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EMM Procedure 5. Periodic TAU

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This document, as the fifth of the EMM Procedure series, will describe the periodic TAU procedure, as defined as EMM Case 5 in our technical document, "Eleven EMM Cases in an EMM Scenario". This procedure is used when a UE, while staying inactive in ECM/RRC-Idle state, informs the MME of its current location (TAI, Tracking Area Identity) upon expiration of the periodic TAU timer. Between a UE and MME, no bearer (E-RAB) is set up, and only a signaling connection (ECM connection) is established. We will learn how the ECM connection is released and the UE returns to Idle state once a new TA is reported. We will also look into how information elements in EPS entities are different before and after the periodic TAU procedure.

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Abbreviations

AKA	Authentication and Key Agreement
ASME	Access Security Management Entity
DL	Downlink
DRB	Data Radio Bearer
ECGI	E-UTRAN Cell Global Identifier
ECM	EPS Connection Management
EMM	EPS Mobility Management
eNB	Evolved Node B
EPS	Evolved Packet System
E-RAB	E-UTRAN Radio Access Bearer
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
GUMMEI	Globally Unique MME ID
GUTI	Globally Unique Temporary Identifier
HSS	Home Subscriber Server
KSI	Key Set Identifier
LTE	Long Term Evolution
MAC	Message Authentication Code
MME	Mobility Management Entity
NAS	Non Access Stratum
PCRF	Policy and Charging Rule Function
P-GW	Packet Data Network Gateway
RRC	Radio Resource Control
S1AP	S1 Application Protocol
S-GW	Serving Gateway
TA	Tracking Area
TAI	Tracking Area Identity
TAU	Tracking Area Update
TIN	Temporary Identifier used in Next update
UE	User Equipment

I. Introduction

This document describes the periodic TAU (Tracking Area Update) procedure defined as EMM Case 5 in our technical document, "Eleven EMM Cases in an EMM Scenario" [1]. This procedure is performed when a UE which entered ECM/RRC-Idle state in the network due to no traffic periodically updates the network (MME) with its current location.

A TAU procedure is initiated when a UE enters a new TA that is not in the list of TAIs allocated by the MME at the time of the UE's attach, or when the TAU timer expires. The EMM Case 5 presented in this document is related to the periodic TAU procedure performed by a UE upon expiration of the TAU timer. A UE in Idle state reports its current location to the MME by sending a **TAU Request** message when the TAU timer expires. After transiting to **ECM/RRC-Connected** state, and performing the periodic TAU procedure, the UE returns to Idle state.

This document explains the periodic TAU procedure performed by a UE in Idle state in an LTE network. Chapter II explains the concept of periodic TAU, and Chapter III describes its specific procedures. Finally, Chapter VI summarizes how information elements in EPS entities are different before and after the procedure.

II. Concept of Periodic TAU

A UE, while in Connected state, has an established end-to-end EPS bearer connecting the UE to the network (P-GW). The network (MME) keeps track of which cell the UE is located in. So, if there is any traffic destined to the UE, the network can deliver it immediately.

However, if a UE enters Idle state, the signaling connection and bearers (E-RAB bearer) between the UE and the network (MME) are all released. Then, the network (MME) loses track of the UE's location. The network should always be aware of the current location of all UEs, whether in Active or Idle state, in order to deliver traffic to UEs that are in Idle state. So, those in Idle states should report their current location, i.e. in which TA (Tracking Area) they are located, to the network (MME) periodically even when there is no data to deliver. A TA is a group of cells, and managed by MME. The location of UEs in Idle state is recognized at a TA level.

To this end, MME provides a UE with a TAI list and TAU timer (T3412) as included in a **Attach Accept** message when the UE initially attaches the network. Using them, the UE performs a TAU procedure upon expiration of the TAU timer.

When MME receives TA information from a UE, it updates the UE's current location information (TA, cell) to keep the latest information. In case there is traffic destined to the UE while it is in Idle state, the MME informs the UE about the new traffic by sending a **Paging Message** to the cells in the TA that has been reported by the UE as its current location[1].

Figure 1 shows an example of a TAU procedure performed by a UE in Idle state. The UE (UE1) has attached Cell 2 in eNB1 upon its initial attach, and has been allocated a TAI list (e.g. TAI={TAI1, TAI2}) and TAU timer (e.g.

[1] Paging in a larger area means more cells to page. So it has a higher chance of locating a particular UE fast, but can cause higher paging load. On the other hand, paging in a smaller area means fewer cells to page. So, it has a lower chance of locating the UE fast, but causes less paging load. Efficient ways to page are beyond the scope of this document, and hence will not be discussed here.

T3412=60 mins) through the **Attach Accept** message sent from the MME. Later, after transiting to Idle state, it travels from ❶ → ❷ → ❸ → ❹. For the purposes of this example, we assume i) the UE travels between only the TAs that are in the TAI list initially allocated through the **Attach Accept** message, ii) the MME the UE reports its TA information to is the one the UE's context is stored in, and iii) both the UE and the MME have kept the NAS security context (K_{NASint}, K_{NASenc}, etc.) valid.

