MIoT Roaming Guidelines
Version 2.0
03 July 2020

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1 Introduction

1.1 Overview

The main goal of this document is to present a standardized view of the MIoT (Mobile Internet of Things, i.e. 3GPP Low Power Wide Area, LPWA technologies) networks when MIoT devices are roaming outside the home network. The aim is to enable the MIoT technology as a part of the existing commercial roaming infrastructure.

3rd Generation Partnership Project (3GPP) has specified the architecture for Machine Type Communication in TS 23.682 [4] to provide end-to-end communications between the MTC (Machine Type Communications) Application in the UE (User Equipment) and the MTC Application in the external network. As the document concentrates on the roaming related aspects of Mobile Internet of Things, MIoT features/functions and issues that do not have any impact on the roaming architecture or interfaces, are not covered in detail by this particular document. General guidance related to MIoT can be found for example in the GSMA Whitepaper “3GPP Low Power Wide Area Technologies” [1].

1.2 Scope

The main scope of this document includes technical guidelines of MIoT roaming. Guidance should be equally applicable whether using LTE-M (Long Term Evolution Category M) or NB-IoT (Narrow Band IoT) as the MIoT RAN (Radio Access Network) access technology, since for MIoT service provision and the actual roaming interfaces between the operators are technology agnostic.

This permanent reference document (PRD) describes the roaming interfaces used to support different MTC procedures listed in 3GPP TS 23.682 [4].

Non-MIoT related aspects of roaming are out of scope, i.e. this document does not try to affect how the existing commercial roaming works for example, in relation to a machine to machine (M2M) service using the normal GPRS (general packet radio service) data roaming. Non-3GPP LPWA technologies like Sigfox or LoRa are also out of scope.

1.3 Definitions

Term	Description
CIoT	Cellular Internet of Things, a 3GPP term referring to the enhancements in Release 13 and upwards on RAN and EPS optimizations for supporting LPWA
IoT	Internet of Things, a generic term for the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment. IoT offers functions and services which go beyond the pure M2M scope. MIoT is a subset of the far bigger IoT concept, for example a group of sensors connected together via Wi-Fi or Bluetooth are a part of IoT but not MIoT
M2M	Machine-to-Machine, a general term referring to any network technology allowing devices to communicate with each other. For example two industrial robots connected to each other via Ethernet in a factory is a part of M2M but not MIoT
MIoT	Mobile Internet of Things, a GSMA term which refers to the 3GPP standardised LPWA technologies using the licenced band (aka LTE-M, NB-IoT and EC-GSM-IoT,

Term	Description
	Extended Coverage GSM for Internet of Things). In 3GPP Release 13 and upwards, the Category of UEs that support power consumption optimisations, extended coverage and lower complexity are part of MIoT (CAT M1, CAT NB1 from Release 13 and CAT M2, CAT NB2 from Release 14). As this particular term is widely used throughout GSMA, it is also utilized also in this document Not to be confused with the term “MIoT” which means 5G massive IoT in 3GPP terminology.
MTC	Machine Type Communications, a 3GPP term referring to pre-Release 13 enhancements for M2M applications over 3GPP technologies. 3GPP further developed the features for Machine Type Communications in Release 13 and upwards, and the term enhanced MTC (eMTC) is used. The term eMTC is known as LTE-M at GSMA
NIDD	Non-IP PDN (Packet Data Network) type allows an, Evolved Packet System EPS UE to transfer data without operating an IP (Internet Protocol) stack and obtaining an IP address. Functions for NIDD (Non IP Data Delivery) may be used to handle mobile originated (MO) and mobile terminated (MT) communication with UEs, where the data used for the communication is considered unstructured from the EPS standpoint (which we refer to also as Non-IP). The support of Non-IP data is part of the CIoT EPS optimizations. The Non-IP data delivery to SCS (Services Capability Server) /AS (Application Server) is accomplished by one of two mechanisms: - Delivery using SCEF;(Service Capability Exposure Function) - Delivery using a Point-to-Point (PtP) SGi tunnel.
Roaming	BA.40 [2] states that roaming is defined as the ability for wireless customers to automatically make and receive voice calls, send and receive data, or access other services when travelling outside the geographical coverage area of their own home network, by means of using a visited network

1.4 Abbreviations

Term	Description
3GPP	3rd Generation Partnership Project
AS	Application Server
APN	Access Point Name
CIA	Configuration Information Answer
CIR	Configuration Information Request
CMA	Connection Management Answer
CMR	Connection Management Request
CN	Core Network
CS	Circuit Switch
C-SGN	CIoT Serving Gateway Node
Db	Decibels
DDN	Downlink Data Notification
DEA	Diameter Edge Agent
EC-GSM	a.k.a. EC-GSM-IoT, Extended Coverage GSM for Internet of Things

Term	Description
eDRX	extended idle mode Discontinuous Reception
eMTC	Enhanced MTC
EPC	Evolved packet Core
EPS	Evolved Packet System
GMSC	Gateway Mobile Switching Centre
GPRS	General Packet Radio Service
GSMA	GSM Association
GTP	GPRS Tunnelling Protocol
HLR	Home Location Register
HPLMN	Home Public Land Mobile Network
HSS	Home Subscriber Server
IDR	Insert Subscriber Data Request
IMSI	International Mobile Subscriber Identity
IoTTF	IoT Task Force, a GSMA NG Packet task force
IPX	IP eXchange
IWF	Interworking Function
IWK-SCEF	Interworking-SCEF
IWMSC	Interworking Mobile Switching Centre
LPWA	Low Power Wide Area
LTE	Long Term Evolution
LTE-M	a.k.a. LTE MTC Cat M1, Long Term Evolution Machine Type Communication Category M1, but also including further Categories like Category M2.
M2M	Machine to Machine
MAP	Mobile Application Part
MCL	Maximum Coupling Loss
MIoT	Mobile IoT
MME	Mobility Management Entity
MO-SMS	Mobile Originated SMS
MSISDN	Mobile Station International ISDN Number
MTC	Machine Type Communications
MT-SMS	Mobile Terminated SMS
MSC	Mobile Switching Centre
NAS	Non-Access Stratum
NB-IoT	Narrowband IoT
NG	Networks Group, a GSMA working group
NIDD	Non IP Data Delivery
ODA	MO-Data-Answer
ODR	MO-Data-Request

Term	Description
PCO	Point of Control
PCRF	Policy Control Rules Function
PDN	Packet Data Network
PGW	PDN Gateway
PLMN	Public Land Mobile Network
PMN	Public Mobile Network
PRD	Permanent Reference Document
PSM	Power Saving Mode
PTW	Paging Time Window
PtP	Point to Point
RAN	Radio Access Network
RIA	Reporting Information Answer
RIR	Reporting Information Request
SCEF	Service Capability Exposure Function
SCS	Services Capability Server
SCS/AS	Services Capability Server / Application Server
SCTP	Stream Control Transmission Protocol)
SG	Service Gateway
SGSN	GPRS Support Node
SMS-SC	Short Message Service-Service Centre
SM RP DA	Short Message Relay-layer Protocol Destination Address
SM RP OA	Short Message Relay-layer Protocol Originating Address
SM RP UI	Short Message Relay-layer Protocol User Information
SGW	Serving Gateway
SMS	Short Message Service
SMS-IWF	SMS Interworking Function
SV	Software Version
UE	User Equipment
UICC	Universal Integrated Circuit Card
VPLMN	Visited Public Land Mobile Network
VLR	Visited Location Register
WSOLU	Wholesale SOLUtions, a subgroup of GSMA working group WAS

1.5 References

Ref	DocNumber	Title
1	CLP.16	3GPP Low Power Wide Area Technologies
2	BA.40	GSMA PRD Roaming Guide
3	TS 23.401	3GPP General Packet Radio Service (GPRS) enhancements for

Ref	DocNumber	Title
		Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access
4	TS 23.682	3GPP Architecture enhancements to facilitate communications with packet data networks and applications
5	TS 29.002	3GPP Mobile Application Part (MAP) specification
6	TS 29.128	3GPP Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) interfaces for interworking with packet data networks and applications
7	RFC 6733	Diameter Base Protocol
8	BA.27	GSMA PRD Charging Principles
9	IR.88	GSMA PRD LTE Roaming Guidelines
10	TS 29.274	3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3
11	TS 29.281	3GPP General Packet Radio System (GPRS) Tunnelling Protocol User Plane (GTPv1-U)
12	TS 29.338	3GPP Diameter based protocols to support Short Message Service (SMS) capable Mobile Management Entities (MMEs)
13	TS 23.003	3GPP Numbering, addressing and identification
14	TS 23.012	3GPP Location management procedures
15	FS.19	GSMA PRD Diameter Interconnect Security
16	TS 23.272	3GPP Circuit Switched (CS) fallback in Evolved Packet System (EPS); Stage 2
17	TS 29.272	3GPP Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol
18	TS 24.008	3GPP Mobile radio interface Layer 3 specification; Core network protocols; Stage 3
19	CLP.29	GSMA white paper; LTE-M deployment guide to basic feature set

2 Architecture

2.1 Background

Mobile IoT is the term used by the GSMA to identify the 3GPP standard LPWA technologies that have been defined in 3GPP Release 13 and upwards. Such technologies include LTE-M, NB-IoT and EC-GSM-IoT (Extended Coverage GSM for Internet of Things). The main characteristics of these technologies compared to the traditional cellular technologies are:

- Optimisation of power consumption in the UE, particularly for devices that are battery powered and cannot be recharged once deployed. A typical example is a water meter which is deployed on the ground which has no power supply.
- Enhanced coverage, 3GPP has designed the technologies for achieving at least 15-20 decibels (Db) maximum coupling loss (MCL) improvement.

- Designed for transmitting small amounts of data, tolerant to latency.

3GPP has specified the Machine Type Communication architecture in TS 23.682 [4] to support end-to-end communications between MIoT Devices and SCS/AS. The Machine Type Communications (MTC) Application in the external network is typically hosted by an Application Server (AS) and may use a SCS for additional value added services. The MTC architecture supports roaming for both the home routed scenarios by securely exposing the 3GPP network service capability exposure to SCS and AS.

2.2 Reference Architecture

The reference roaming architecture of MIoT and Service Capability Exposure are depicted in Figure 2 (as referenced in Figure 4.2-1b of TS 23.682 [4]) and Figure 8 (as referenced in Figure 4.2-3 of TS 23.682 [4]) respectively. The architecture and procedures used for MIoT-based services is based on 3GPP specifications such as TS 23.682 [4] and TS 23.401 [3].

