporting triggered by a PSM UE when the UE sends a `Tracking Area Update Request`, `Service Request`, or `Control Plane Service Request` message to the MME:

1. A UE using PSM is attached.

2. The SCEF sends a `Configuration Information Request` message to the HSS. In this message, the `Monitoring Event Configuration` IE includes the `UE_REACHABILITY` and `REACHABILITY_FOR_DATA` parameters.

3. The HSS sends an `Insert Subscriber Data Request` message to the MME that includes the `Monitoring Event Configuration` IE.

4. The MME is configured and sends an `Insert Subscriber Data Answer` message to the HSS. In this message, the `Monitoring Event Config Status` IE indicates a successful configuration.

5. The HSS sends a `Configuration Information Answer` message to the SCEF.

6. The UE using PSM is in sleep mode or active mode.

7. The UE sends an initial message to the MME. This message can include a `Tracking Area Update Request` or `Service Request`, or `Control Plane Service Request`.

8. The MME responds with a `Tracking Area Update Accept` or `Service Accept`, or `Control Plane Service Accept` message to the UE.

9. The S1 connection between the UE and the MME is not released since there is a pending UE Reachability event configuration. The MME sends a `Reporting Information Request` message to the SCEF. In this message, the `Monitoring Event Report` IE indicates that the UE is reachable for data.

10. The SCEF sends a `Reporting Information Answer` message to the MME.

11. Optionally, if there is mobile terminated data available for the UE in the Application Server, the SCEF sends a `Mobile Terminated Data Request` message to the MME.

12. Optionally, if the MME receives a `Mobile Terminated Data Request` from the SCEF, the MME transfers the data to the UE.

13. After the MME has transferred the data to UE, it sends a `Mobile Terminated Data Answer` message to the SCEF.

11.1.1.2 UE Reachability Configuration in Update Location Answer

Figure 11 shows the configuration in the `Update Location Answer` message for UE Reachability.

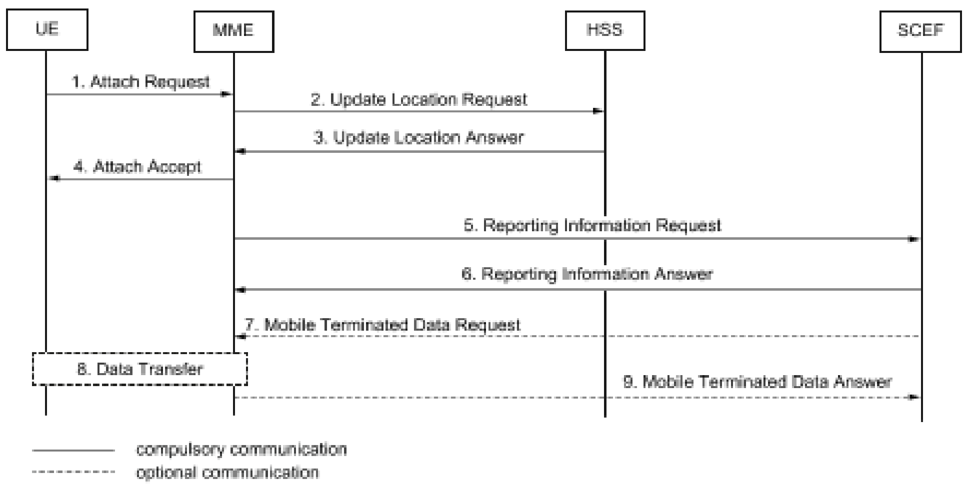

Figure 11 UE Reachability Configuration in Update Location Answer

The following steps describe the UE Reachability configuration in the `Update Location Answer` message for one-time reporting:

1. The UE sends an `Attach Request` message to the MME.

2. The MME sends an `Update Location Request` message to the HSS.

3. The HSS responds to the MME with an `Update Location Answer` message. In this message, the `Monitoring Event Configuration` IE includes the `UE_REACHABILITY` and `REACHABILITY_FOR_DATA` parameters.

4. The Attach procedure completes.

5. The MME sends a `Reporting Information Request` message to the SCEF. In this message, the `Monitoring Event Report` IE indicates that the UE is reachable for data.

6. The SCEF responds with a `Reporting Information Answer` message to the MME.

7. Optionally, if there is mobile terminated data available for the UE in the Application Server, the SCEF sends a `Mobile Terminated Data Request` message to the MME.

8. Optionally, if the MME receives a `Mobile Terminated Data Request` from the SCEF, the MME transfers the data to the UE.

9. After the MME has transferred the data to UE, it sends a `Mobile Terminated Data Answer` message to the SCEF.

11.1.1.3 Report Triggered by a PSM UE in the ECM Connected State

Figure 12 shows the report triggered by a PSM UE in the ECM Connected state.