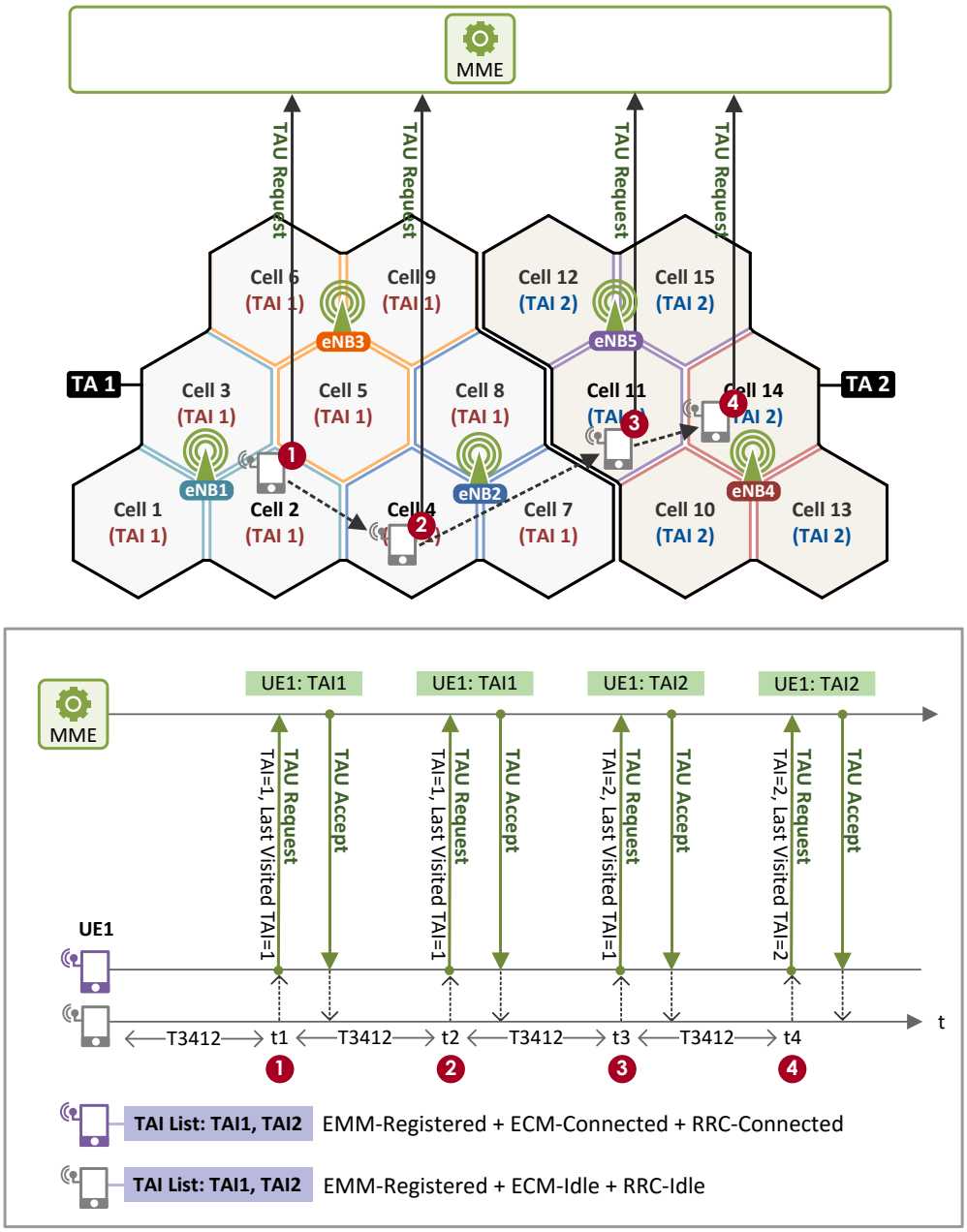

Figure 1. Concept of Periodic TAU

After attaching and transiting to Idle state in Cell 2, UE1 wakes up and establishes an ECM signaling connection with the MME when the TAU timer expires at T1. Next, it sends the MME a **TAU Request** (TAI=TAI1, Last Visited TAI=TAI1) message that includes the TAI of its current cell, and the last visited TAI (the one reported through the last TAU request) (❶). Then, UE1 returns to Idle state when it receives a **TAU Accept** message. After receiving the **TAU Request** message from the Idle UE, the MME checks whether the UE's last TAI (TAI of

Last TAU) has been changed or not, and updates it with the latest information if it has been changed. If there is traffic heading to UE1, and thus the S-GW notifies the MME of the DL traffic, the MME finds out which TA the UE was in last time based on the TAI of Last TAU information, and sends a **Paging Message** to the cells in the TA (see our LTE technical document, "LTE EMM Procedure 4. Service Request" [2] for detailed information). Later, if UE1 moves to Cell 4, and the TAU timer expires (❷), UE1 sends the MME a **TAU Request** (TAI=TAI1, Last Visited TAI=TAI1) message as it is still in TA1. If UE1 moves to Cell 11, and the timer expires (❸), it sends the MME a **TAU Request** (TAI=TAI2, Last Visited TAI=TAI1) message, including TAI2 instead of TAI1, as now it belongs to TA2. Then the MME accordingly updates UE1's TAI of Last TAU with TAI2.

Figure 2 shows the connections established, and the states of UE and MME in the user and control planes before and after the periodic TAU procedure.