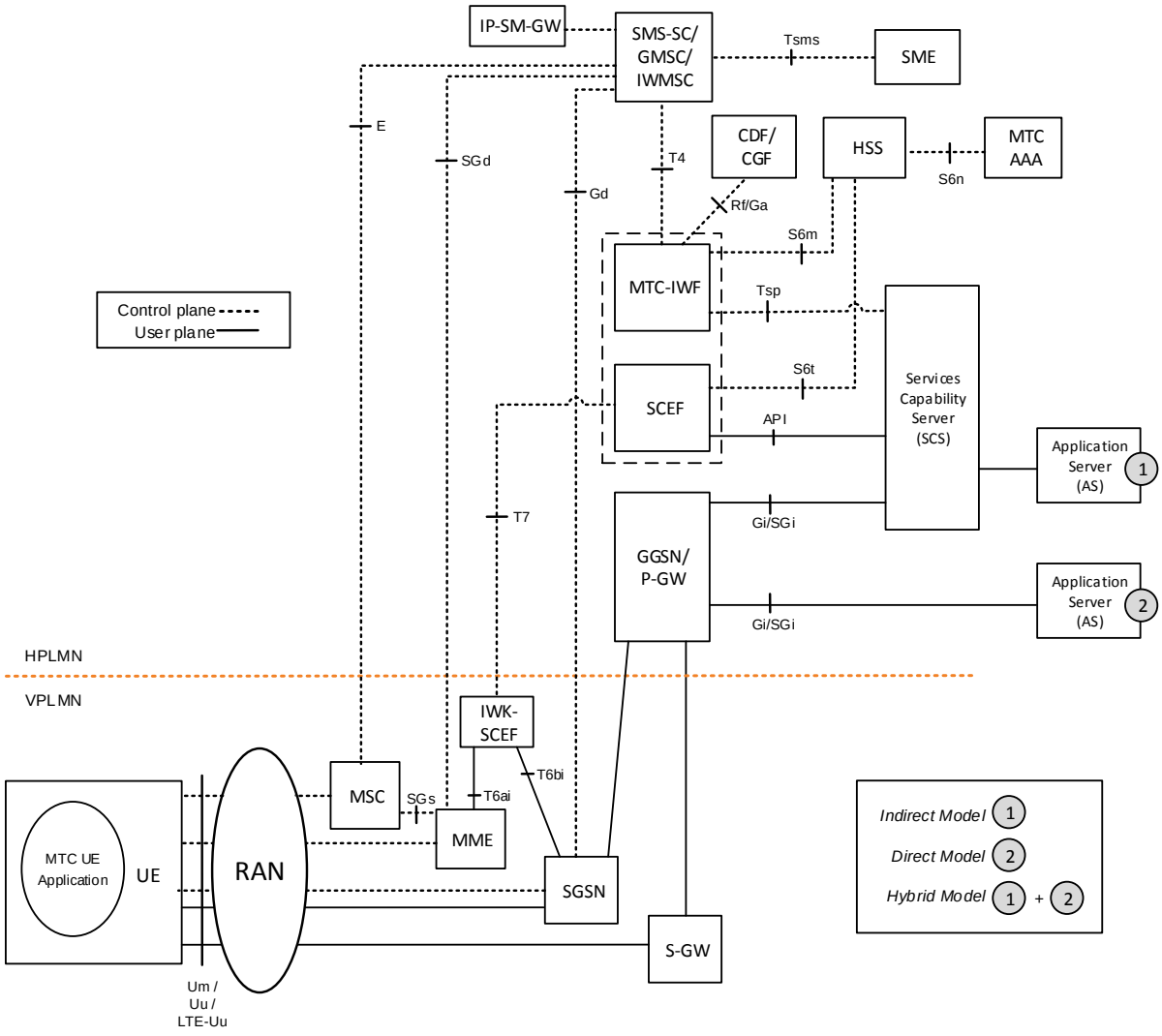

Figure 1: 3GPP Architecture for MIoT (Roaming)

Note: MO-SMS via T4 is defined in TS 23.682 [4].

Note: Architecture supports both the home routed and the local breakout scenarios (see TS 23.622 clause 4.2 NOTE 3).

Note: See TS 23.401 clause 4.10 for an introduction to MIoT related EPS optimizations.

2.3 Roaming Interfaces

The following interfaces are used to support MIoT Roaming:

Nodes	Interface ID	Protocol
MME - HSS	S6a	Diameter Base Protocol (IETF RFC 6733 [7]) and 3GPP TS 29.272 [17])
S4-SGSN - HSS	S6d	Diameter Base Protocol (IETF RFC 6733 [7]) and 3GPP TS 29.272 [17])
	Gr	See Notes below
SGW in VPLMN and PGW in HPLMN	S8	GTP (GTP-C 3GPP TS 29.274 [10] and GTP-U 3GPP TS 29.281 [11])
IWK-SCEF in VPLMN and SCEF in HPLMN	T7	Diameter Base Protocol (IETF RFC 6733 [7]) and 3GPP TS 29.128 [6])
MSC/MME in VPLMN and SMS/GMSC in HPLMN	MAP-E	3GPP TS 29.002 [5]
	SGd	Diameter Base Protocol (IETF RFC 6733 [7]) and 3GPP TS 29.338 [12])
MSC in VPLMN and HLR in HPLMN	MAP-D	3GPP TS 29.002 [5]

Table 1 Interfaces for MIoT

Note: For Gr and Gp interfaces, see GSMA PRD IR.33 [10].

2.4 Network Elements

2.4.1 General

The following 3GPP network elements provide functionality to support MIoT Roaming:

2.4.2 SMS-SC/GMSC/IWMSC

This functionality resides in the HPLMN and includes the following:

- Terminate MAP-E (Mobile Application Part – E) interface from the MSC (as SMS-IWF, SMS Interworking Function) and SGd interface from the Mobility Management Entity (MME) in the Visited Public Land Mobile Network (VPLMN).

2.4.3 Mobile Switching Centre (MSC)

This functionality resides in the VPLMN (Visited Public Land Mobile Network) and includes the following:

Terminate MAP-E and MAP-D interfaces from the SMS-SC/GMSC/IWMSC (Short Message Service-Service Centre/Gateway Mobile Switching Centre/ Interworking Mobile Switching centre) and the HSS (Home Subscriber Server) in the HPLMN (Public Land Mobile Network), respectively.

2.4.4 MME, Mobility Management Entity

This functionality resides in the VPLMN.

MME is a specific functionality required for:

- MIoT roaming, which is described in TS 23.682 [4] clause 4.4.5, includes the following:
    - Terminates the SGd interface from SMS-SC/GSMC/IWMSC in the HPLMN
- MIoT roaming, which is described in TS 23.682 [4] clause 4.4.5, includes the following:
    - Terminates the T6ai interface from IWK-SCEF (Interworking Service Capability Exposure Function) in the VPLMN

2.4.5 HSS

HSS/HLR (Home Location Register) resides in the HPLMN. Functionality, which is described in TS 23.682 [4] clause 4.4.3 and includes the following:

- Terminates the MAP-D interface from MSC (as SMS IWF in VPLMN)
- Mapping from External Identifiers to MSISDN (Mobile Station International ISDN Number) is also provided for legacy SMS infrastructure not supporting MSISDN-less SMS

2.4.6 SCEF

The Service Capability Exposure Function (SCEF) resides in the HPLMN. Functionality, which is described in 3GPP TS 23.682 [4] clause 4.4.8 and includes the following:

- Terminates the T7 interface from IWK-SCEF in the VPLMN
- Accounting in the HPLMN for operator settlements
- Access: issues related to external interconnection and point of contact

2.4.7 IWK-SCEF

The Interworking SCEF (IWK-SCEF) resides in the VPLMN. Functionality, which is described in 3GPP TS 23.682 [4] clause 4.4.9 and includes the following:

- Terminates the T7 interface from SCEF in the HPLMN
- Normalization of reports; e.g. monitoring events reporting, according to roaming agreement between HPLMN and VPLMN

- Generate charging/accounting information for Event Monitoring and non-IP data

3 Technical Requirements and Recommendations for Roaming Interfaces

3.1 General requirements for Inter-PMN interfaces

Detailed requirements to support MIoT Roaming for Inter-PMN IP backbone network, SCTP (Stream Control Transmission Protocol), Diameter protocol and S8 interface are covered under IR.88[9]

Figure 2 shows the diameter end to end architecture to support MIoT Roaming. Diameter Edge Agents or DEAs can be used for the interconnection ensuring load balancing and resiliency.

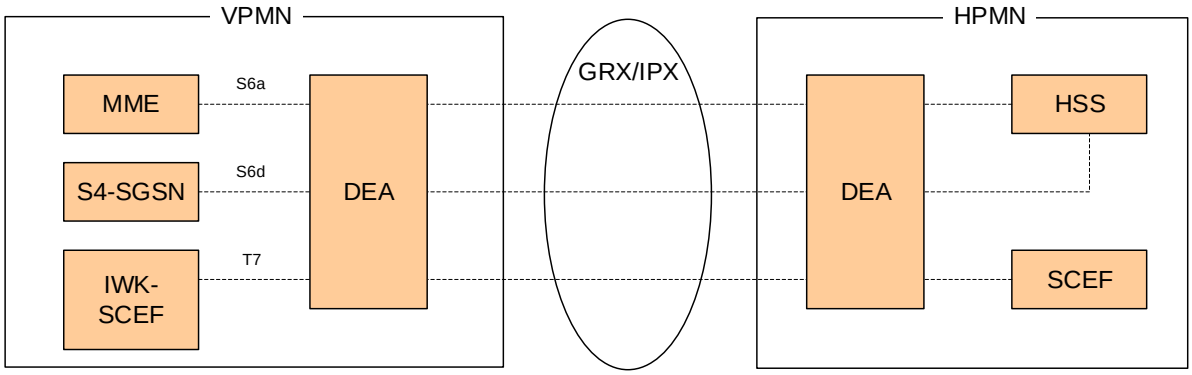

Figure 2: Diameter Roaming Implementation Architecture to support MIoT Roaming

IR.88[9] describes the different IPX (Internet Protocol eXchange) connectivity options to support interconnection between PMN (Public Mobile Network)

3.1.1 MAP-D/SGd Roaming Interfaces

The following Figure depicts the roaming interfaces between SMS-SC/GMSC/IWMSC in the HPLMN and MSC/MME in the VPLMN for MIoT architecture.

Note: The interface between the applications and SCS is out of scope of 3GPP.

Note: C-SGN (CIoT Serving Gateway Node) is an implementation option of EPC (Evolved Packet Core) nodes as a combined node (see Annex L of 3GPP TS 23.401 [3]).

