

EMM Procedure 8 & 9. Handover and Cell Reselection with TAU

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This document will describe two types of EMM procedures: i) handover where UE in Connected state (EMM-Registered, ECM-Connected, RRC-Connected) moves to a non-registered TA (EMM Case 8) and ii) cell reselection where UE in Idle state (EMM-Registered, ECM-Idle, RRC-Idle) moves to a non-registered TA (EMM Case 9). The handover and cell reselection procedures are the same as in EMM Case 6 (Handover without TAU) and Case 7 (Cell Reselection without TAU), respectively, except that a TAU procedure is required after handover/cell reselection as this time UE moves to a non-registered TA. As in EMM Cases 6 and 7, we will discuss intra-LTE handover and intra-frequency cell reselection only.

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Abbreviations

ASME	Access Security Management Entity
DL	Downlink
ECGI	E-UTRAN Cell Global Identifier
ECM	EPS Connection Management
EMM	EPS Mobility Management
eNB	Evolved Node B
EPS	Evolved Packet System
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
GUTI	Globally Unique Temporary Identifier
KSI	Home Subscriber Server
LTE	Long Term Evolution
MAC	Message Authentication Code
MME	Mobility Management Entity
NAS	Non Access Stratum
PCRF	Policy and Charging Rule Function
PDU	Protocol Data Unit
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
UE	User Equipment
UL	Uplink

I. Introduction

When UE accesses the network, a group of Tracking Areas (TAs) is assigned by the network (MME) through the Tracking Area Identity (TAI) list. The UE then can move within these TAs without having to report its location to the network. The network does not know which cell the UE is camping on, but knows it is in one of the assigned TAs. So, if a call/packet arrives for UE in Idle state, the network initiates paging within these TAs where the UE is registered. The TAI list assigned to the UE is a list of the areas where the UE has been registered. Because of this, if UE moves to a TA not in the TAI list, it must perform a TAU procedure, requesting for TA update, so that the network can update the UE's TAI list and assign the updated list accordingly.

This document concerns the EMM cases, where UE moves to a TA that it is not registered to, specifically “EMM Case 8. Handover with TAU” and “EMM Case 9. Cell Reselection with TAU” [1].

In EMM Case 8, UE moves to another TA while it stays in Connected state (**EMM-Registered, ECM-Connected, RRC-Connected**). During this move, the procedure for handover from the source eNB to the target eNB is the same as described in our EMM Case 6. Handover without TAU documents [2][3][4]. What is different from the previous case is that thereafter the UE performs a TAU procedure at the new cell in the target eNB. On the other hand, in EMM Case 9, UE moves while in Idle state (**EMM-Registered, ECM-Idle, RRC-Idle**). Here, the procedure for cell reselection at the serving cell is the same as in EMM Case 7. Cell Reselection without TAU [5]. Again, this time however the UE, after cell reselection, must perform a TAU procedure before it camps on the new cell.

This document is organized as follows: Chapter II explains the EMM Case 8 procedure, and Chapter III discusses the EMM Case 9 procedure. In Chapter IV, we will learn how information elements in EPS entities are different before and after the procedures.

II. EMM Case 8. Handover with TAU

Figure 1 shows a handover procedure performed when UE in Connected state moves to a TA that it is not registered to. When the UE initially attached the network, MME selected TA1 and TA2 for the UE, and sent a TAI list = {TAI=1, TAI=2}, as included in the **Attach Accept** message. Initially, the UE was served through eNB2 (Cell 5 in it, to be exact) in TA1. Now it is moving toward eNB5 (Cell 13, to be exact) in TA3 which is not in the TAI list. As this document concerns intra-LTE handover only, we assume both eNB2 and eNB5 are connected to the same MME and S-GW.