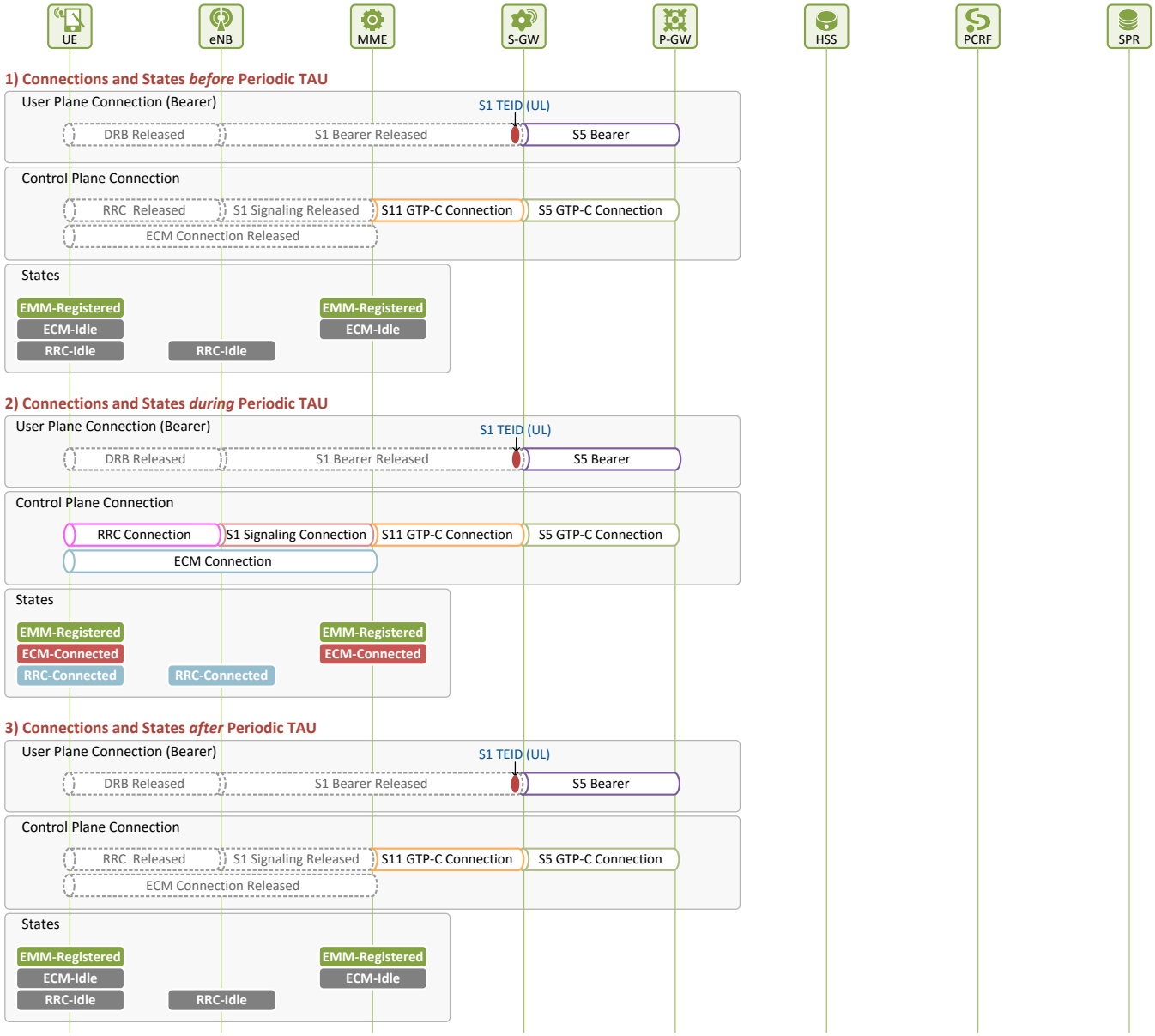

Figure 2. Connections and States before/after TAU

A UE's states before, during and after a periodic TAU procedure are as follows:

(i) Before the procedure, the UE stays in **EMM-Registered, ECM-Idle** and **RRC-Idle** state, and any

resources allocated by E-UTRAN, i.e. the E-RAB (except for the uplink S1 bearer) and ECM signaling connection between the UE and the MME, are kept released.

(ii) During the procedure, the UE stays in **EMM-Registered, ECM-Connected** and **RRC-Connected** state. The periodic TAU procedure is different from procedures for initial attach or service request in that no E-RAB (between UE and MME) is set up, and only the signaling connection (ECM signaling connection) for delivering periodic TAU-related NAS messages is set up during this procedure.

(iii) After the procedure, the ECM signaling connection set between the two entities is released, releasing the E-UTRAN resources. Then, the UE returns to **EMM-Registered, ECM-Idle** and **RRC-Idle** state again.

Figure 3 is another illustration that shows the state transition of a UE before/after a periodic TAU procedure. Upon the expiration of T3412, the UE which has been in Idle state sends the MME a **TAU Request** message to report its current TA and last TA (then it transits to Connected state). Then the MME returns a **TAU Accept** message to the UE after updating the UE's location information (TA). As a result, the signaling connection between the two entities is released, and the UE transits back to Idle state.