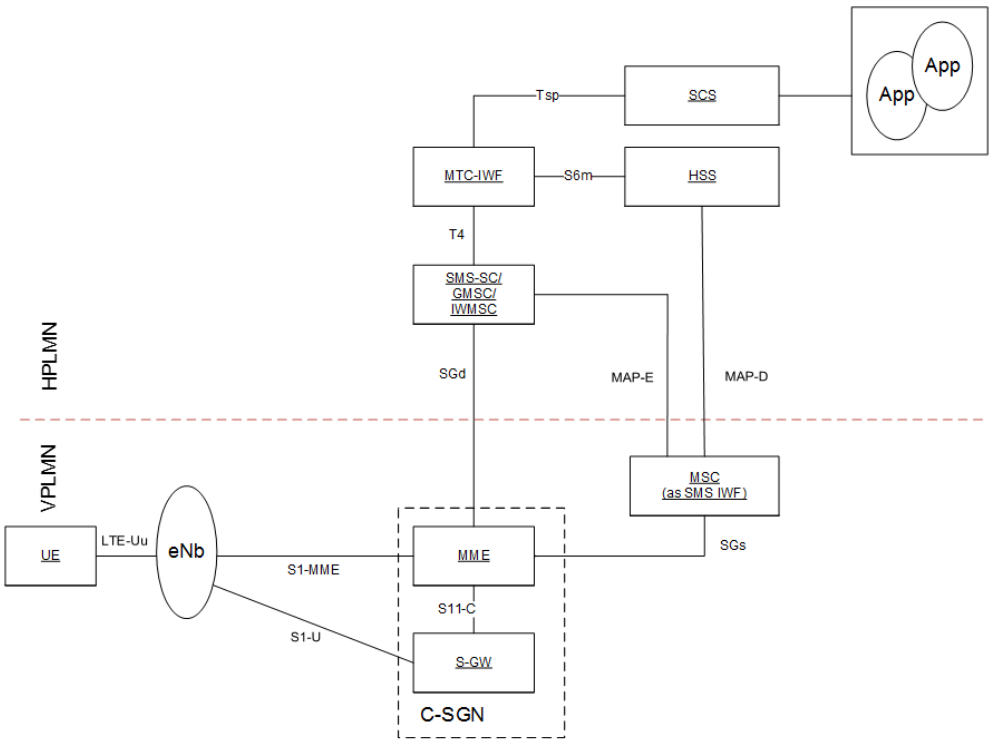

Figure 3: MAP-E/SGd Roaming interfaces related to MIoT Architecture

The following roaming interfaces are used:

MAP-E: This is a MAP interface defined in 3GPP TS 29.002 [5]. It is used for delivering Mobile Terminated MT-SMS triggers due to T4 or Mobile Originated, MO-SMS from the UE to the Short Message Service-Service Centre SMS-SC. The UE identifier used in this interface is IMSI.

MAP-D: This is a Mobile Application Part (MAP) interface defined in 3GPP TS 29.002 [5]. It is used for Circuit Switch (CS) attachment triggered by the Service Gateways SGs (see 3GPP TS 23.272 [16]). The UE identifier used in this interface is IMSI.

Note: See 3GPP TS 23.012 [14] section 3.6.1.5 for “Support for subscription without MSISDN”

SGd: This is a Diameter interface defined in 3GPP TS 29.338 [12]. It is used for delivering MT-SMS triggers due to T4 or MO-SMS (Mobile Outgoing SMS) from the UE to the SMS-SC. The UE identifier used in this interface is IMSI.

Note: If HPLMN does not support SGd, an IWF as described in Annex C of 3GPP TS 23.272 16] is needed for the conversion between MAP-E and SGd.

For MSISDN-less UE, the MO-SMS carries a dummy MSISDN of the UE to meet the protocol requirements. According to 3GPP TS 23.003 [13], when the MSISDN is not available in the message and the presence of the MSISDN is required for backward compatibility reasons, the MSISDN shall take the dummy MSISDN value composed of 15 digits set to 0 (encoded as an E.164 international number).

3.1.2 S6a and S6d interface

Details of S6a/d interface recommendations for roaming scenarios are covered in IR.88[9]. This interface is used for MIoT device authentication, mobility management and subscriber data management procedures.

S6a/d is also used for monitoring event configuration and reporting via HSS for MIoT roaming devices as explained in section 4.2.1.

3.1.3 T7 Roaming Interface

The figure below depicts the roaming interfaces between SCEF in the HPLMN and IWK-SCEF in the VPLMN for MIoT architecture.

Note: The interface between the applications and SCEF is out of scope of 3GPP.

Note: C-SGN (CIoT Serving Gateway Node) is an EPC implementation option with combined nodes (see Annex L of 3GPP TS 23.401 [3]).

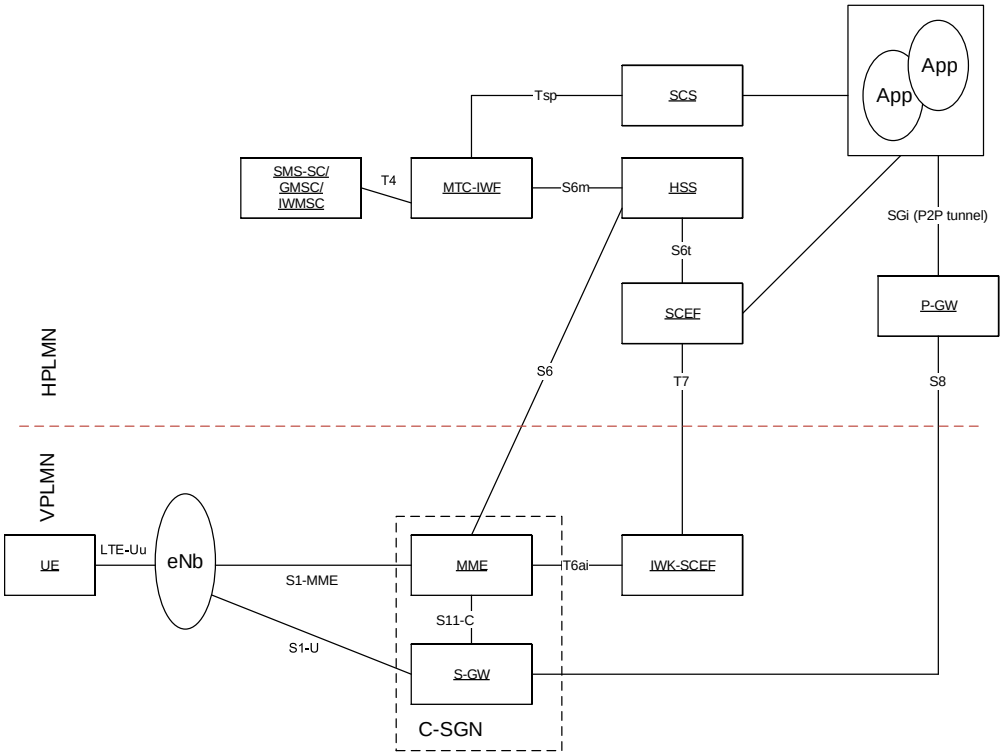

Figure 4: T7 Roaming interface related to MIoT Architecture

The following roaming interfaces are used:

S6: This is a Diameter interface defined in 3GPP TS 29.272 [17]. It contains the user subscription profile.

T7: This is a Diameter interface defined in 3GPP TS 29.128 [6]. The UE identifier used in this interface is the IMSI.

S8: This is a GTPv2 interface defined in 3GPP TS 29.274 [10] and 3GPP TS 29.281 [11]. IR.88 [9] and describes the behaviour of this interface.

4 Technical Requirements and Recommendations to support MIoT roaming for different MTC procedures

4.1 Device Triggering Procedure

4.1.1 MAP-E

The following figure shows the MTC device trigger delivery using T4 trigger over MAP-E.

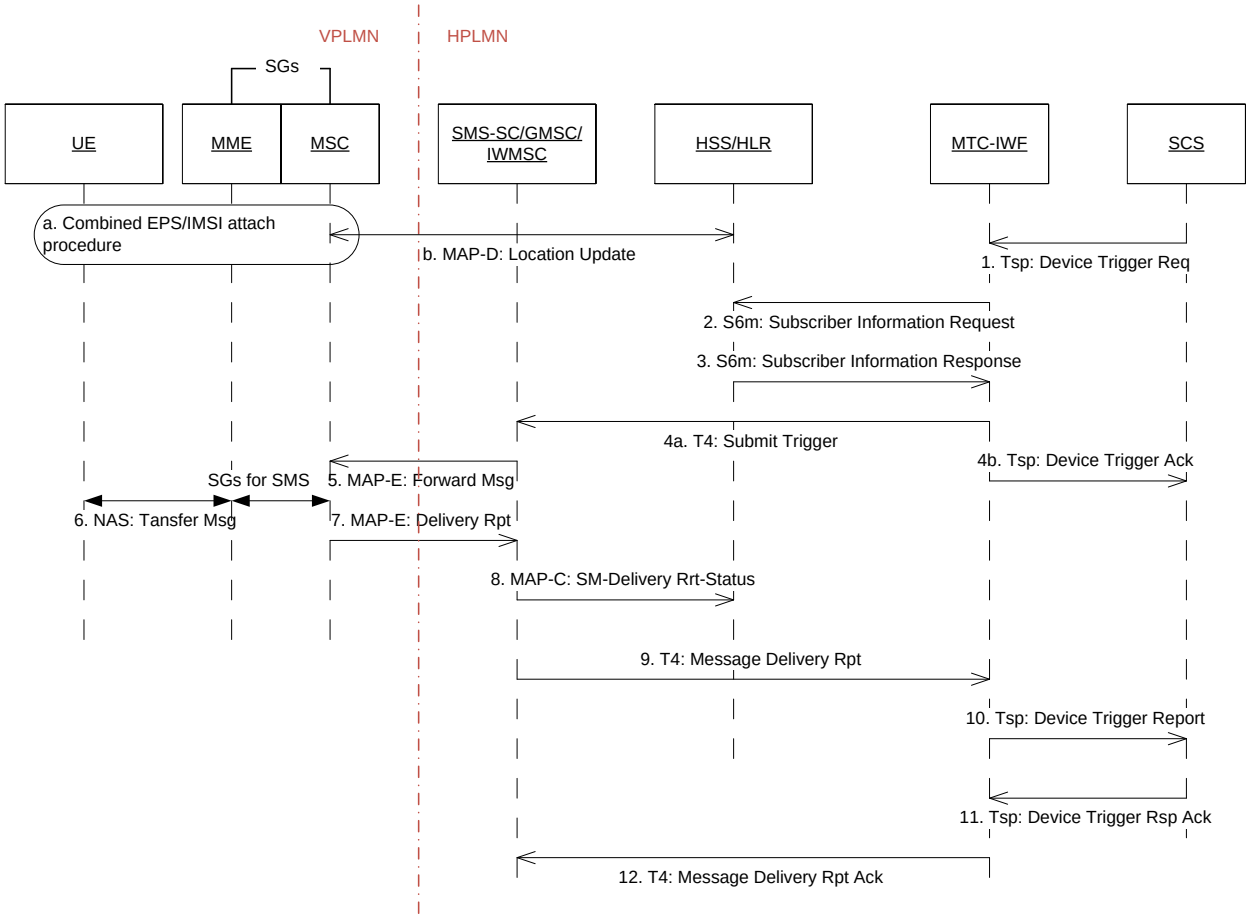

Figure 5: MIoT delivery using T4 trigger over MAP-E.