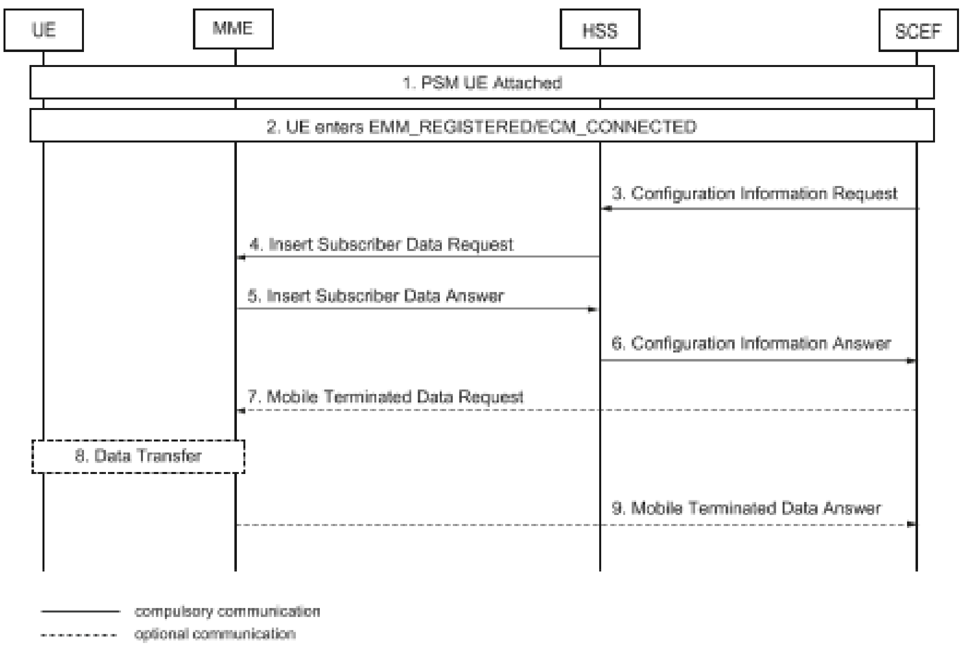

Figure 12 Report Triggered by a PSM UE in the ECM Connected State

The following steps describe the report triggered by a PSM UE in the ECM Connected state:

1. A UE using PSM is attached.

2. The UE enters the EMM_REGISTERED and ECM_CONNECTED state.

3. The SCEF sends a Configuration Information Request message to the HSS.

4. The HSS sends an Insert Subscriber Data Request message to the MME. In this message, the Monitoring Event Configuration IE includes the UE_REACHABILITY and REACHABILITY_FOR_DATA parameters.

5. The MME is configured and sends an Insert Subscriber Data Answer message to the HSS. In this message, the Monitoring Event Report IE indicates that the UE is reachable for data.

6. The HSS sends a Configuration Information Answer message to the SCEF.

7. Optionally, if there is mobile terminated data available for the UE in the Application Server, the SCEF sends a Mobile Terminated Data Request message to the MME.

8. Optionally, if the MME receives a Mobile Terminated Data Request message from the SCEF, the MME transfers the data to the UE.

9. After the MME has transferred the data to UE, it sends a Mobile Terminated Data Answer message to the SCEF.

11.1.2 UE Reachability for SMS

When Reachability for SMS is requested, the SCEF subscribes with the HSS. The HSS performs the UE Reachability Notification Procedure. This procedure is used to notify the HSS when the UE becomes reachable. For more information about the legacy behavior for Notification Procedure, see Subscriber Data Management.

11.2 Deletion of Event Configuration for One-Time and Continuous Reporting

When an event has been fully reported, the SCEF sends a deletion request to the HSS.

Figure 13 shows the deletion of the event configuration for both one-time and Continuous Reporting.

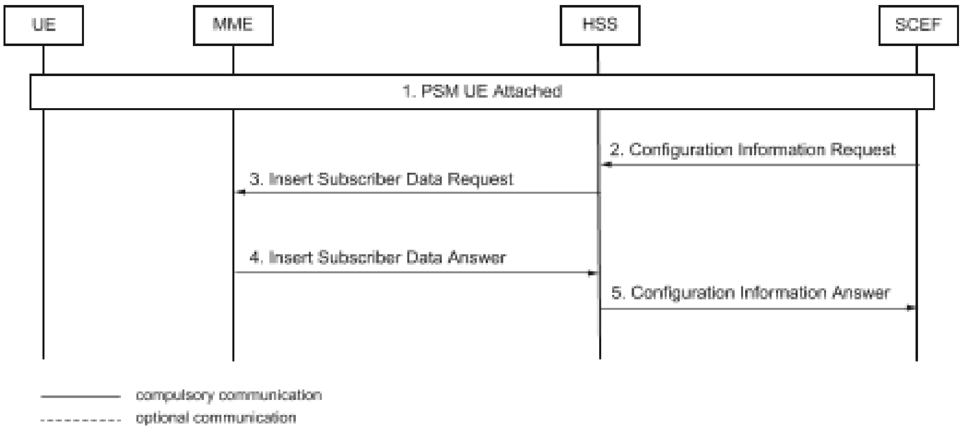

Figure 13 Deletion of Event Configuration

The following steps describe the deletion of the event configuration:

1. A UE using PSM is attached.

2. The SCEF sends a `Configuration Information Request` message to the HSS for the deletion of the event configuration.

3. The HSS sends an `Insert Subscriber Data Request` message to the MME that includes a `Monitoring Event Configuration` IE.