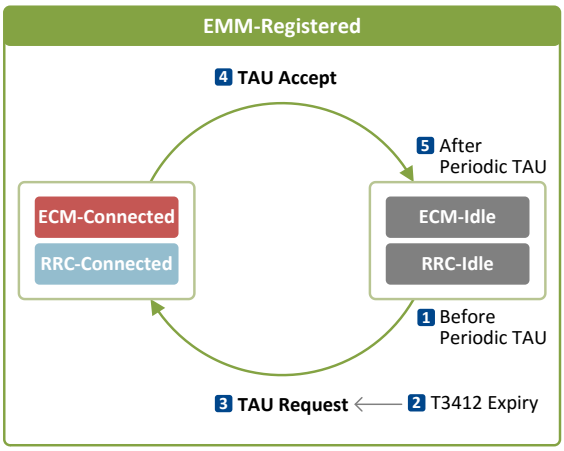

Figure 3. State Transition of a User Performing Periodic TAU

III. Procedure of Periodic TAU

Figure 4 and 5 illustrate procedures for a periodic TAU by a UE in Idle state. In Figure 4, the NAS layer at UE reports its new TA to the MME by sending a **TAU Request** message with its update type indicated as "Periodic Updating"[2]. As a "Periodic Updating" type TAU does not require bearer establishment, the UE sends a **TAU Request** message after establishing an ECM signaling connection only. When it receives a **TAU Accept** message, it releases the ECM signaling connection. The **TAU Request** message is sent as integrity-protected with K_{NASint}, the NAS integrity key (i.e. by including NAS-MAC). So, the MME decides whether to perform UE authentication or not by conducting an integrity check on the message.

[2] If a UE, in ECM/RRC-Connected state, moves into a cell that is not in the TAI list, a **TAU Request** message is sent with its update type indicated as "TA Updating".

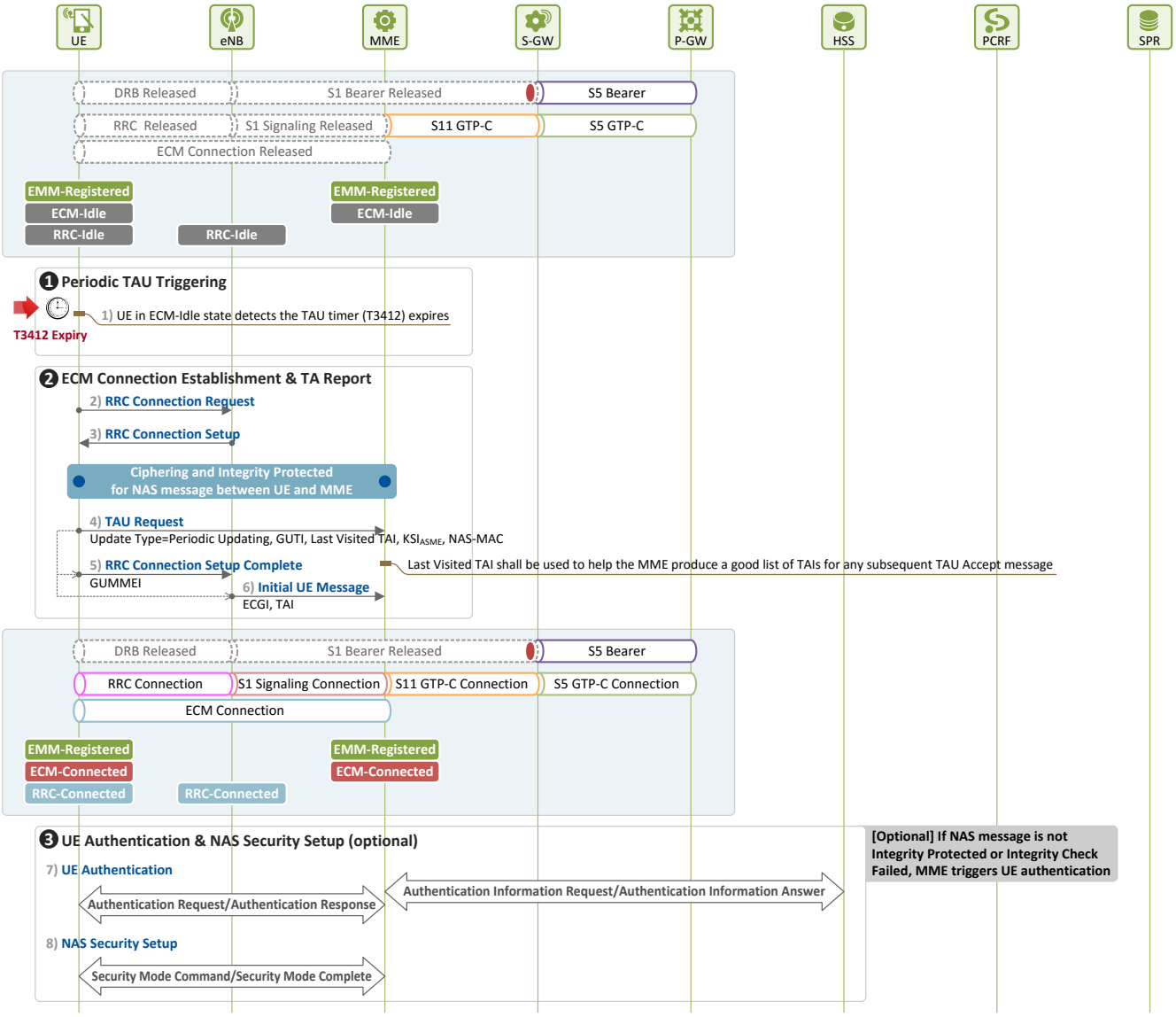

Figure 4. Procedure for Periodic TAU (1)

1 Periodic TAU Triggering

1) [UE] TAU Timer Expiry

The UE in Idle state triggers a periodic TAU procedure to report its current location to the MME upon expiration of the TAU timer (T3412).