- UE performs combined EPS/IMSI attached as defined in 3GPP TS 23.272 16]. This allows the MSC/VLR (Visited Location Register) to register the UE with the HLR via MAP-D Location Update procedure.
- If MSC/VLR supports MSISDN-less operation, it must indicate this support in the MAP-D: Location Update Request. The HLR shall download the subscriber parameters to the VLR without an MSISDN for an MSISDN-less subscription if the VLR indicates support of the MSISDN-less operation. Otherwise, the HLR should reject a MAP Update Location request received for an MSISDN-less subscription (see 3GPP TS 23.012 14])

1. SCS sends the Device Trigger Request to the MTC-IWF. External Identifier or MSISDN is used to identify the device.

2. MTC-IWF sends a Subscriber Information Request to the HSS/HLR to resolve the External Identifier or MSISDN to an IMSI and retrieve the related HSS stored “Routing information” including the identities of the UE's serving the CN (Core Network) node(s). In this case, it is assumed that the serving CN node is the MSC address, i.e., UE registered to this MSC using SMS over SGs procedure defined in 3GPP TS 23.272 16].
3. HSS/HLR sends the Subscriber Information Response to MTC-IWF. The IMSI and the serving CN node (i.e., MSC address) are included in this message.

Note: Optionally, the HSS/HLR can provide a mapping of External Identifiers and the MSISDN, for legacy SMS infrastructure that does not support MSISDN-less SMS.

4. The MTC-IWF selects a suitable SMS-SC based on the configured information. The MTC-IWF sends a Submit Trigger to the SMS-SC. The External Identifier or MSISDN, the IMSI, and the serving node ID = MSC address are included in this message to the SMS-SC.
5. The SMS-GMSC uses the MAP-MT-FORWARD-SHORT-MESSAGE service to send the MT-SMS to the UE.

From a MAP-E protocol standpoint, the following parameter settings are needed to send this message to MSC properly:

- Short Message Relay Layer Protocol Destination Address (SM RP DA): This is set to the IMSI of the receiver.
- Short Message Relay Layer Protocol Originating Address (SM RP OA): This is set to the SMS-SC address.
- Short Message Relay Layer Protocol User Information (SM RP UI): This carries the short message transfer protocol data unit (i.e., short message payload and short message protocol information e.g., application port ID and sender’s E.164 address).

6. The SMS over the SGs procedure is used to deliver the MT SMS to the UE via Long Term Evolution (LTE).
7. The MSC sends back a positive acknowledgement to the MT-FORWARD-SHORT-MESSAGE from step 5.
8. If the message delivery is not successful, then the SMS-SC requests the HLR/HSS to add the SMS-SC address to the Message Waiting list for redelivery attempt later.

9-12 SMS-SC sends delivery report to MTC-IWF to allow MTC-IWF to indicate the delivery status to SCS.

Note: The MAP-E for delivering MT-SMS does not depend on the MSISDN of the receiver. The sender’s E.164 (i.e., MSISDN) must be included as part of the SMS protocol. This sender’s E.164 corresponds to the “SCS-Identity” received from SCS in step 1.

Note: The MSC/VLR which supports the MSISDN-less operation needs to indicate this capability to the HSS via MAP-D Location Update Request. The HLR

shall download the subscriber parameters to the VLR without a MSISDN for a MSISDN-less subscription if the VLR indicates the support of MSISDN-less operation. Otherwise, the HLR should reject the MAP Update Location request received for an MSISDN-less subscription (see 3GPP TS 23.012 14]).

4.1.2 SGd

The following figure shows MIoT delivery using T4 trigger over SGd.

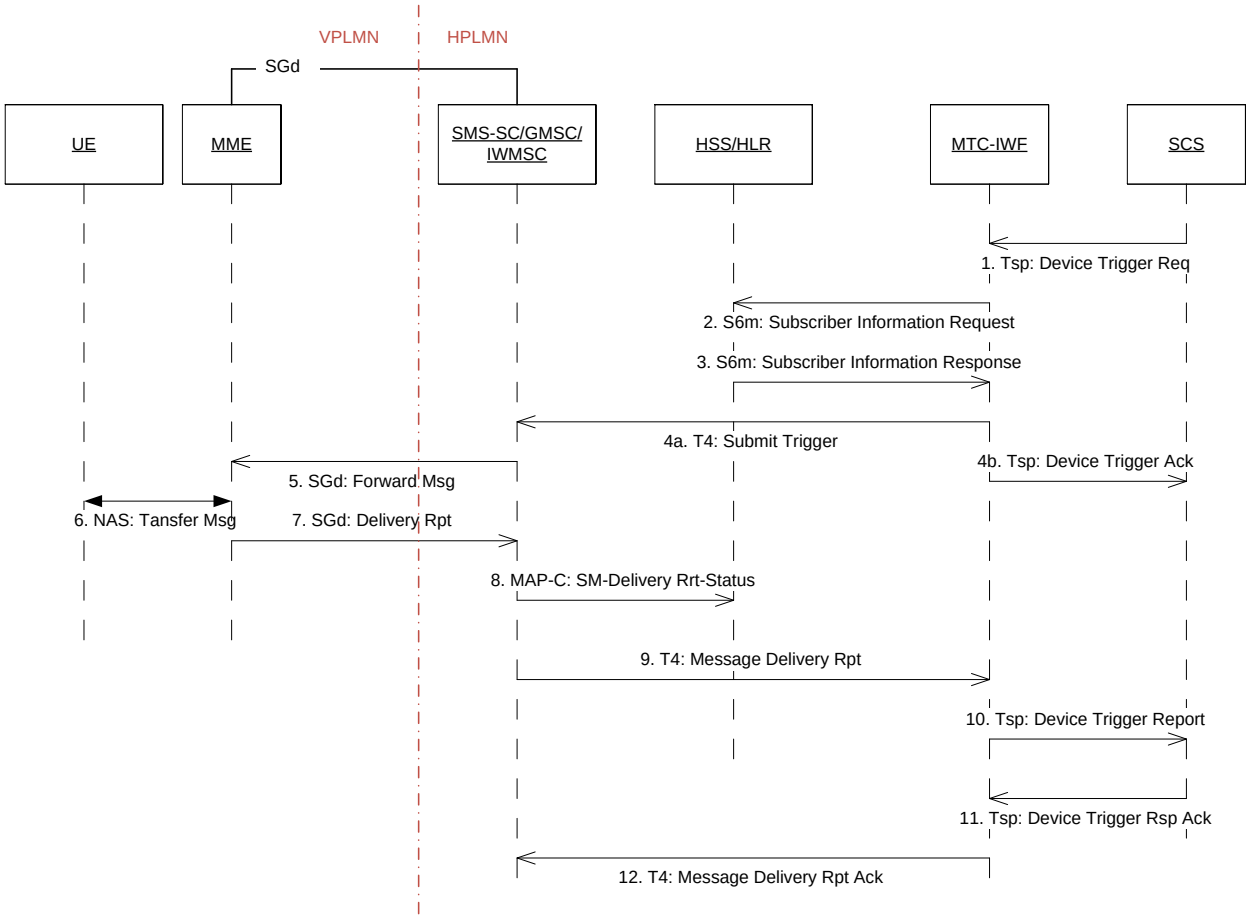

Figure 6: MIoT delivery using T4 trigger over SGd.

Compared to Figure 6 (T4 trigger with MAP-E), the difference is that the step a/b is not performed, the serving node ID in step 2 and 4a is pointing to MME instead of MSC, and step 5 and 7 use the Diameter protocol to deliver the information that is equivalent to the information over the MAP-E interface.

Note: SGd for delivering MT-SMS does not depend on the MSISDN of the receiver. The sender's E.164 (i.e., MSISDN) must be included as part of the SMS protocol.

4.1.3 Non IP Data Delivery Procedure

The Non-IP data delivery for MIoT Roaming devices is accomplished by one of two mechanisms:

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

The delivery using a Point-to-Point (PtP) SGi tunnel is further described in 3GPP TS 23.401 [3]. Following sections describe the Non IP Data Delivery (NIDD) via SCEF using Packet Data Network (PDN) connection for MIoT roaming devices.

4.1.3.1 T6 Connection Establishment Procedure

When the roaming MIoT UE performs the EPS attach procedure (see 3GPP TS 23.401 [3]) with PDN type of "Non-IP", and the subscription information corresponding to either the default Access Point Name (APN) for PDN type of "Non-IP" or the UE requested APN, includes the "Invoke SCEF Selection" indicator, then the visited network MME initiates a T6a/T6b connection towards the home network SCEF, corresponding to the "SCEF ID" indicator for that APN.

The following figure depicts the T6 connection establishment for MIoT Roaming UE:

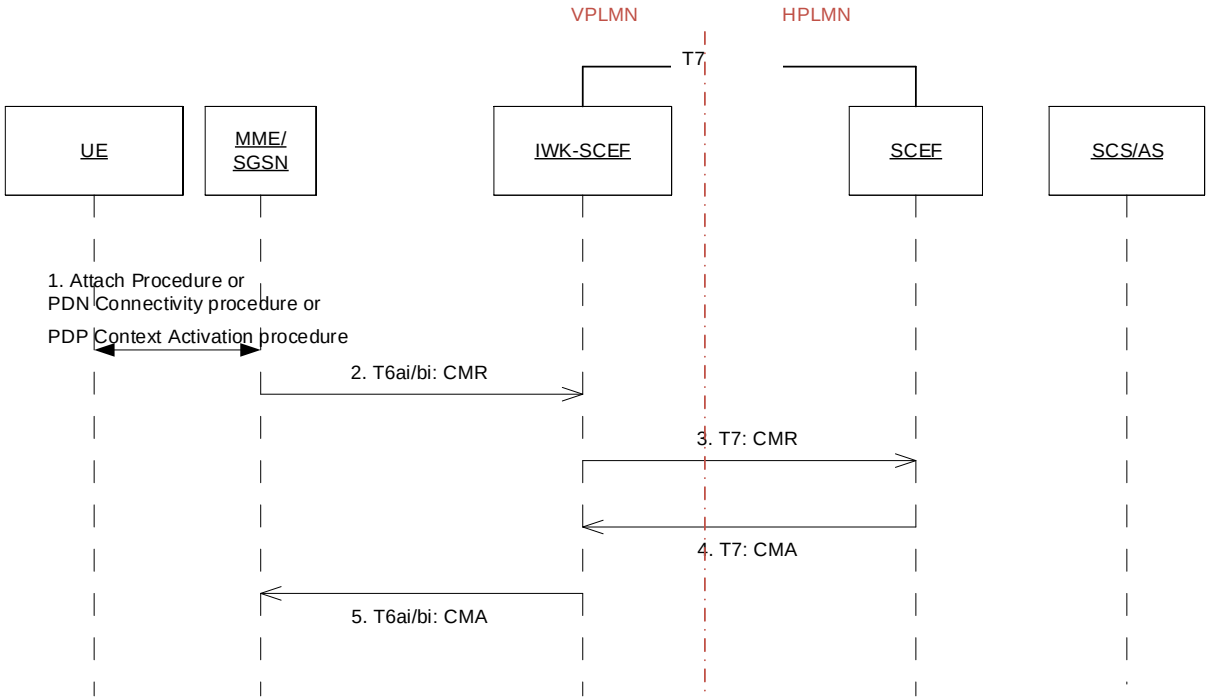

Figure 7: MIoT T6a/T6b Connection Establishment Procedure for roaming MIoT Device

1. The UE performs steps 1-11 of the E-UTRAN Initial Attach procedure or step 1 of the UE requested PDN Connectivity procedure (see 3GPP TS 23.401 [5]) or PDP Context Activation Procedure (see 3GPP TS 23.060 [6]). The MME/SGSN (Mobility Management Entity/GPRS Support Node) receives subscription information for a non-IP PDN connection to an APN that is associated with an "Invoke SCEF Selection" indicator, and SCEF ID. If the MSISDN is also associated with the user's subscription, then it is made available as User Identity to the visited network MME/SGSN by the home network HSS.
2. If the subscription information corresponding to either the default APN for PDN type of "Non-IP" or the UE requested APN includes "Invoke SCEF Selection" indicator, then MME/SGSN shall create the PDN connection with home network SCEF by sending T6ai Connection Management Request (CMR) with Connection-Action AVP set to “CONNECTION_ESTABLISHMENT” through IWK-SCEF.