4. The MME is configured and sends an `Insert Subscriber Data Answer` message to the HSS to delete the event configuration.

5. The HSS sends a `Configuration Information Answer` message to the SCEF.

11.3 Continuous Reporting

All types of Monitoring events can be configured using Continuous Reporting. This event configuration enables the MME to report multiple times as indicated by either a maximum number of reports or a set date and time in the future. However, for Continuous Reporting, the `Insert Subscriber Data Request` message sent from the HSS to the MME must include either a `Maximum Number of Reports` or `Monitoring Duration` IE inside the `Monitoring Event Configuration` IE.

Figure 14 shows the reporting procedure for Continuous Reporting.

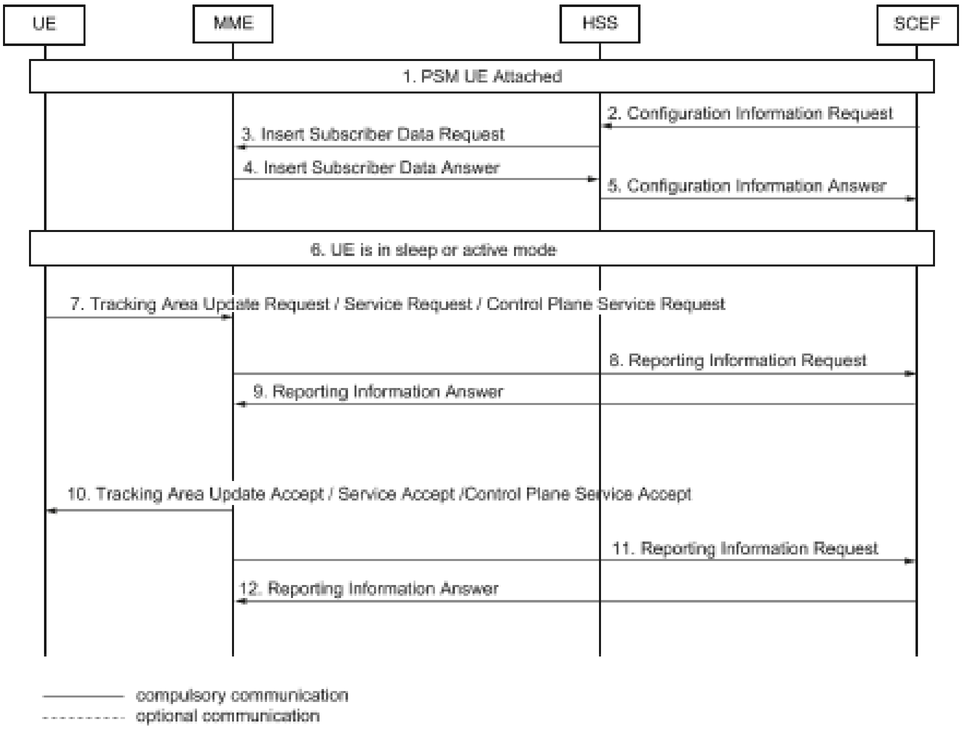

Figure 14 Report Triggered by a UE for Continuous Reporting

The following steps describe the reporting triggered by a UE configured for Continuous Reporting:

1. A UE using PSM is attached.

2. The SCEF sends a `Configuration Information Request` message to the HSS. In this message, the `Monitoring Event Configuration` IE includes the `UE_REACHABILITY` and `REACHABILITY_FOR_DATA` parameters.

3. The HSS sends an `Insert Subscriber Data Request` message to the MME that includes the `Monitoring Event Configuration` IE.

4. The MME is configured and sends an `Insert Subscriber Data Answer` message to the HSS. In this message, the `Monitoring Event Config Status` IE indicates a successful configuration.

5. The HSS sends a `Configuration Information Answer` message to the SCEF.

6. The UE using PSM is in sleep mode or active mode.

7. The UE sends an initial message to the MME. This message can include a `Tracking Area Update Request` , a `Service Request`, or a `Control Plane Service Request` message.

8. The S1 connection between the UE and the MME is not released, since there is a pending UE Reachability event configuration. The MME sends a `Reporting Information Request` message to the SCEF. In this message, the `Monitoring Event Report` IE indicates that the UE is reachable for data.

9. The SCEF sends a `Reporting Information Answer` message to the MME.

10. The UE sends an initial message to the MME. This message can include a `Tracking Area Update Request` , a `Service Request`, or a `Control Plane Service Request` message.

11. The S1 connection between the UE and the MME is not released, since there is a pending UE Reachability event configuration. The MME sends a `Reporting Information Request` message to the SCEF. In this message, the `Monitoring Event Report` IE indicates that the UE is reachable for data.

12. The SCEF sends a `Reporting Information Answer` message to the MME.

The MME stops reporting to the SCEF either when the `Maximum Number of Reports` has been met or the `Monitoring Duration` has expired.

11.4 Loss of Connectivity

The Loss of Connectivity monitoring event indicates that the UE is no longer reachable for either signaling or user plane communication.