2 ECM Connection Establishment) and TA Report

The NAS layer at the UE i) configures a **TAU Request** message, and ii) sends it with RRC parameters (e.g. old GUMMEI[3]) down to the RRC layer at the UE.

2), 3) [UE – eNB] RRC Connection Establishment

Upon receiving the **TAU Request** message, the RRC layer at the UE sends the eNB an **RRC Connection Request** message, requesting dedicated signaling resources. The eNB establishes an RRC connection by allocating an SRB channel and sending the UE an **RRC Connection Setup** message (see our Initial Attach document [4] for detailed procedures).

[3] It identifies the MME that a UE was last registered at in the LTE network, and is derived from the UE's GUTI [3].

4), 5), 6) [UE → MME] ECM Connection Establishment Request and TA Report

The **TAU Request** message is delivered as included in an **RRC Connection Setup Complete** message, an RRC message, from the UE to the eNB, and then in an **Initial UE Message**, an S1AP message, from the eNB to the MME. As the NAS security context has been kept valid between the UE and the MME, the **TAU Request** message is sent integrity-protected with the NAS integrity key (K_{NASint}) and encrypted with the encryption key (K_{NASenc}). The **TAU Request** message for the periodic TAU procedure includes the following information:

TAU Request (Update Type=Periodic Updating, Active Flag=0, GUTI, Last Visited TAI, KSI_{ASME}, NAS-MAC)

- **Update Type**: indicates the TAU type. Set as **Periodic Updating** when the TAU timer (T3412) is expired
- **Active Flag**: indicates whether there is uplink user traffic data or signaling to send. If there is, this parameter is set as 1, establishing a bearer and maintaining the ECM connection after TAU.
- **GUTI**: UE ID, previously allocated by MME, that MME uses to identify UEs
- **Last Visited TAI**: the TAI reported last time through TAU Request (TAI that UE was last registered at)
- **KSI_{ASME}**: index for K_{ASME}, the NAS security base key
- **NAS-MAC**: MAC used when the **TAU Request** message is integrity-protected using the NAS integrity key (K_{NASint})

For faster delivery of the **TAU Request** message received from the NAS layer, the RRC layer at the UE sends the eNB the message, as piggybacked on an **RRC Connection Setup Complete** message, the last step of the RRC connection procedures. At this time, the **RRC Connection Setup Complete** message includes a GUMMEI. This ID is derived from the GUTI that was received from the NAS layer, and indicates at which MME the UE is registered. In general, an eNB can be connected with more than one operator network and MME. So, upon receiving the **RRC Connection Setup Complete** message, the eNB checks whether the indicated MME is connected with itself or not.[4]

Then, the eNB sends the **TAU Request** message as included in an **Initial UE Message** message to the MME. At this time, the eNB allocates an eNB S1AP UE ID to the **Initial UE Message** message, and the MME, upon receipt of the **Initial UE Message** message, allocates an MME S1AP UE ID, setting up an S1 signaling connection between the two entities. This completes an ECM signaling connection between the UE and the MME, allowing the UE to transit to Connected state.

❸ UE Authentication and NAS Security Setup (Optional)

7) [UE – MME – HSS] UE Authentication

The MME, upon receiving the **TAU Request** message from the UE, conducts an integrity check on the NAS-MAC. If the check passes, the MME can skip UE authentication, and continue to use the NAS security context it has kept in delivering NAS messages. If the check fails, it has to perform UE authentication through EPS-AKA.[5]

[4] In EMM Case 5, **TAU Request** messages sent by UE in Idle state are delivered to the MME that the UE was registered at during initial attach. Cases of sending **TAU Request** messages to other MME will not be discussed here.

[5] MME obtains AVs for the UE from HSS, and performs UE authentication on behalf of the HSS [5].

8) [UE – MME] NAS Security Setup

Once the UE is authenticated in Step 7), NAS security keys (K_{NASenc}, K_{NASint}) to be used in communicating NAS messages are generated based on a new K_{ASME} and through a NAS security setup procedure.