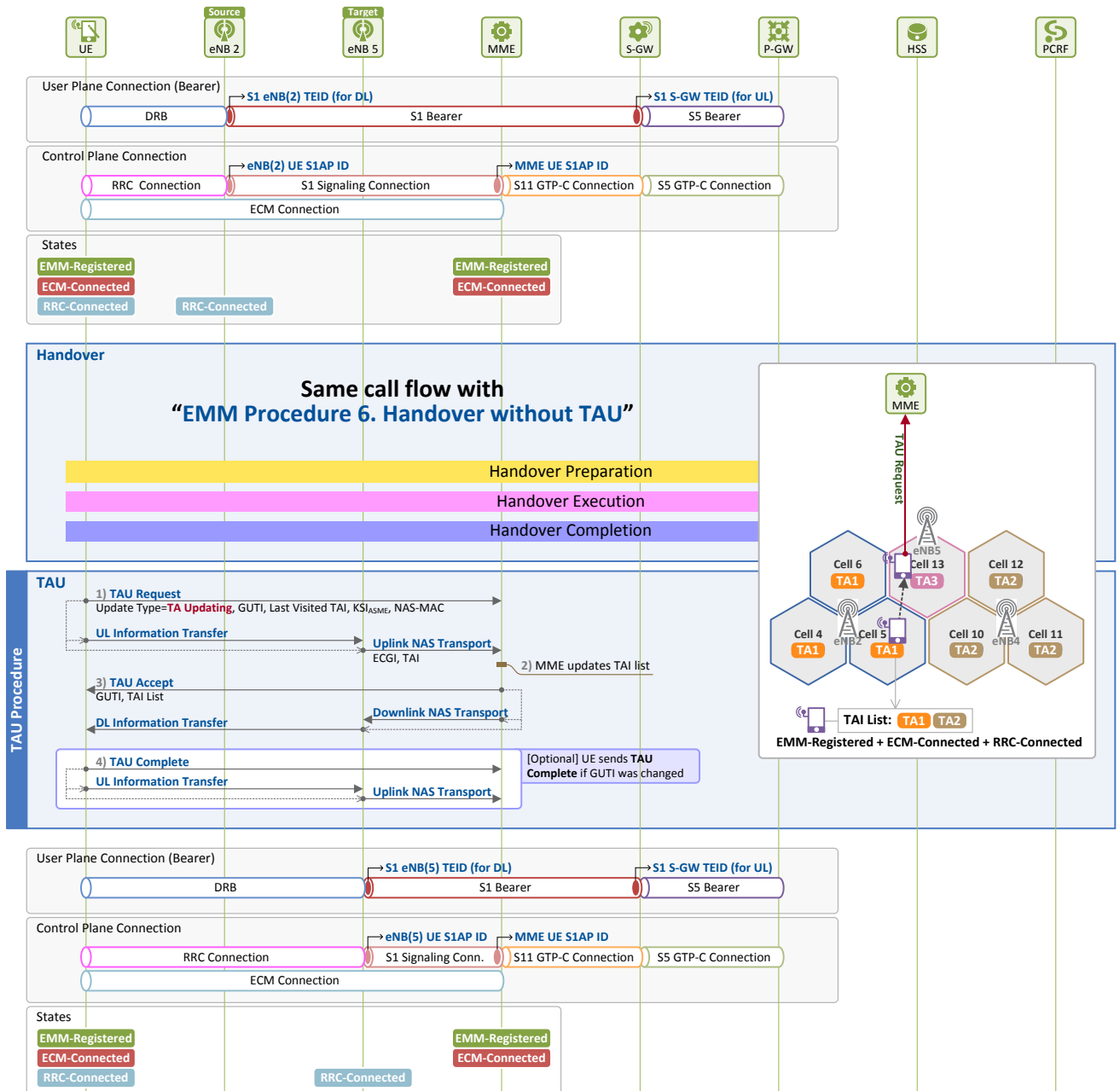


Figure 1. Handover (to a non-registered TA)

Handover

In the figure above, as the UE moves toward eNB5, a handover event¹ is triggered. The UE measures the signal strength of the serving cell and neighbor cells, and sends the results to eNB2, as included in the **Measurement Report** message. First, the source eNB (e.g. eNB2 above) chooses the type of handover to perform, X2 or S1. In X2 handover, it is the source eNB that selects the target eNB (e.g. eNB5 above), whereas it is MME in S1 handover. Next, handover is performed from eNB2 (Cell 5 in it to be more exact) to eNB5 (Cell 13 in it) (see the previous documents [2][3][4] for detailed handover procedure).