Figure 15 shows that the Loss of Connectivity event sent when the Mobile Reachable Timer expires.

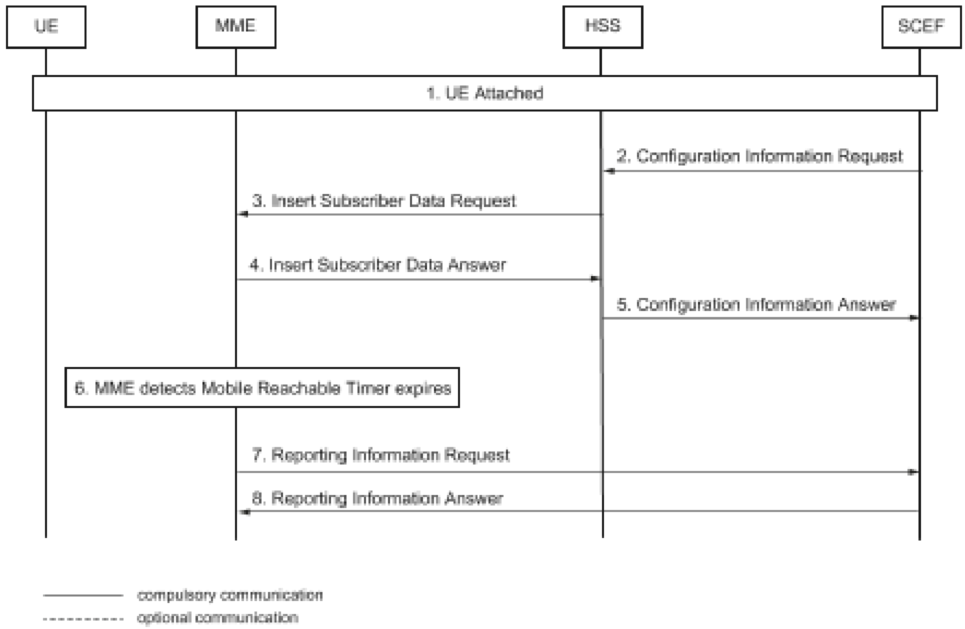

Figure 15 Loss of Connectivity Event Sent When the Mobile Reachable Timer Expires

The following steps describe the Loss of Connectivity monitoring event:

1. A UE is attached.

2. The SCEF sends a `Configuration Information Request` message to the HSS that includes a `Monitoring Event Configuration` IE.

3. The HSS sends an `Insert Subscriber Data Request` message to the MME that includes the `Monitoring Event Configuration` IE for monitoring Loss of Connectivity.

4. The MME is configured and sends an `Insert Subscriber Data Answer` message to the HSS. In this message, the `Monitoring Event Config Status` IE indicates a successful configuration.

5. The HSS sends a `Configuration Information Answer` message to the SCEF.

6. The MME detects that the Mobile Reachable Timer has expired.

7. The MME sends a `Reporting Information Request` message to the SCEF that includes a `Monitoring Event Report` IE. The `Monitoring Event Report` IE includes a `Loss of Connectivity Reason` IE, which is set to value `MAX_DETECTION_TIME_EXPIRED_MME`.

8. The SCEF responds with a `Reporting Information Answer` message to the MME.

For the Detach scenario, if the UE is switched off, it sends an initial message to the MME. This message includes a `Detach Request` message. The MME then sends a `Reporting Information Request` message to the SCEF that includes the `Monitoring Event Report` IE. The `Monitoring Event Report` IE includes the `Loss of Connectivity Reason` IE, which is set to value `UE_DETACHED_MME`.

A PSM UE that is monitored for Loss of Connectivity triggers a report to be sent to SCEF when its active timer runs out and it transitions into PSM.

11.5 Communication Failure

The Communication Failure event indicates communication failures in the radio network.

Figure 16 shows the Communication Failure event.

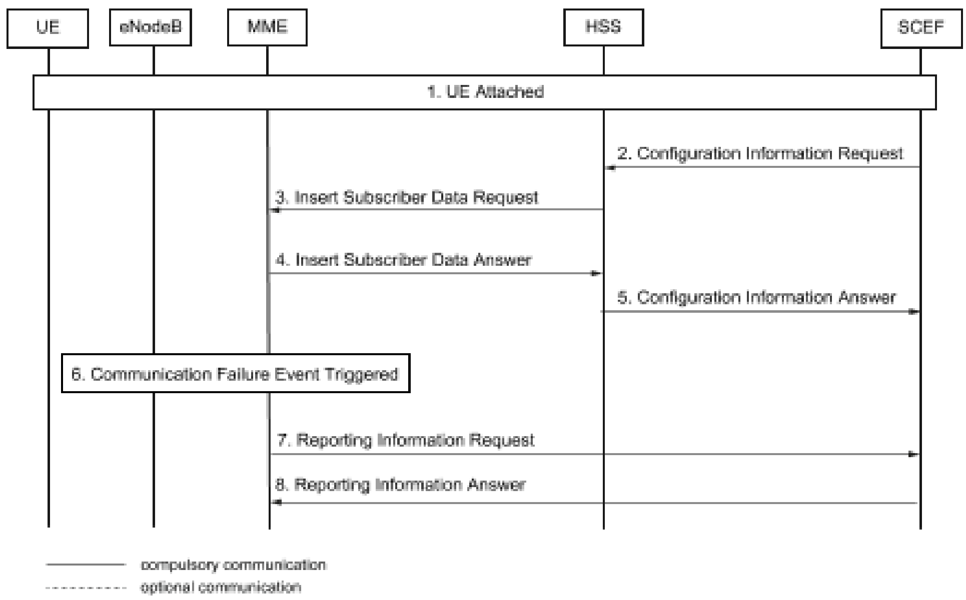

Figure 16 Communication Failure Event

The following steps describe the Communication Failure Monitoring Event:

1. A UE is attached.

2. The SCEF sends a `Configuration Information Request` message to the HSS that includes a `Monitoring Event Configuration` IE.

3. The HSS sends an `Insert Subscriber Data Request` message to the MME that includes the `Monitoring Event Configuration` IE for monitoring Communication Failure.

4. The MME is configured and sends an `Insert Subscriber Data Answer` message to the HSS. In this message, the `Monitoring Event Config Status` IE indicates a successful configuration.

5. The HSS sends a `Configuration Information Answer` message to the SCEF.

6. A communication failure event is triggered when an S1-AP message is received with a failure cause code set.

7. The MME sends a `Reporting Information Request` message to the SCEF that includes a `Monitoring Event Report` IE. The `Monitoring Event Report IE` contains a Communication Failure Information IE which includes the `S1-AP Cause`. The `S1-AP Cause` is sent within the message indicating that a communication failure had occurred. The `S1-AP Cause` can be set to either `RADIO_RESOURCES_NOT_AVAILABLE` or `RADIO_CONNECTION_WITH_UE_LOST` cause codes.

8. The SCEF responds with a `Reporting Information Answer` message to the MME.

11.6 Support Configuration of PSM UE Timers

Figure 17 shows the support for configuration of the PSM UE Active Timer T3324.

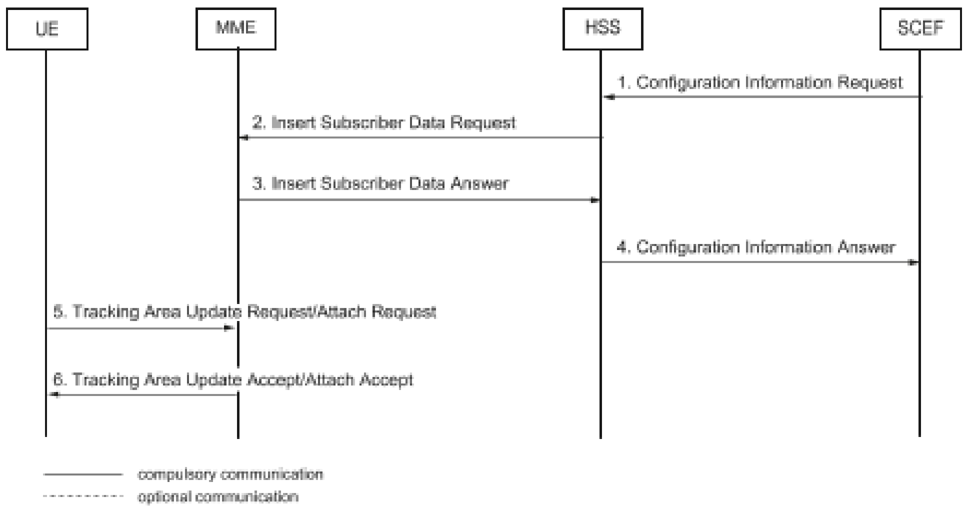

Figure 17 Support for Configuration of the PSM UE Active Timer T3324

The following steps describe the support for configuration of the PSM UE Active Timer T3324:

1. The SCEF sends a `Configuration Information Request` message to the HSS that includes a `Monitoring Event Configuration` IE.

2. The HSS sends an `Insert Subscriber Data Request` message to the MME that includes the `Monitoring Event Configuration` IE. The `Monitoring Event Configuration` IE includes the `Maximum Response Time` IE.

3. The MME is configured and sends an `Insert Subscriber Data Answer` message to the HSS. In this message, the `Monitoring Event Config Status` IE indicates a successful configuration.

4. The HSS sends a `Configuration Information Answer` message to the SCEF.

5. The UE sends an initial message to the MME. This message can include a `Tracking Area Update Request` or `Attach Request` message.

6. The MME responds with a `Tracking Area Update Accept` or `Attach Accept` message to the UE. The previously received `Maximum Response Time` is now set as the new PSM Active Time in either the `Tracking Area Update Accept` or `Attach Accept` message.

11.7 Location Reporting

The Location Reporting monitoring event allows for reporting the last known location of a UE to the SCEF.

11.7.1 Last Known Location

11.7.1.1 Report Triggered by Insert Subscriber Data Request

Figure 18 shows the reporting procedure triggered by the `Insert Subscriber Data Request` message for one-time reporting.