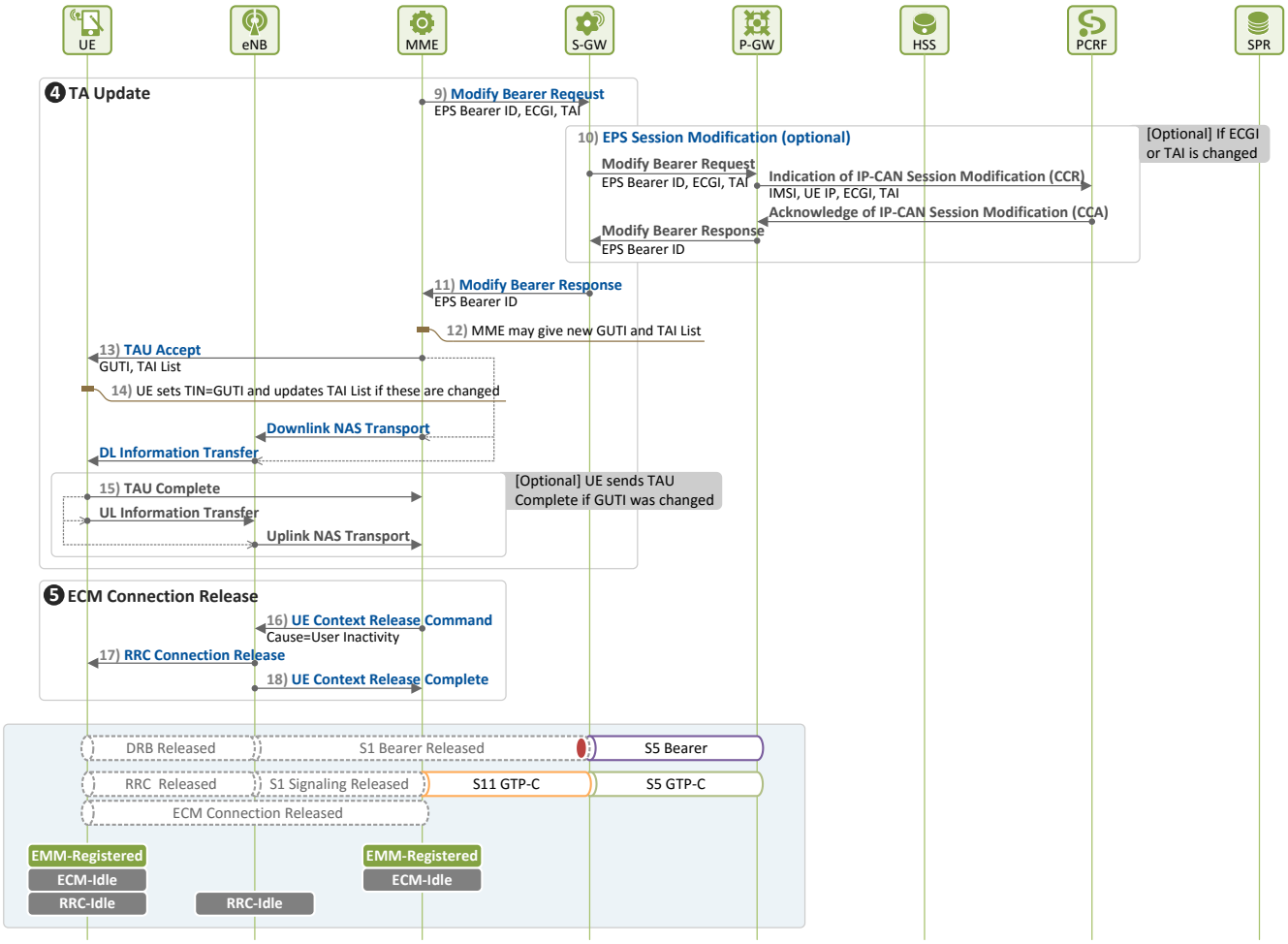

Figure 5. Procedures for Periodic TAU (2)

4 TA Update

9) [MME → S-GW] TA Update

When the MME receives the **TAU Request** message from the UE, it resets the TAU timer (T3412), and sends the S-GW a **Modify Bearer Request** message, forwarding the UE's location information (ECGI, TAI).

10) EPS Session Modification (Optional)

The S-GW that receives the UE location information checks whether the UE's cell (ECGI) or TA (TAI) is changed or not. If changed, it sends a **Modify Bearer Request** to the P-GW to inform such change. Then, the P-GW reports the same to the PCRF through an EPS session modification procedure.[6]

[6] During UE's initial attach, PCRF can provide MME, S-GW and P-GW with its reporting policies on UE location changes through Change Reporting Action parameters included in a **CCA** message [4].

11) [MME ← S-GW] Responding to TA Update Request

The S-GW sends the MME a **Modify Bearer Response** message as a response to the **Modify Bearer Request** message received in Step 9).

12) [MME] Preparing TAU Accept Message

The MME may configure a new TAI list to reflect the current location of the UE, or allocate a new GUTI, depending on implementation.

13) [UE ← MME] Sending TAU Accept Message

The MME sends the UE a **TAU Accept** message, as integrity-protected and encrypted. This message is delivered through a **Downlink NAS Transport** message, an S1AP message, from the eNB to the MME, and then through a **DL Information Transfer** message, an RRC message, from the UE to the eNB.

14) [UE] Updating TIN and TAI List

When the UE receives the **TAU Accept** message from the MME, it checks the GUTI and TAI list values. If these values are changed, it updates the TIN (Temporary Identifier used in Next update) and the TAI list with these new values. Here, the TIN is a user ID to be used next time the UE sends a **TAU Request** message, and is updated with the GUTI included in a **TAU Accept** message every time the message is received.