3. IWK-SCEF acts as a Diameter Proxy/Relay agent which forwards the received CMR to the home network SCEF using T7 interface. IWK-SCEF shall optionally apply access control policies to allow or reject the PDN connection establishment on CMR based on roaming partner agreements.
4. The home network SCEF rejects or accepts the PDN connection establishment request by responding back with a Connection Management Answer (CMA). A successful CMA shall include User Identity, EPS Bearer Identity, SCEF ID, APN, PCO (point of control) and the NIDD Charging ID message. This CMA should go towards the MME/SGSN of the visited network through the IWK-SCEF confirming the establishment of the PDN connection to the SCEF for the UE.
5. The IWK-SCEF receives the CMA message from the SCEF and relays the same to MME/SGSN.

4.1.3.2 MIoT Mobile Terminated NIDD procedure

The figure below illustrates the procedure using which the SCS/AS sends the non-IP data to a MIoT Roaming IoT Device. This procedure assumes that non-IP PDN connection is established between the roaming MIoT Device and the home network SCEF.

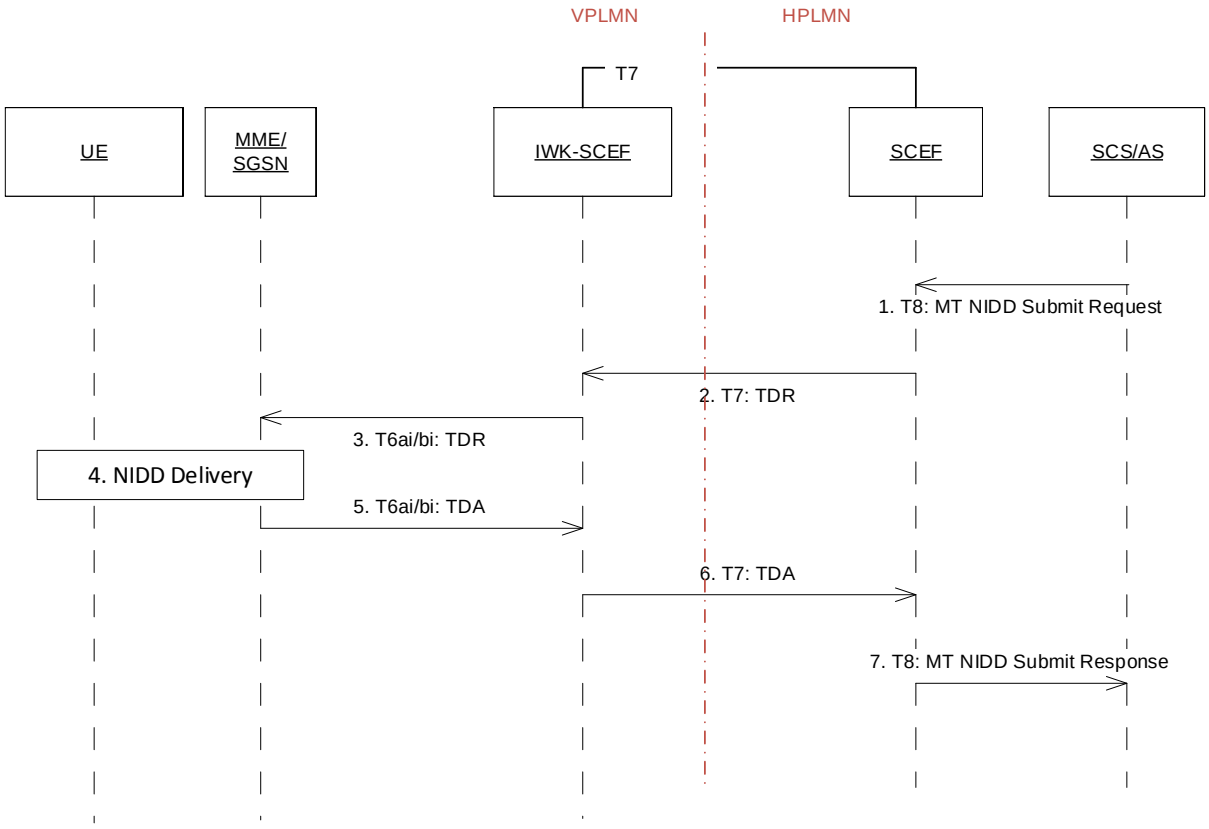

Figure 8: MIoT Mobile Terminated NIDD Procedure for roaming MIoT Device

1. The home network SCS/AS sends to the home network, a MT NIDD Submit Request for given MIoT roaming device, using T8 NIDD Submit request

2. If SCEF EPS bearer context is found for a given MIoT device, then SCEF sends MT-Data-Request(MTR) towards the visited network MME via IWK-SCEF using T7 interface.
3. The visited network IWK-SCEF acts as a proxy/relay agent which relays the received TDR to MME/SGSN through T6ai/bi. IWK-SCEF shall optionally apply downlink non IP data rate control based on roaming agreements.
4. The MME/SGSN shall immediately deliver the non-IP data to the UE if the UE is already in ECM_CONNECTED mode. If the UE is in ECM_IDLE, MME/SGSN may initiate paging procedure and deliver the message.
5. The MME/SGSN shall respond back to the home network SCEF with a delivery status using T6ai/bi TDA message through IWK-SCEF.
6. The IWK-SCEF shall relay the received TDA back to the home network SCEF.
7. The home SCEF shall send a T8 MT NIDD Submit Response to the SCS/AS informing of the received results from the MME/SGSN or buffer the MT Non IP Data based on operator's local policies if UE is not reachable.

4.1.3.3 MIoT Mobile Originated NIDD procedure

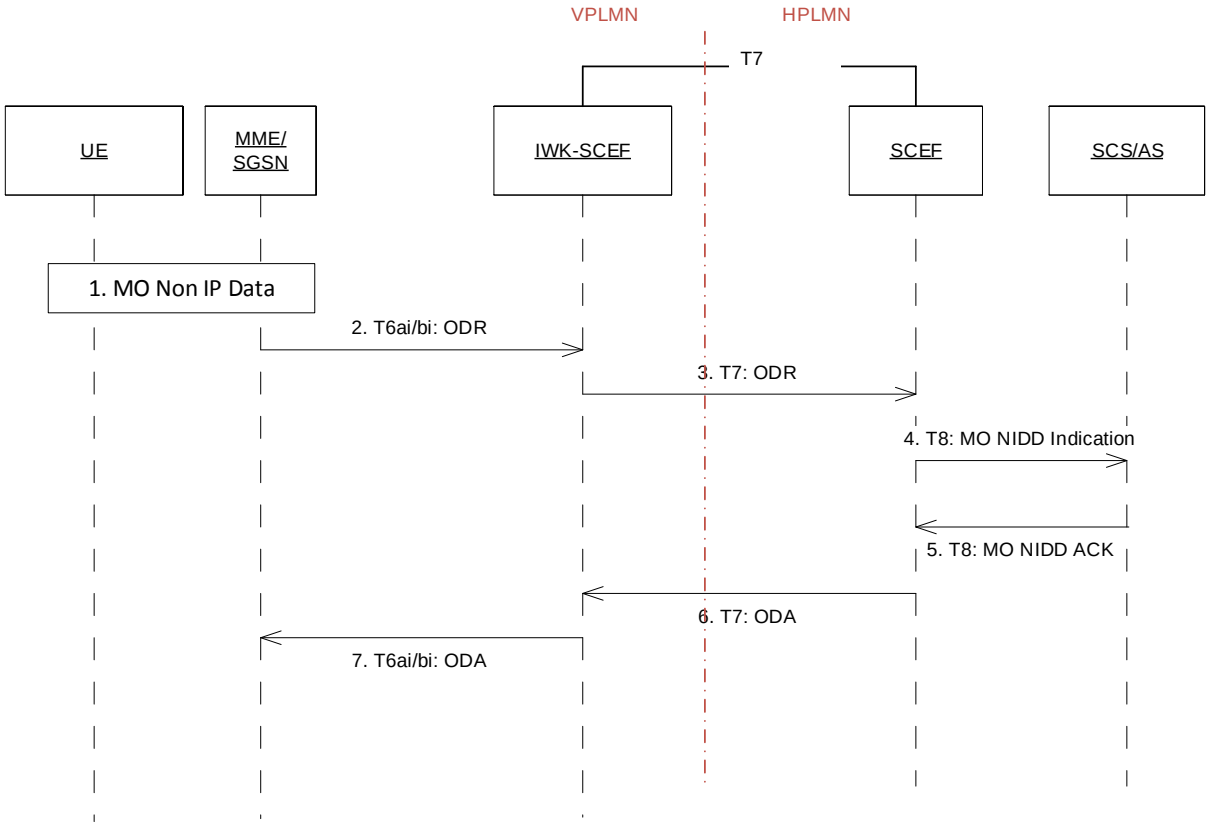

Figure 9: MIoT Mobile Originated NIDD Procedure for roaming MIoT Device

1. The MIoT Roaming UE sends a NAS message with EPS bearer ID and non-IP data. The Reliable Data Service header is included if the Reliable data service is enabled, to the MME as per the procedure described in clause 5.3.4B.2 of 3GPP TS 23.401 [5] (steps 0 - 2) or else the UE sends data to the SGSN (see clause 9.3 and 9.6 of 3GPP TS 23.060 [6]) on a PDP Context of PDN type Non-IP associated with a T6b interface.