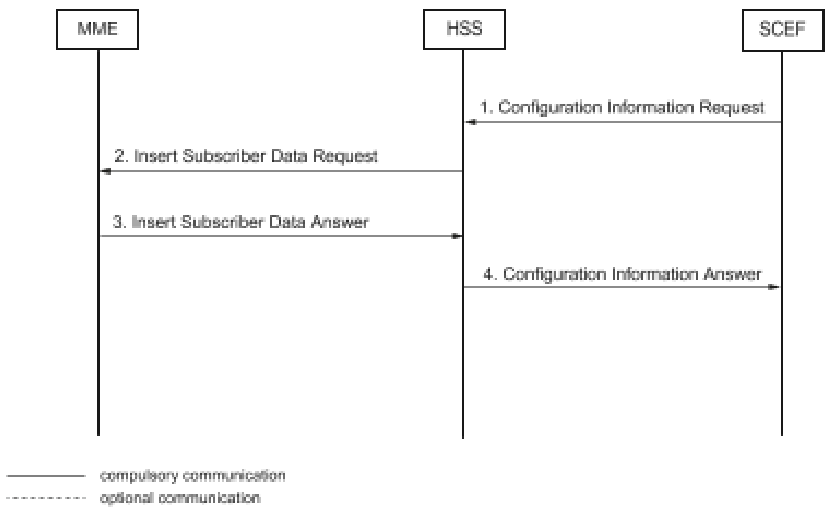

Figure 18 Report Triggered by Insert Subscriber Data Request

The following steps describe the reporting procedure triggered by `Insert Subscriber Data Request` message:

1. The SCEF sends a `Configuration Information Request` message to the HSS.

2. The HSS sends an `Insert Subscriber Data Request` message to the MME that includes the `Monitoring Event Configuration` IE. The `Monitoring Event Configuration` IE includes a `Location Information Configuration` IE. The `Location Information Configuration` IE includes the `MONTE-Location-Type` field which is set to value `LAST_KNOWN_LOCATION`.

3. The MME is configured and sends an `Insert Subscriber Data Answer` message to the HSS that includes the `Monitoring Event Report` and `Monitoring Event Config Status` IE. The `Monitoring Event Report` IE includes the `EPS Location Information` IE which contains information about the last know location of a UE. The `Monitoring Event Config Status` IE indicates a successful configuration.

4. The HSS sends a `Configuration Information Answer` message to the SCEF.

11.7.1.2 Report Triggered by Update Location Answer

Figure 19 shows the reporting procedure triggered by the `Update Location Answer` message for one-time reporting.

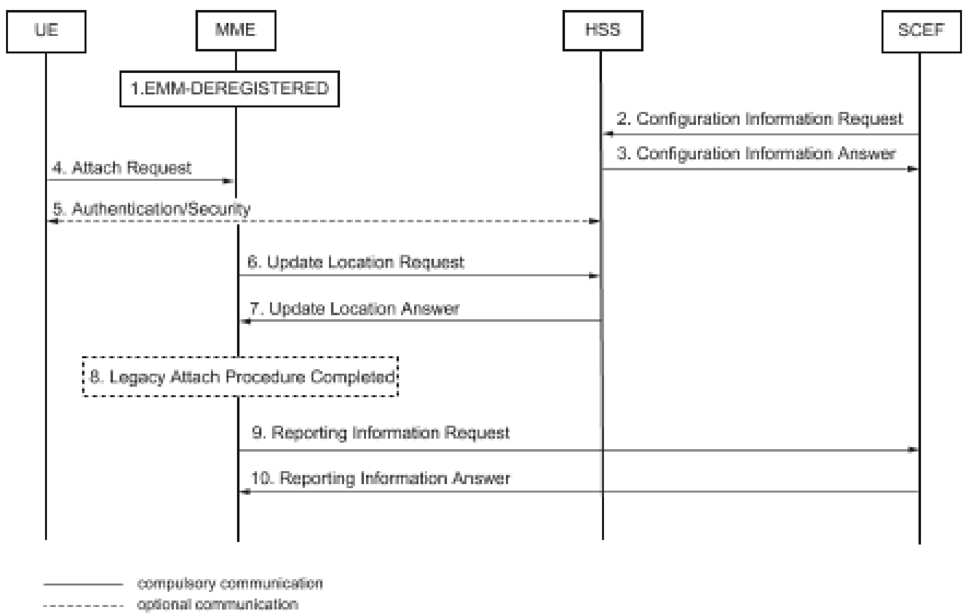

Figure 19 Report Triggered in Update Location Answer

The following steps describe the reporting procedure triggered by `Update Location Answer` message:

1. The MME enters the `EMM_DEREGISTERED` state.
2. The SCEF sends a `Configuration Information Request` message to the HSS.
3. The HSS sends a `Configuration Information Answer` message to the SCEF.
4. The UE sends an `Attach Request` message to the MME
5. Optionally, the security functions are performed and the subscriber is authenticated.
6. An `Update Location Request` message is sent to the HSS.
7. The HSS sends an `Update Location Answer` message to the MME that includes the `Monitoring Event Configuration` IE with the `Location Information Configuration` IE. The `Location Information Configuration` IE includes the `MONTE-Location-Type` field which is set to value `LAST_KNOWN_LOCATION`.
8. The legacy Attach procedure completes.
9. The MME sends a `Reporting Information Request` message to the SCEF that includes a `Monitoring Event Report` IE. The `Monitoring Event Report` IE includes the `EPS Location Information` IE which contains information about the last know location of a UE. Here, the MME reports the event directly using the stored location information that was obtained from the legacy Attach procedure.
10. The SCEF responds with a `Reporting Information Answer` message to the MME.