¹ For details about handover triggering events, see our previous document [2].

Tracking Area Update (TAU)

1) [UE → MME] TAU Request

When being handed over to the target eNB (eNB5), the UE knows eNB5 does not belong to its assigned TAs. Thus, as soon as the handover is completed, it sends a **TAU Request (Update Type=TA Updating, GUTI, Last Visited TAI, KSI_{ASME} , NAS-MAC)** message to MME, requesting TA update. At this time, the message includes the following information:

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

- **Update Type:** indicates the TAU type. Set as **TA Updating** unless UE is handed over to a registered TA
- **GUTI:** UE ID previously allocated by MME. Used by MME for UE identification.
- **Last Visited TAI:** TAI reported through **TAU Request** last time
- **KSI_{ASME} :** index for K_{ASME} , the NAS security base key
- **NAS-MAC:** message authentication code used in protecting the integrity of **TAU Request** with NAS integrity Key (K_{NASInt}).

The **TAU Request** message is sent through an **UL Information Transfer** message from UE to eNB (as RRC message), and then through an **Uplink NAS Transport (NAS-PDU (TAU Request), ECGI, TAI)** message from eNB to MME (as S1AP message). The **Uplink NAS Transport** message, including the **TAU Request** message and the current cell's ECGI and TAI, is forwarded to MME.

As the NAS security context has already been established between the UE and MME, the **TAU Request** message that the UE sends is integrity-protected with the NAS integrity key (K_{NASInt}). If the MME's integrity check on the received **TAU Request** message fails, the MME performs user authentication and NAS security setup procedures (see the previous document [6]). In this document, we will only discuss cases where the MME succeeds the integrity check.

2) [MME] TA Update: Allocating New TAs

Because the UE has moved to a TA that it is not registered to, the MME selects a group of TAs to allocate and configures a new TAI list for the UE. At this time, a new Globally Unique Temporary Identifier (GUTI) may also be allocated.

3) [UE ← MME] TAU Accept

The MME sends the newly selected TAs (and GUTI if applicable), as included in a **TAU Accept (GUTI, TAI List)** message. This message, after being encrypted and integrity-protected, is sent through a **Downlink NAS Transport** message from MME to eNB (as S1AP message), and then through a **DL Information Transfer** message from eNB to UE (as RRC message).

4) [UE → MME] TAU Complete

If a new GUTI was allocated, the UE sends the MME a **TAU Complete** message to acknowledge the receipt of the new GUTI.

Once the TAU procedure is completed, the UE, now with the new TAI list (and GUTI if applicable), can be served through eNB5.

III. EMM Case 9. Cell Reselection with TAU

Figure 2 illustrates the cell reselection procedure required when UE in Idle state moves to a TA that it is not registered to. In the figure, the UE camping on Cell 5 (at eNB2) moves toward Cell 13 (at eNB5). Again, please note that this document concerns intra-frequency cell reselection only.