2. The visited MME/SGSN sends the MO-Data-Request(ODR) message to the IWK-SCEF over T6ai/bi.
3. The IWK-SCEF relays the ODR to the home network SCEF using T7 interface. IWK-SCEF shall optionally perform apply uplink data rate control for MO non IP data based on roaming agreements.
4. The home network SCEF finds the EPS bearer context for the received ODR and sends the non-IP data to the SCS/AS.
5. The SCS/AS responds to the SCEF with a MO NIDD Acknowledgement.
6. The SCEF sends the MO-Data-Answer(ODA) message to the IWK-SCEF over T7.
7. IWK-SCEF relays the received ODA to MME/SGSN over T6ai/bi

4.1.3.4 T6 Connection Release

MME/SGSN Initiated T6a/T6b Connection Release procedure

4.1.3.4.1

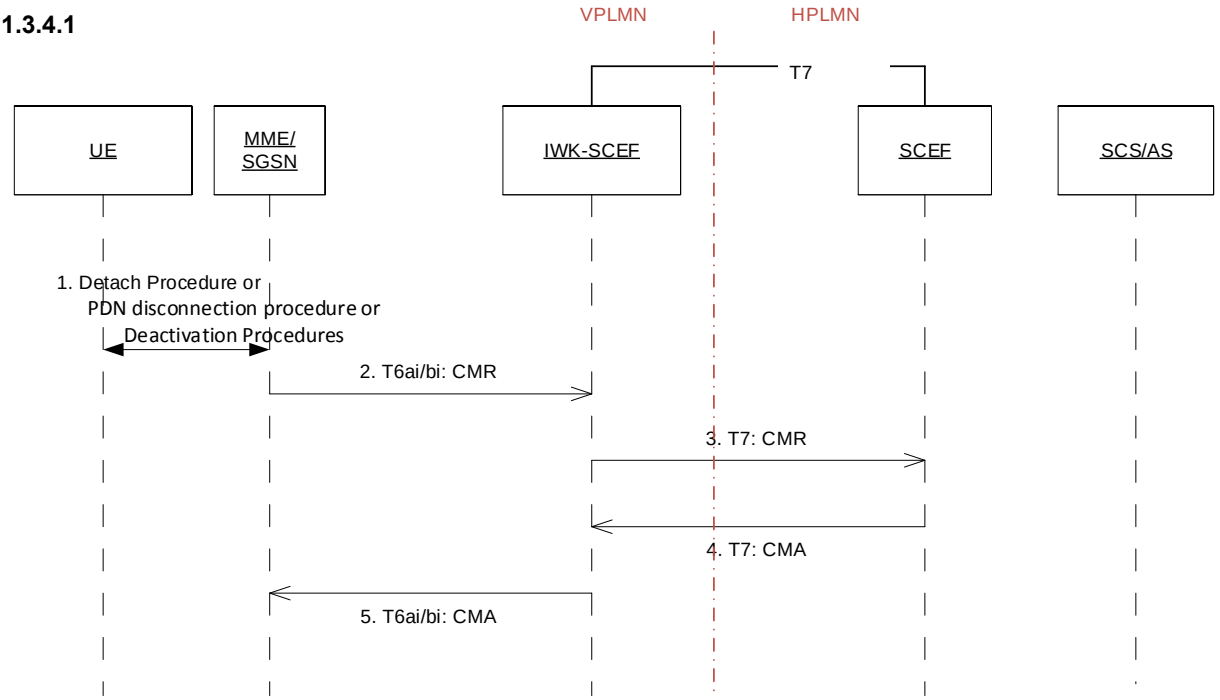

Figure 10: MME/SGSN Initiated T6a/T6b Connection ReleaseProcedure

1. Either the UE performs step 1 of the UE-initiated Detach procedure for E-UTRAN (see clause 5.3.8.2.1 3GPP TS 23.401 [3]), or the MME performs the MME-initiated Detach procedure (see clause 5.3.8.3 of 3GPP TS 23.401 [3]), or the HSS performs step 1a of the HSS-initiated Detach procedure (see clause 5.3.8.4 of 3GPP TS 23.401 [3]), or the UE/MME performs steps 1a-1b of the UE or MME requested PDN disconnection procedure (see clause 5.10.3 of 3GPP TS 23.401 [3]), or a Detach Procedure specified in 3GPP TS 23.060 [6] clause 6,6 is performed, or an MS or network initiated Deactivation Procedure specified in 3GPP TS 23.060 [6] clause 9.2.4 is performed, for which the PDN/PDP connection to an SCEF exists.
2. The visited network MME/SGSN shall send the Delete connection request with home network SCEF by sending a T6ai/bi CMR with Connection-Action AVP set to “CONNECTION_RELEASE” through IWK-SCEF.

3. IWK-SCEF forwards the received CMR to the home network SCEF over T7 interface
4. The SCEF sends a Delete SCEF Connection Response using a CMA message towards the MME/SGSN indicating acceptance of the removal of SCEF Connection information for the UE through IWK-SCEF
5. The IWK-SCEF relays the received CMA to MME/SGSN

SCEF Initiated T6 Connection Release procedure

4.1.3.4.2

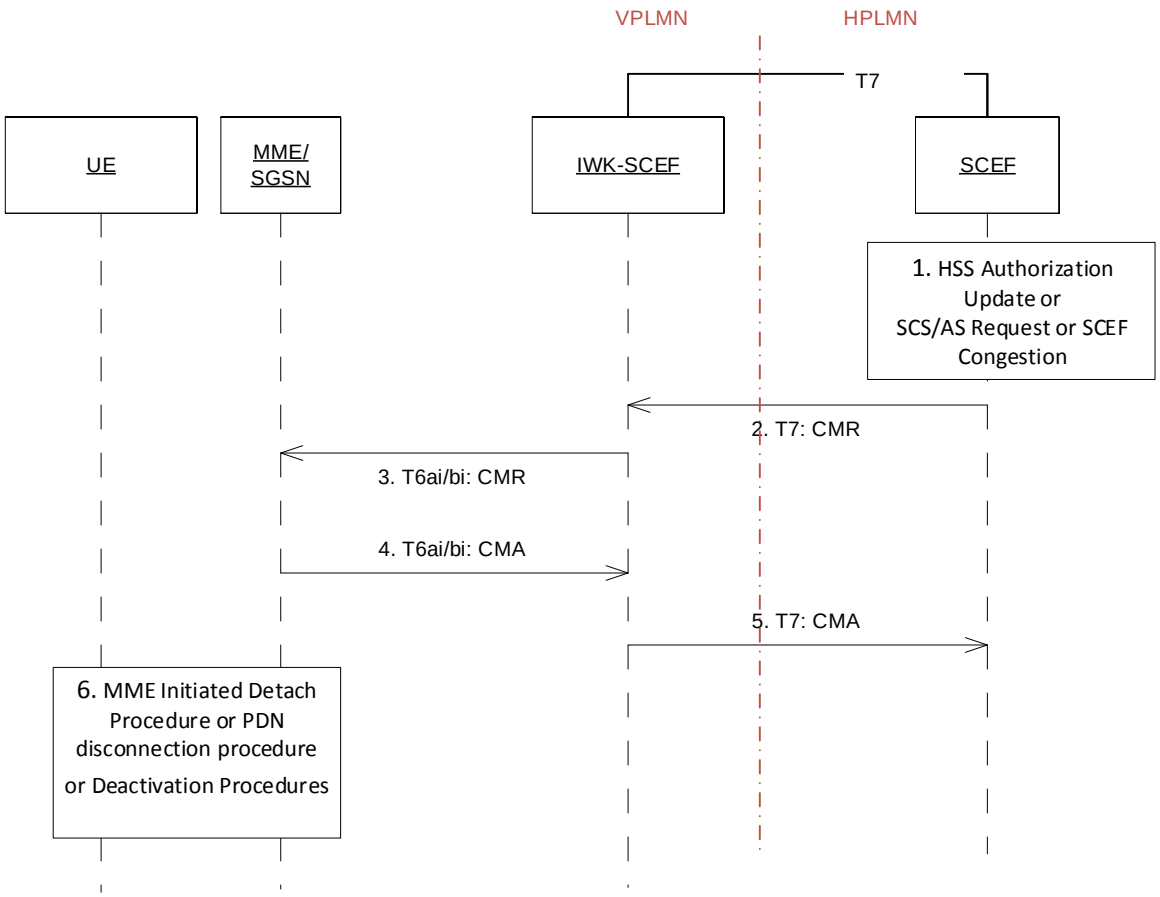

Figure 11: SCEF Initiated T6 Connection ReleaseProcedure for roaming MIoT Device

1. The SCEF initiates deletion of the PDN connection for the following cases:

   - an NIDD Authorization Update request from the HSS indicates that the User is no longer authorized for NIDD, or
   - the SCS/AS indicates that the User's NIDD PDN connection is no longer needed, or
   - the SCEF determines to release a T6a/b connection.

2. The SCEF sends a Delete SCEF CMR message towards the MME/SGSN via IWK-SCEF. The SCEF deletes the SCEF EPS bearer context corresponding to the PDN connection.

3. The IWK-SCEF forwards the received CMR to the home network MME/SGSN over T6ai/bi interface
4. The MME acknowledges the removal of SCEF Connection information for the UE by sending Delete Connection Response using CMA towards the home network SCEF via IWK-SCEF. The MME/SGSN deletes the EPS bearer context/PDP Context corresponding to the PDN connection.
5. The IWK-SCEF relays the received CMA towards the home network SCEF over T7 interface
6. The MME may perform the MME-initiated Detach procedure (see clause 5.3.8.3 of 3GPP TS 23.401 [3]), or step 1b of the UE or MME requested PDN disconnection procedure (see clause 5.10.3 of 3GPP TS 23.401 [3]). A SGSN may perform SGSN-Initiated Detach Procedure specified in 3GPP TS 23.060 [6] clause 6.6.2.1, or a network initiated Deactivation Procedure specified in 3GPP TS 23.060 [6] clause 9.2.4, reason why the PDN/PDP to a SCEF connection exists.

4.2 Monitoring Event Procedure

The Monitoring event procedure allows SCS/AS to monitor the events related to the MIoT device status information through 3GPP core network elements. It is comprised of means that allow the identification of the 3GPP network elements suitable for configuring the specific events, the event detection, and the event for reporting to the authorised users. Monitoring events apply to both individual or group of devices. Monitoring events can be requested by SCS/AS for one time reporting or continuous reporting.

To support monitoring features in roaming scenarios, a roaming agreement needs to be made between the HPLMN and the VPLMN. Monitoring event configuration and deletion can be done through HSS, MME/SGSN and PCRF 3GPP (Policy Control Rules Function) core network elements via SCEF. The scope of this document includes Monitoring Events configuration and deletion for roaming scenarios directly at the HSS.

4.2.1 Monitoring Event Procedure via HSS

Configuration and reporting of the following monitoring events are supported via HSS:

- Monitoring the association of the UE and UICC (Universal Integrated Circuit Card) and/or new IMSI-IMEI-SV (International Mobile Subscriber Identity -International Mobile Equipment Identifier- Software Version) association;
- UE reachability;
- Location of the UE, and change in location of the UE;
- Loss of connectivity;
- Communication failure;
- Roaming status (i.e. Roaming or No Roaming) of the UE, and change in roaming status of the UE; and
- Availability after DDN (Downlink Data Notification) failure.