12 Connection Suspend and Resume

The Connection Suspend and Resume feature allows the MME to store information needed to resume a UE that has been suspended. Using the Connection Suspend and Resume procedures allows for UE services to be resumed faster, since both the S1-AP signaling and the radio signaling are reduced.

Note: The use of the Connection Suspend and Resume procedures requires support for User Plane (UP) CIoT EPS optimization in the MME, the eNodeB, and the UE in accordance with the 3GPP Technical Specifications.

Note: This licensed feature is applicable for the LTE and NB-IoT RAT types.

The UE requests to use the Connection Suspend and Resume functionality in the Attach or TAU procedures. This is done by indicating UP CIoT EPS optimization as supported in the `UE network capability` IE included in the `Attach Request` or `TAU Request` message sent to the MME.

The UE can request to use UP CIoT EPS optimization by indicating support for CIoT EPS optimization in either of the following ways:

— Support for both User Plane (UP) and Control Plane (CP) CIoT EPS optimization in the `UE network capability` IE, with UP CIoT EPS optimization indicated as preferred in the `Additional Update Type` IE

— Support for UP CIoT EPS optimization only in the `UE network capability` IE

The MME confirms UP CIoT EPS optimization as the granted behavior by setting the `UE User Plane CIoT Support Indicator` IE to 'supported' in the `Initial Context Setup Request` message to the eNodeB.

If the MME does not confirm UP CIoT EPS optimization as the granted behavior, the UE is instead granted use of CP CIoT EPS optimization. This happens if CP CIoT EPS optimization is supported by the UE and the MME.

If the MME does not confirm either UP or CP CIoT EPS optimization as the granted behavior, the normal Attach and S1-Release procedures are used.

For more information on the Connection Suspend and Resume feature, see LTE Mobility Management and S1-MME Interface Description.

For information on enabling the Connection Suspend and Resume feature, see Features and Functions Management.

13 Rate Control for CIoT EPS Optimization

The rate of user data sent to and from a UE using CIoT EPS Optimization can be controlled in two ways:

— Serving PLMN Rate Control

— APN Rate Control

13.1 DoNAS, Serving PLMN Rate Control

Serving PLMN Rate Control enables the Serving PLMN to protect its MME and the Signaling Radio Bearers in the E-UTRAN from the load generated by NAS Data PDUs.

Serving PLMN Rate Control is applicable when the PDN connection is using S11-U interface and is set to `Control Plane Only` or when the PDN connection is using T6a interface.

Serving PLMN Rate Control is configurable in the MME by using the parameters UplinkRateControlLimit and DownlinkRateControlLimit. The two parameters define the maximum number of NAS Data PDUs that can be transferred by the serving network per deci-hour in the uplink and downlink, respectively. The parameters can be configured on the PLMN level, IMSINS level, or both levels. If a UE belongs to an IMSINS configured with Serving PLMN Rate Control and the Serving PLMN of the UE is also configured with Serving PLMN Rate Control, the IMSINS-level configurations apply for the UE.

When Serving PLMN Rate Control applies, the MME informs the UE and the PGW/SCEF of the rate control that the Serving PLMN intends to enforce for NAS Data PDUs.

The following example describes how the MME informs the UE, and the PGW/SCEF of the rate control at PDN connection establishment:

The `Serving PLMN Rate Control` IE is supported. The MME indicates Serving PLMN Rate Control to the PGW in a `Create Session Request` message, to the SCEF in a `Connection Management Request` message, and to the UE in an `Activate Default EPS Bearer Context Request` message.

As specified in 3GPP TS 23.401, the MME can enforce Serving PLMN Rate Control by discarding or delaying packets that exceed this limit. Currently, the MME does not perform these policing actions.

Note: The Serving PLMN Rate does not include SMS messages sent in NAS Transport PDUs.

13.2 APN Rate Control

APN Rate Control enables the HPLMN to control the maximum number of user data messages sent to and from a UE in a time interval on an APN.

APN Rate Control applies to data PDUs sent on an APN by either Data Radio Bearers (S1-U) or Signaling Radio Bearers (NAS Data PDUs).

APN Rate Control is configured in the PGW or the SCEF. The PGW can indicate APN rate control parameters to the UE using the Protocol Configuration Options (PCO) or Extended Protocol Configuration Options (ePCO) IE. The ePCO IE is encoded the same as the PCO IE but removes the size limitation that the PCO IE has. The SCEF can indicate APN rate control parameters to the UE only using the

Extended Protocol Configuration Options (ePCO) IE. The MME can transfer the ePCO IE transparently between the UE and the PGW/SCEF.