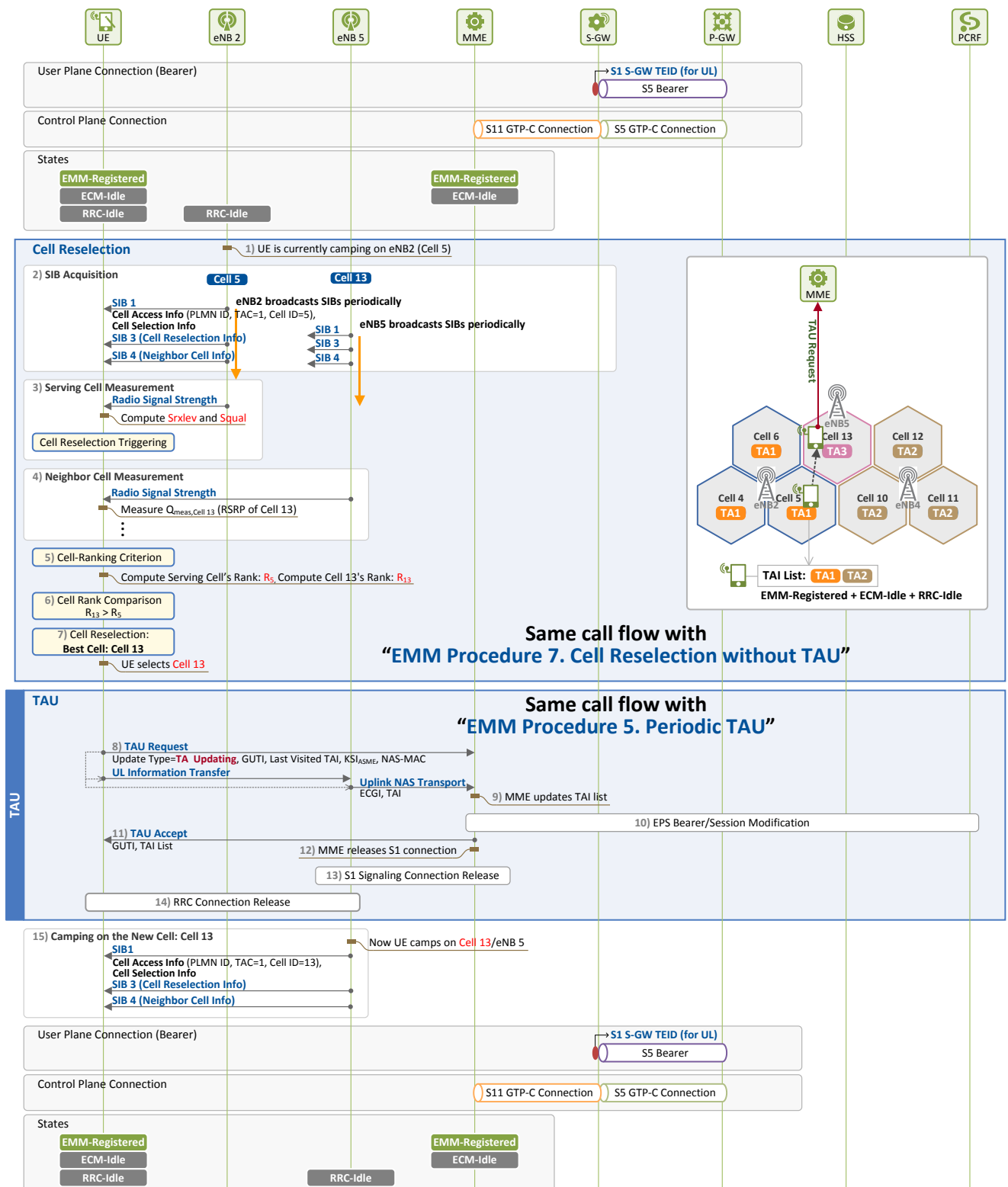


Figure 2. Intra-frequency cell reselection (when moving to a non-registered TA)

Cell Reselection

1) ~ 7) [UE] Cell Reselection

The UE moves toward eNB5, triggering a cell reselection.² So, it measures neighbor cells to rank them, and, based on the result, selects Cell 13 (at eNB5) as the best cell that satisfies the cell reselection criteria most. Here, the cell reselection procedure is the same as explained in the previous document, “EMM Procedure 7. Cell Reselection without TAU” [5].

Tracking Area Update (TAU)

When selecting Cell 13 (at eNB5) during the foregoing procedure, the UE knows the cell does not belong to one of its previously assigned TAs. So, it performs a TAU procedure as soon as the reselection procedure is completed. The TAU procedure here is the same as explained in the previous document, “EMM Procedure 5. Periodic TAU” [7]. The only difference between two cases is what initiates a TAU procedure. That is, in case of periodic TAU, UE performs a TAU to report its current location to the network due to the expiration of the TAU timer (T3412). Whereas, in case of the above mentioned TAU, UE performs one because it moves to a non-registered TA. So, the TA update type in the **TAU Request** message this time is set as “TA Updating”, not as “Periodic Updating”. Below, the TAU procedure is briefly described.