4.2.1.1 Monitoring event configuration and deletion via HSS procedure

The figure below depicts the monitoring event configuration and deletion via home network HSS for MIoT roaming devices:

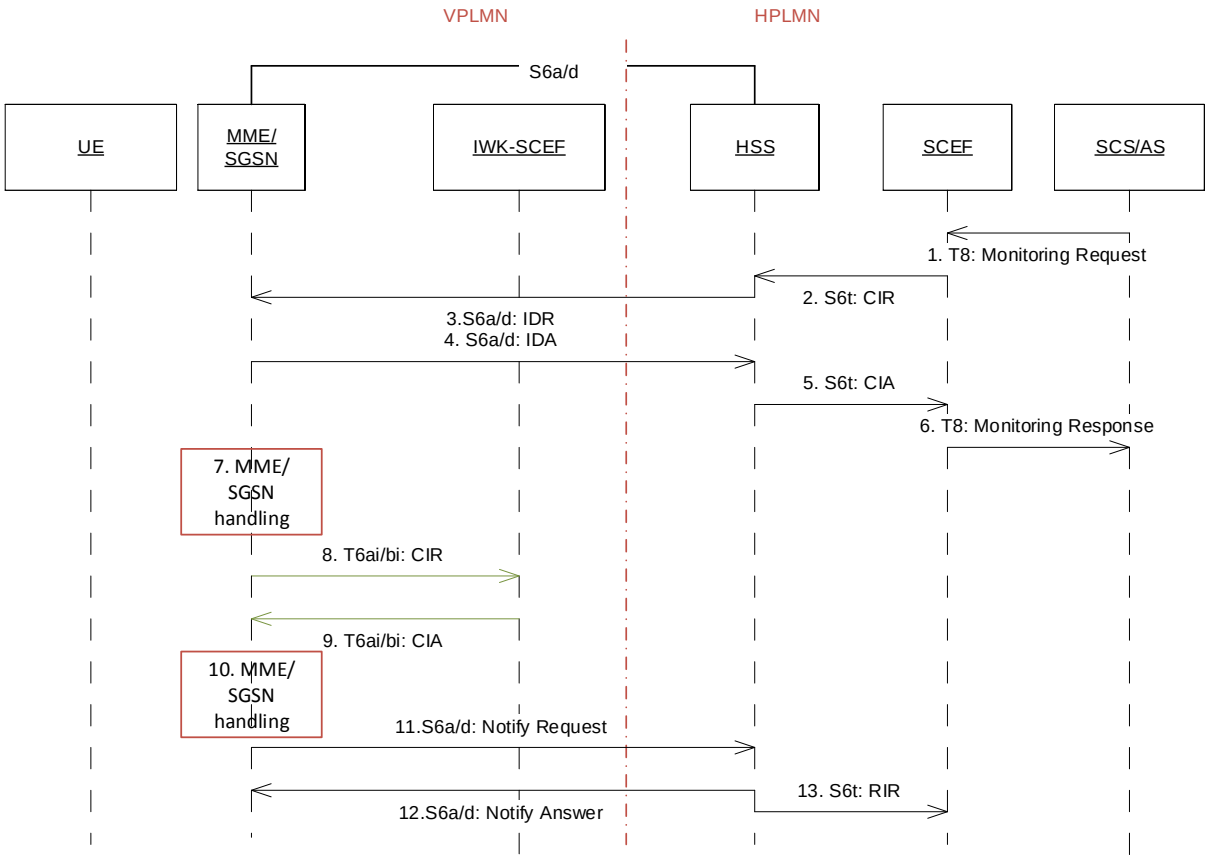

Figure 12: Monitoring Event Configuration Via HSS for roaming MIoT Device

1. The SCS/AS sends a Monitoring Request message to the SCEF for a given MIoT Device to configure or delete a monitoring event.
2. The home network SCEF shall perform authorization of SCS/AS and validation of the monitoring request as described in 3GPP TS 23.682 [4]. The SCEF sends the Configuration Information Request(CIR) using S6t interface to configure the monitoring event to the HSS.
3. The HSS sends an Insert Subscriber Data Request(IDR) on S6a/d interface to visited network serving MME/SGSN when the Monitoring Event(s) is supported by the visited network MME/SGSN.
4. If the visited network MME/SGSN is configured to use an IWK-SCEF for the PLMN of the SCEF then Step 7 applies. Otherwise, the MME/SGSN verifies the request, e.g. if the Monitoring Type is covered by a roaming agreement when the request is from another PLMN or whether it serves the SCEF Reference ID for Deletion and can delete it. If this check fails, the MME/SGSN follows step 7 and provides a Cause value indicating the reason for the failure condition to the HSS in Insert Subscriber Data Answer(IDA). Based on operator policies, the MME/SGSN may also reject the request due to other reasons (e.g., overload or HSS has exceeded its quota or rate of submitting monitoring requests defined by an SLA). The MME/SGSN shall delete the monitoring configuration identified by the SCEF Reference ID for Deletion as long as it is provided in the Insert Subscriber Data Request(IDR) from the Home network HSS. If the requested Monitoring Event is available to the MME/SGSN at the time of

sending the Insert Subscriber Data Answer, then the MME/SGSN includes the Monitoring Event Report in the Insert Subscriber Data Answer message.

5. The home network HSS sends a Monitoring Response using the Configuration Information Answer(CIA) message to the SCEF as acknowledge acceptance of the Monitoring Request and the deletion of the identified monitoring event configuration, if requested.
6. The home network SCEF sends a Monitoring Response message to the SCS/AS as acknowledge acceptance of the Monitoring Request and the deletion of the identified monitoring event configuration, if s requested.
7. If the MME/SGSN is configured to use an IWK-SCEF for the PLMN of the SCEF then step 8 through 13 applies.
8. The visited network MME/SGSN shall send CIR on T6ai/bi interface to IWK-SCEF and shall optionally include event report if available.
9. The IWK-SCEF shall authorize the CIR according to the roaming agreements and the acknowledgement to the MME/SGSN with a CIA response. If the request included a Monitoring Event Data, then the IWK-SCEF may perform a normalization of the data according to operator policies.
10. If the monitoring event configuration status received from IWK-SCEF is different than the result reported to the HSS in Step 4.
11. The visited network MME/SGSN shall send the Notify Request to the HSS using S6a/d interface to inform the monitoring event configuration status received from IWK-SCEF
12. If the HSS receives in step 11 the monitoring event configuration status from the MME/SGSN through a Notify request, the HSS shall respond back to MME/SGSN using Notify Answer messages.
13. The home network HSS shall notify the SCEF that the configured Monitoring Event is cancelled for the individual UE and for the rest of those monitoring event configurations for which the status received from the MME/SGSN is marked as not accepted using Reporting Information Request(RIR) through S6t interface. The HSS shall subsequently locally delete the Monitoring Event for the individual UE and for the individual group member UE if the Monitoring Event is configured in the HSS, and steps 1-5 of clause 5.6.9 of 3GPP TS 23.682 [4] are executed.

4.2.2 Reporting of Monitoring Events from the HSS or the MME/SGSN for roaming scenarios

The figure below depicts the monitoring event reporting for roaming scenarios:

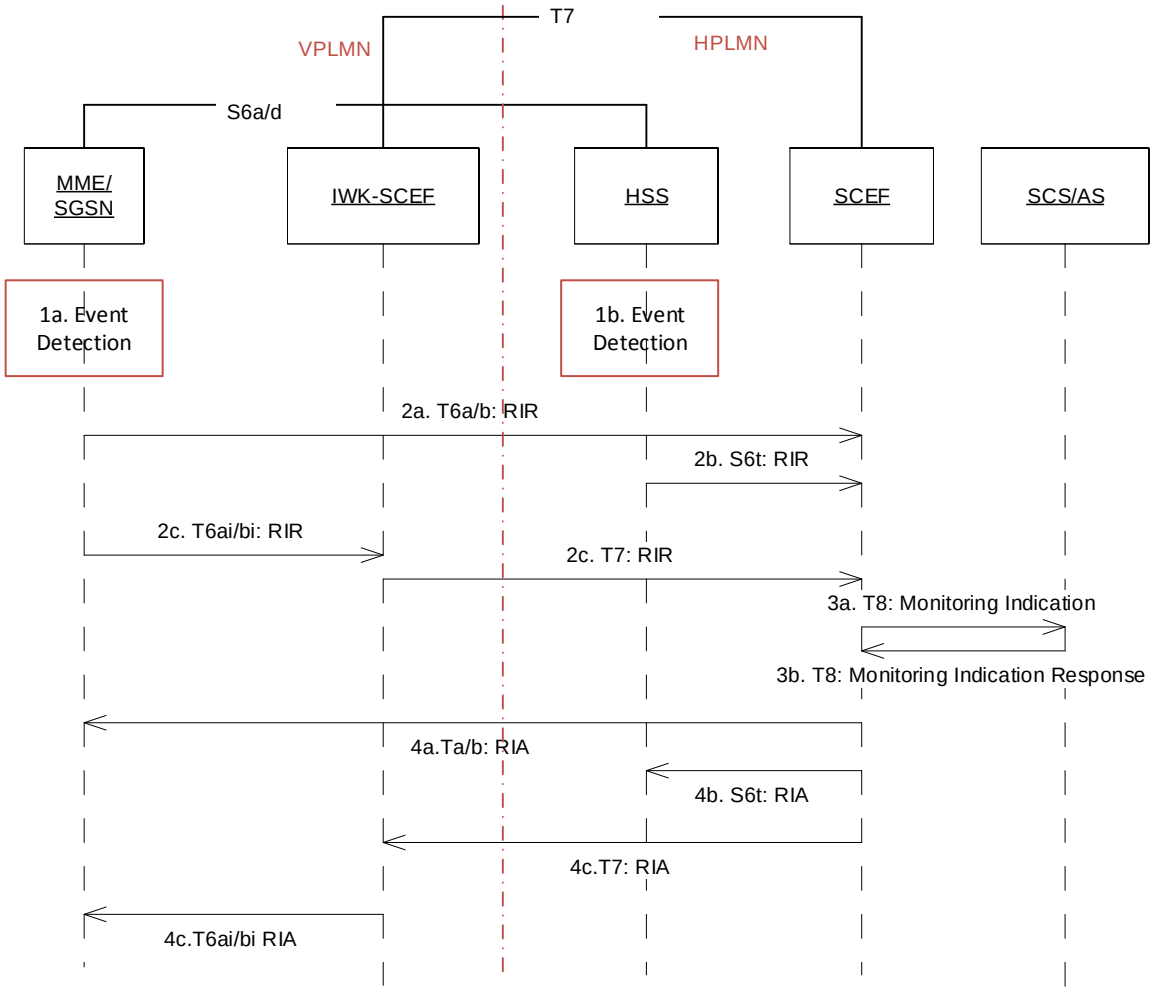

Figure 13: Monitoring Event Reporting for roaming MIoT Device

1. A monitoring event is detected at the visited network MME/SGSN or home network HSS

   a) A Monitoring Event is detected by the MME/SGSN in which the Monitoring Event is configured.
   b) Either a Monitoring Event is detected by the HSS, or the HSS needs to inform the SCEF about the change of status (suspend/resume/cancel) of an ongoing monitoring if an event related with the change of monitoring support at the serving node, (e.g. lack of monitoring support in MME/SGSN or revocation of monitoring authorization) is detected in the HSS.