15) [UE] Acknowledging New GUTI

If a new GUTI is allocated by the MME, the UE sends a **TAU Complete** message to the MME, acknowledging receipt of the new GUTI.

❺ ECM Connection Release

16) [eNB ← MME] Requiring E-UTRAN to Release UE Context

After updating the UE's location information, the MME sends a **UE Context Release Command** message to the eNB in order to release the ECM connection used for delivering messages relating to periodic TAU, and also release the UE context stored in E-UTRAN.

17) [UE ← eNB] Releasing RRC Connection

Upon receiving the **UE Context Release Command** message from the MME, the eNB deletes the UE context, and release all the E-UTRAN resources that were allocated to the UE. Then, to the UE, it sends an **RRC Connection Release** message to release the RRC connection, thereby releasing the SRB (Signaling Radio Bearer) allocated to the UE as well.

18) [eNB → MME] Announcing Release of UE Context from E-UTRAN

Also, the eNB sends a **UE Context Release Complete** message to the MME, indicating the S1 signaling connection has been released.

Now, the ECM connection that was established for **TAU Request** message delivery is released, and the UE transits back to Idle state (**ECM/RRC-Idle**).

IV. EPS Entity Information: Before/After Periodic TAU

This chapter will describe how information elements in the EPS entities are different before and after the periodic TAU procedure. All the information elements are categorized into UE ID, UE Location, Security, and EPS Session/Bearer information.

4.1 Before Periodic TAU

As explained in the EMM scenario document [1], before a periodic TAU procedure is triggered, a UE stays in **EMM-Registered**, **ECM-Idle and RRC-Idle**. Therefore, all the information elements stored before the service request in the EMM Case 4 is made remain the same in the EPS entities until a periodic TAU procedure is performed [2]. That is, information elements related to the radio resources allocated by E-UTRAN (eNB) and those related to the EPS bearer and signaling connection established in E-UTRAN (i.e. downlink S1 bearer and S1 signaling information) are now deleted from the EPS entities. In Figure 6, information elements stored in each EPS entity before a periodic TAU procedure is triggered are marked in **black**.