8) [UE → MME] TAU Request

The UE requests TA update by sending a **TAU Request (Update Type=TA Updating, GUTI, Last Visited TAI, KSI_{ASME}, NAS-MAC)** message to the MME. The **TAU Request** message includes the same information as listed in Chapter II above. Then, it is sent integrity-protected with the NAS integrity key (K_{NASint}). The UE establishes an RRC connection with the eNB, and sends the message, thereby transiting from Idle state (**EMM-Registered, ECM-Idle, RRC-Idle**) to Connected state (**EMM-Registered, ECM-Connected, RRC-Connected**).

9) [MME] TA Update: Allocating a New TA

Upon receiving the **TAU Request** message conveyed through the **Uplink NAS Transport** message, the MME identifies the TA on which the UE is currently camping (i.e. TA3 in this case) from the TAI included in the **Uplink NAS Transport**, and also the last reported TA (i.e. TA1 in this case) from the Last Visited TAI included in the **TAU Request** message.

Because the TA the UE is currently camping on (i.e. TA3) is not one of its previously allocated TAs (TA1 and TA2), the MME, by referring to the UE's Last Visited TAI value, allocates a new set of TAs that best suit the UE's current location and speed. To a fast-travelling UE, a wider range of TAs may be allocated to reduce the signaling load caused by TAU. In such case, however, the signaling load caused by paging may increase, and the paging response may take longer when a call/packet is arriving for the UE while it is in Idle state. In case different TAI lists must be allocated per UE, the trade-off between TAU signaling load and paging performance is taken into account.³ The MME also updates the “Last Visited TAI” value included in the UE context with the UE's current “TAI” value.

10) [MME, S-GW, P-GW, PCRF] EPS Bearer/Session Modification

As the UE's location is changed, the MME informs the S-GW of such change by sending a **Modify Bearer Request** message. If MME is required to report any TA change to PCRF, as set in the Change Report

² See the previous document [5] for more information about cell reselection triggering.

³ TAI list allocation is not within the scope of this document, and hence will not be discussed here.

Action parameters received from PCRF when the UE established the EPS session after initial attach, a session modification procedure is performed, reporting the TA change to PCRF accordingly.

11) [UE ← MME] TAU Accept

The MME sends the UE a new TAI list (and GUTI if applicable) through a **TAU Accept (GUTI, TAI List)** message. At this time, the message includes the same information as listed in Chapter II above, and is sent integrity-protected and encrypted.

12) ~ 14) [UE, eNB, MME] Transiting to Idle State

After the TAU procedure is completed, the MME releases the S1 connection (see the previous document [8]), thereby releasing the S1 signaling connection between eNB5 and MME. Then, eNB5 releases the RRC connection established with the UE. Now, the ECM connection between the UE and MME is removed, and the UE turns to Idle state (**EMM-Registered, ECM-Idle, RRC-Idle**), back from Connected state (**EMM-Registered, ECM-Connected, RRC-Connected**).

15) [UE] Camping on Cell 13

Once back to Idle state, the UE camps on Cell 13. Now with the new TAI list, it wakes up at the end of every DRX cycle and measures the signal of Cell 13 (RSRP, RSRQ).

IV. EPS Entity Information

The Information elements stored in the EPS entities before and after the handover with TAU procedure in EMM Case 8 are:

- Same as those kept before and after the handover without TAU procedure [3][4]. However, the TAI (and GUTI) information is changed due to TA update.

The Information elements stored in the EPS entities before and after the cell reselection with TAU procedure in EMM Case 9 are:

- Same as those kept before and after the cell reselection without TAU procedure [5]. However, the TAI (and GUTI) information is changed due to TA update.

V. Closing

We have so far learned about the handover and cell reselection procedures performed when UE moves to a non-registered TA after it is registered to the network (MME), i.e., after a TAI list is allocated. We also learned the UE, after completing a handover/cell reselection procedure, obtains a newly allocated TAI list through a TAU procedure at the new cell.

The next document [9], the last of our EMM procedure series, will discuss the procedures performed when UE moves to another city (City 1 → City 2), including procedures for detach in City 1 and initial attach in City 2 (as in EMM Cases 10 and 11 [1]).

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