2. Reporting of monitoring event from different network elements:

   c) If the visited network MME/SGSN is not configured to use an IWK-SCEF for the PLMN of the SCEF then the MME/SGSN shall send a RIR on T6a/b interface to home network SCEF.
   d) When reporting for a MIoT device, the home network HSS sends a Monitoring event report using a RIR message on S6t interface.

e) If the MME/SGSN is configured to use an IWK-SCEF for the PLMN of the SCEF, then the MME/SGSN sends a RIR message to the IWK-SCEF using T6ai/bi interface. The IWK-SCEF sends a RIR message to the home network SCEF using T7 interface.

3. SCEF shall send the monitoring indication message to SCS/AS containing the monitoring event report. SCS/AS shall acknowledge with a monitoring event indication response back to SCEF.
4. SCEF shall respond back Monitoring indication response using a Reporting Information Answer (RIA) to the network elements that sent the RIR in step 2: Responses could be as below:

f) SCEF shall respond back to the visited network MME/SGSN using RIA response on T6a/b interface
g) SCEF shall respond back to the home network HSS using RIA response on S6t interface
h) SCEF shall respond back to the visited network IWK-SCEF using RIA response on T7 interface. IWK-SCEF shall relay the RIA response back to MME/SGSN on T6ai/bi interface.

5 Technical Requirements for QoS support

This section illustrates the required functionality that are needed in the VPMN and the HPMN in order to support QoS procedures for MIoT roaming based on LTE-M.

Support of QoS procedures whilst roaming has several aspects:

1. Ensuring that an outbound roamer will be given the expected level of QoS for the service they are using, within the limits of the roaming agreement.
2. Ensuring that the QoS parameters of an inbound roamer are within the limits of the roaming agreement.
3. Enforcement of the actual QoS by the VPMN.

6 Other Technical requirements and recommendations

6.1 Access control of MIoT roaming traffic

IR.88 [9] specifies the technical recommendations to perform access control for the inbound roaming subscribers at the VPMN when there is no explicit roaming agreement to support MIoT roaming in their LTE network during the attach procedure. It also covers all technical requirements and recommendations to perform access control for outbound roaming MIoT subscribers at HPMN during the update location procedures.

MNO’s shall also define the access policies for all different roaming partners at IWK-SCEF to support different MTC procedures for MIoT roaming Devices based on the roaming agreements.

6.1.1 Non IP Data Delivery

IWK-SCEF shall perform the access control for NIDD based MIoT Roaming traffic using following parameters.

6.2 Number of PDN Connections

IWK-SCEF shall optionally control the number of non IP PDN connection establishment requests for Roaming MIoT Devices. MNO's shall define the number of allowed PDN connections based on roaming agreements and local policies. IWK-SCEF shall reject the PDN connection establishment requests i.e. CMR, received from MME/SGSN on T6ai/bi interface when the number of connection establishment requests i.e. CMR's exceeds the configured thresholds.

6.3 Uplink and Downlink Non-IP Data Volume

IWK-SCEF shall optionally apply the uplink and downlink non-IP data rate control for MO, and MT non-IP data, based on roaming agreements and operator local policies.

6.3.1 Monitoring events

IWK-SCEF shall optionally perform monitoring event configuration request authorization and normalization of monitoring event reports as specified in section 4.2.

6.4 LTE-M Differentiation

LTE-M devices can be differentiated by the MME using the LTE-M RAT type as described in section 5.11.5 of Release 15 of 3GPP TS 23.401 [3].

6.5 Security

6.5.1 Diameter Security

MNO's shall deploy the Diameter Firewall either integrated with a Diameter Edge Agent or as an independent Diameter Firewall network element which shall screen the MIoT Roaming Diameter Signalling traffic and apply different security countermeasures specified in FS.19 [15] and IR.88[9].

6.6 Charging

Charging models and requirements for MIoT are described in the BA.27 [8].

6.7 MIoT timers

To reduce power consumption and increase battery life, Power Saving Mode (PSM) and extended idle mode Discontinuous Reception (eDRX) are deployed in MIoT roaming. The PSM mode has two timers, active timer T3324 and T3412 extended. The eDRX mode has also two timer parameters, Paging Time Window (PTW) and eDRX cycle [18].

The PSM and eDRX modes are negotiated between the individual roaming device and the VPMN during the Attach and Tracking Area Update (TAU) procedures. The device will request to enable PSM, eDRX or both PSM and eDRX in the Attach or TAU Request. The device will also provide timer values for PSM and eDRX requested.

The MIoT timers are a part of the subscription data which are transmitted via the Diameter-based MME-HSS, S6a interface (ref. 3GPP TS 29.272) [17]. The below mapping table shows the relation between the MIoT PSM and eDRX parameters contained in the subscription data AVP for MME and the MIoT timer parameters from MME conveyed to the MIoT devices.

MIoT timer for UE	T3412 ext	T3324 (active)	eDRX cycle	PTW
Subscribed data for MME	Subscribed-Periodic-RAU-TAU-Timer	Maximum-Response-Time	eDRX-Cycle-Length, eDRX-Cycle-Length-value, eDRX-Related-RAT	Paging Time Window, Operation-Mode, Paging-Time-Window-Length

Table 2: MIoT timer's parameters for MME and UE

The VPMN MME will decide to accept the proposed PSM and/or eDRX mode by the roaming MIoT device and the timer values, or to provide different ones in the Attach/TAU Accept, depending on the network configurations. It is generally recommended that the VPMN respects the PSM or eDTX setting requested by the device application. The negotiated active timer T3324 value is considered as the maximum response time of the device, i.e. MT-communication latency. The roaming MIoT devices must accept and deploy the MIoT timer values provided by the network.

The following table summarizes the value range of MIoT timers.

MIoT timer	T3412 ext	T3324 (active)	eDRX cycle	PTW
LTE-M	4 h – 413 days	16 s – 3 h	5 s – 44 min	1 s – 20 s
NB-IoT	4 h – 413 days	16 s – 3 h	20 s – 3 h	3 s – 41 s

Table 3: MIoT timers value range

If the network accepts the use of both PSM and eDRX, the eDRXcycle and PTW must allow multiple paging occasions for the concerned MIoT device before the active timer T3324 expires.

6.7.1 PSM Timers

For PSM deployment, it is recommended in CLP.29 [19]:

- the minimum T3324 = 16 s,
- the minimum T3412 ext = 4 h,
- the hibernate ratio > 90%, where hibernate ratio = 1 - T3324 / T3412 ext.

The roaming MIoT devices (LTE-M or NB-IoT) and the VPMN must apply the PSM timer values in the selectable list specified in 3GPP TS 24.008 [18]. For convenience, the following two tables list all relevant and selectable PSM timer values commonly valid for LTE-M and NB-IoT devices.

Formula	T3412 ext values	Unit
n x 10 min (n = 24, 25 … 31)	240, 250, ... 310	minute
n x 1 h (n = 4, 5, … 31)	4, 5, … 31	hour
n x 10 h (n = 1, 2, … 31)	10, 20, … 310	hour
n x 320 h (n = 1, 2, … 31)	320, 640, … 9920 (413 days)	hour

Table 4: Recommended T3412 ext selectable values for LTE-M & NB-IoT

Formula	T3324 values (active time)	Unit
n x 2 s (n = 8, 9, … 31)	16, 18, … 62	second
n x 1 min (n = 1, 2, … 31)	1, 2, … 31	minute
n x 6 min (n = 1, 2, … 31)	6, 12, …186	minute

Table 5: Recommended T3324 selectable values for LTE-M & NB-IoT

6.7.1.1 Short PSM active timer

Some MIoT applications require very low battery consumption. Consequently, the PSM active timer T3324 can be set to < 16s, i.e. in the range of (2, 4, 6, 8, 10, 12, 14s).

In case of roaming, such short PSM active timer setting requires VPMN to be capable of:

- Respecting and accepting the PSM timer values requested by the device without modification,
- Supporting the same SMS type as the device, e.g. SMSinMME (SMSoNAS) or SMSoIP,
- Delivering a subsequent MT SMS or MT data transfer to the device by using the same connection without paging while T3324 is running.

6.7.2 eDRX Timers

The roaming MIoT devices (LTE-M or NB-IoT) and the VPMN must apply the eDRX parameter values in the selectable list specified in 3GPP TS 24.008 [18]. For convenience, the following two tables list all relevant and selectable eDRX timer parameter values, valid for LTE-M or NB-IoT devices respectively.

eDRX Parameters	Formula	LTE-M	Unit
PTW	n x 1.28s (n = 1, 2, … 16)	1.28, 2.56, 3.84, 5.12, 6.40, 7.68, 8.96, 10.24, 11.52, 12.80, 14.08, 15.36, 16.64, 17.92, 19.20, 20.48	second
eDRX cycle	2^n x 5.12s (n = 0, 1, … 9)	5.12, 10.24, 20.48, 40.96, 81.92, 163.84, 327.68, 655.36, 1310.72, 2621.44	second

Table 6: Recommended eDRX selectable timer values for LTE-M

eDRX Parameters	Formula	NB-IoT	Unit
PTW	n x 2.56s (n = 1, 2, … 16)	2.56, 5.12, 7.68, 10.24, 12.80, 15.36, 17.92, 20.48, 23.04, 25.60, 28.16, 30.72, 33.28, 35.84, 38.40, 40.96	second
eDRX cycle	n x 20.48s (n = 1, 2, 3, 4, 5, 6, 7, 8, 16, 32, 64, 128, 256, 512)	20.48, 40.96, 61.44, 81.92, 102.40, 122.88, 143.36, 163.84, 327.68, 655.36, 1310.72, 2621.44, 5242.88, 10485.76 (~3h)	second

Table 7: Recommended eDRX selectable timer values for NB-IoT

Annex A Document Management

A.1 Document History

Version	Date	Brief Description of Change	Approval Authority	Editor / Company
1.0	27 February 2019	New PRD.	TG #13	Kazuto Shimizu (NTT DOCOMO)
2.0	3rd July 2020	Inclusion of the following CRs: NG.117 CR1002 CR to NG.117 on MIoT timers NG.117 CR1003 Change on T3324 timer	NG	Jo Takahashi (NTT DOCOMO)

A.2 Other Information

Type	Description
Document Owner	Networks Group
Editor / Company	Jo Takahashi (NTT DOCOMO)

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