The following example describes how ePCO capability is exchanged and ePCO is transferred during attach:

1. If a UE supports ePCO, the ePCO bit is set to `Extended protocol configuration options supported` in the `UE network capability` IE contained in the `Attach Request` message. The UE can carry an `APN rate control support indicator` in the PCO IE of the `PDN Connectivity Request` message during Initial Attach.

2. When the MME learns that the UE supports ePCO, the MME does the following:

   — Indicates the UE and MME support by using the `Extended PCO Support Indication` (EPCOSI) flag in the `Create Session Request` message, or in the `Connection Management Request` message.

   — Forwards the PCO IE, if any, to the SGW.

   — Forwards the ePCO IE, if any, to the SCEF.

3. If the SGW supports ePCO, it forwards the EPCOSI flag to the PGW and relays the PCO IE received from the UE.

4. If the PGW also supports ePCO, it can send an ePCO IE to the MME in the `Create Session Response` message. If the SCEF supports ePCO, it can send an ePCO IE to the MME in the `Connection Management Answer` message.

5. The MME does the following:

   — Informs the UE that it supports ePCO by setting the ePCO bit in the `EPS network feature support` IE of the `Attach Accept` message, and

   — Forwards the ePCO IE to the UE in the `Activate Default EPS Bearer Context Request` message or the `Deactivate EPS Bearer Context Request` message.

   Note: A UE considers a PGW as an ePCO-supporting PGW only if it receives the ePCO IE from the PGW.

14 Limitations

This section describes limitations for the Massive IoT features.

14.1 Limitations for NB-IoT

Certain functionality is not supported for UEs using NB-IoT access. The following requests are rejected and the UE remains attached:

— Handover Request, when the source eNodeB is located in a TA with RAT type NB-IoT.

The following requests are rejected and the UE is detached with detach type `re-attach required`:

— Path Switch Request, when the source eNodeB is located in a TA with RAT type NB-IoT.

Also, if the eNodeB reconfigures a TA and changes RAT type for the TA from LTE to NB-IoT, or the opposite, the UE remains in the TA when the eNodeB changes RAT type. When the UE performs the next intra-TAU, if the RAT type in the current TA and the RAT type in new TA are different, the UE is detached. This is because the UE is not allowed to change RAT type during intra-TAU.

14.2 Limitations for eDRX for GSM

The eDRX for GSM feature in this release provides limited functionality. The following are the limitations:

— The eDRX for GSM feature is only supported by Gn-SGSN.

— The extended buffering of downlink data in Gn-SGSN for High Latency Communication (HLcom) is not supported.

— The forwarding of downlink data buffered in old Gn-SGSN to new Gn-SGSN or MME during inter-node RAU or TAU for an MS in eDRX mode is not supported.

— The deferred handling of downlink signaling for a delay-tolerant PDN connection at new Gn-SGSN or MME during inter-node mobility for an MS in eDRX mode is not supported.

— The deferred handling of Mobile Terminated Location Request and Short Message Service for an MS in eDRX mode is not supported.

14.3 Limitations for DoNAS

Certain functionality is disabled for UEs while attached through DoNAS. The following requests are rejected and the UE remains attached:

— Additional PDN Connectivity Request.

— Create Bearer Request.

The following request is rejected when using DoNAS:

— Emergency Attach Request.

For the LTE smooth pool move operation, the UEs attached with DoNAS are not moved. Instead the UEs are ignored and remain attached. For more information about moving UEs using DoNAS between MMEs in an MME pool, see section 10.7.

15 Configuration Guidelines

For information on configuring Massive IoT features, see Configuring Massive IoT.

16 Operation and Maintenance

16.1 Parameters

The following parameter sections are valid for Massive IoT:

- Battery Saving
- License-Controlled Features
- Feature Management - FunctionName Values
- GTPv2
- IMSI Number Series
- Mobility Management
- S6a Interface
- Serving PLMN Rate Control

16.2 Counters and Gauges

The following PmGroups are valid for Massive IoT:

- SGSN-MME_BSSGP
- SGSN-MME_M2M_E

- SGSN-MME_M2M_G
- SGSN-MME_Mobility_MM_E
- SGSN-MME_Mobility_MM_G
- SGSN-MME_IoT_MM_E
- SGSN-MME_IoT_SEC_E
- SGSN-MME_IoT_SM_E

16.3 Alarms and Events

The following alarms and events are valid for Massive IoT:

- epsTaRatTypeChanged
- lowPriorityDdnThrottlingLevel1
- lowPriorityDdnThrottlingLevel2

16.4 EBM

For descriptions of Sub-Cause Codes and EBM Events, see EBM Cause Codes and EBM Events and Parameters.

17 Compliance

The SGSN-MME supports Massive IoT in accordance with:

- SoC with 3GPP TS 23.060
- SoC with 3GPP TS 23.272
- SoC with 3GPP TS 23.401
- SoC with 3GPP TS 23.682
- SoC with 3GPP TS 24.008
- SoC with 3GPP TS 24.301
- SoC with 3GPP TS 29.118

- SoC with 3GPP TS 29.274
- SoC with 3GPP TS 48.018