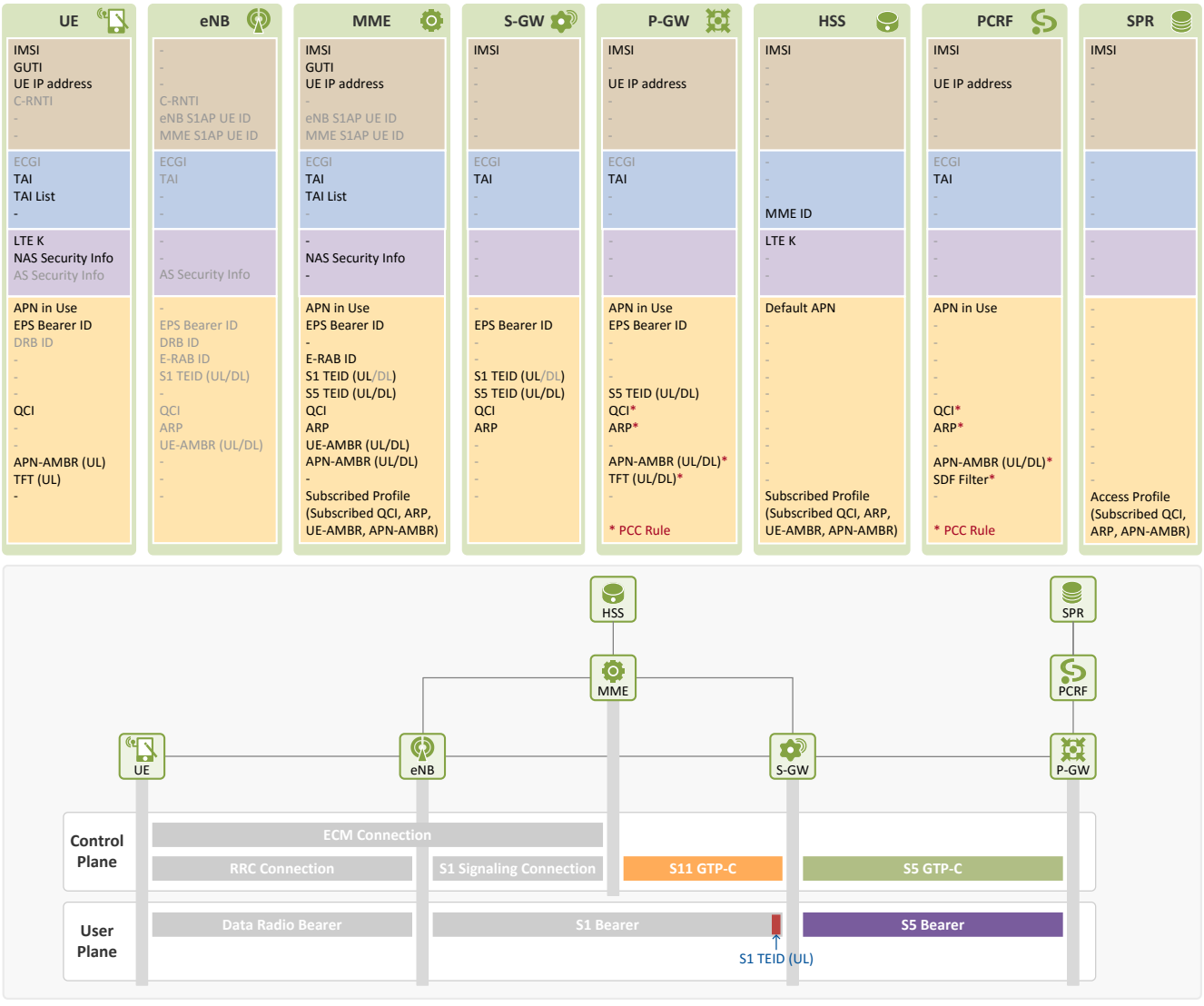

Figure 6. Information in EPS entities before and after Periodic TAU

4.2 After Periodic TAU

After a periodic TAU procedure, the ECM connection is released, and the UE transits back to Idle state (**EMM-Registered**, **ECM-Idle and RRC-Idle**) it used to be in before the periodic TAU procedure. The information elements stored in each EPS entity after the periodic TAU procedure are the same as those kept before the procedure, as to be seen in Figure 6.

V. Closing

We have learned the periodic TAU procedure ("EMM Case 5" in [1]) required when a UE, staying in Idle state (**ECM/RRC-Idle**) after attaching an LTE network, updates its location upon expiration of the TAU timer. Unlike a service request procedure, this procedure does not require establishment of an E-RAB bearer, but requires establishment of an ECM connection, for TAU. After TAU is performed, the ECM connection is released, allowing the UE to transit back to Idle state. If a UE has uplink data to send (this case is not discussed in this document, though), an E-RAB bearer is set up first, and then the data is sent after TAU, just like in a service request procedure. The subsequent document will cover a case when a UE, in Connected (**ECM/RRC-Connected**) state, moves between TAs in the TAI list, causing a handover, but no TAU procedure is required.

References

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[6] NMC Consulting Group Confidential Internal Report, "E2E LTE Network Design", August 2010

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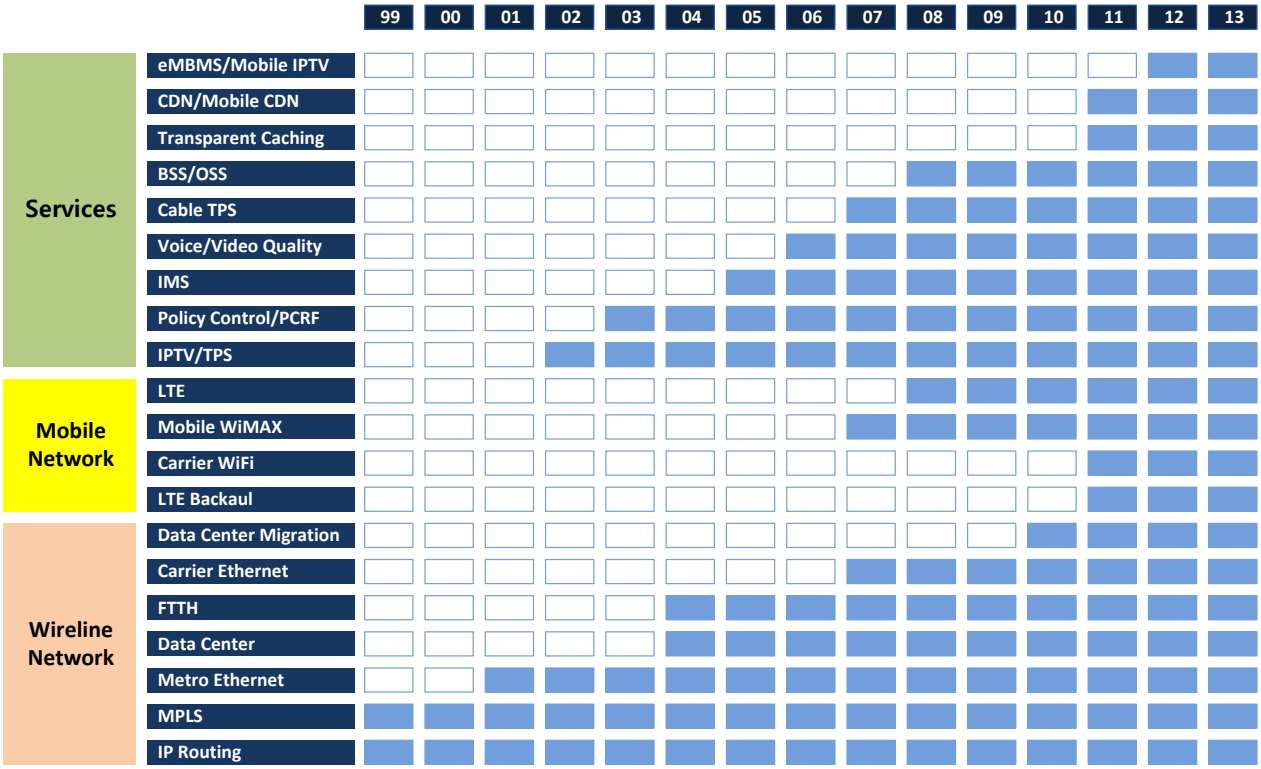

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