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EMM Procedure 10 & 11. Move to Another City and Attach

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This document will describe the two procedures defined as EMM Cases 10 and 11 in our technical document, "Eleven EMM Cases in an EMM Scenario". These procedures consist of i) a detach procedure required when UE moves from its current location (e.g. City 1) to another city (e.g. City 2), and thereby leaves the LTE coverage in City 1, and ii) an initial attach procedure required for the UE to attach again the network using its Old Globally Unique Temporary Identifier (Old GUTI) after entering the LTE coverage in City 2. In EMM Cases 10 and 11, we assume an LTE network operator that serves several geographically separated cities through operation of an LTE-only network that uses a single LTE carrier frequency.

June 11, 2014

(Initial Released: May 30, 2013)

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NMC Consulting Group (tech@netmanias.com)

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Abbreviations

AMBR	Aggregated Maximum Bit Rate
APN	Access Point Name
ARP	Allocation and Retention Priority
ASME	Access Security Management Entity
AV	Authentication Vector
DL	Downlink
ECGI	E-UTRAN Cell Global Identifier
ECM	EPS Connection Management
EMM	EPS Mobility Management
eNB	Evolved Node B
EPS	Evolved Packet System
GUTI	Globally Unique Temporary Identifier
HSS	Home Subscriber Server
IMSI	International Mobile Subscriber Identity
KSI	key Set Identifier
LTE	Long Term Evolution
MAC	Message Authentication Code
MME	Mobility Management Entity
M-TMSI	MME Temporary Mobile Subscriber Identity
NAS	Non Access Stratum
PCRF	Policy and Charging Rule Function
P-GW	Packet Data Network Gateway
PPF	Paging Proceed Flag
QCI	QoS Class Identifier
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

UE attempts a handover or cell reselection when the received signal strength from its serving cell becomes weak as it moves. If there is no neighbor cell at all near the travelling UE, the signal strength will get gradually weaker until finally the UE is detached from the network. Then, once within an LTE coverage again, it will make initial attach to the network again through cell selection.

This document discusses EMM cases where UE detaches from the network as it moves out of one LTE coverage area, and moves into another one, attaching the network again, as in EMM Case 10, "Move to Another City", and EMM Case 11, "Initial Attach in Another City" [1]. Figure 1 illustrates the two cases.

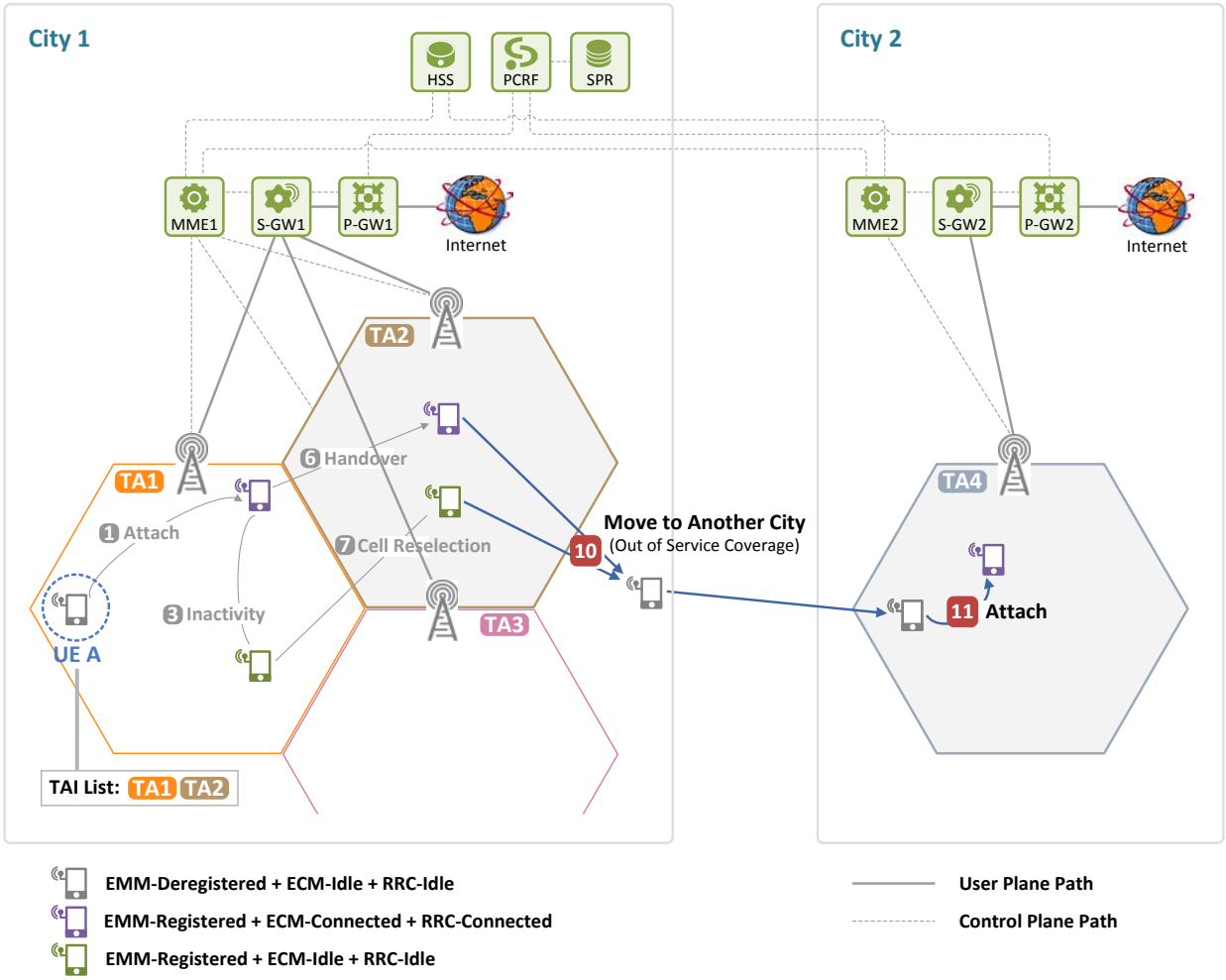


Figure 1. EMM Cases 10 and 11

For the purpose of the two EMM cases, this document assumes a mobile operator that:

- is serving several cities,
- is operating an LTE-only network with no 2G/3G network,
- has MME, S-GW and P-GW in each city that it serves,
- has HSS, PCRF and SPR installed in only one city, and
- has all the MMEs connected through S10 interface.

Figure 1 shows City 1 and City 2 only, and the user is moving from City 1 to City 2 in a car.

In EMM Case 10, UE detaches from the network as it leaves City 1, thereby moving out of the LTE coverage. The UE, either while using services in Connected state (**EMM-Registered, ECM-Connected, RRC-Connected**) or while camping on its serving cell in Idle state (**EMM-Registered, ECM-Idle, RRC-Idle**), transits to Detach state (**EMM-Deregistered, ECM-Idle, RRC-Idle**) as it leaves City 1, and hence is detached from the network by MME.[1]

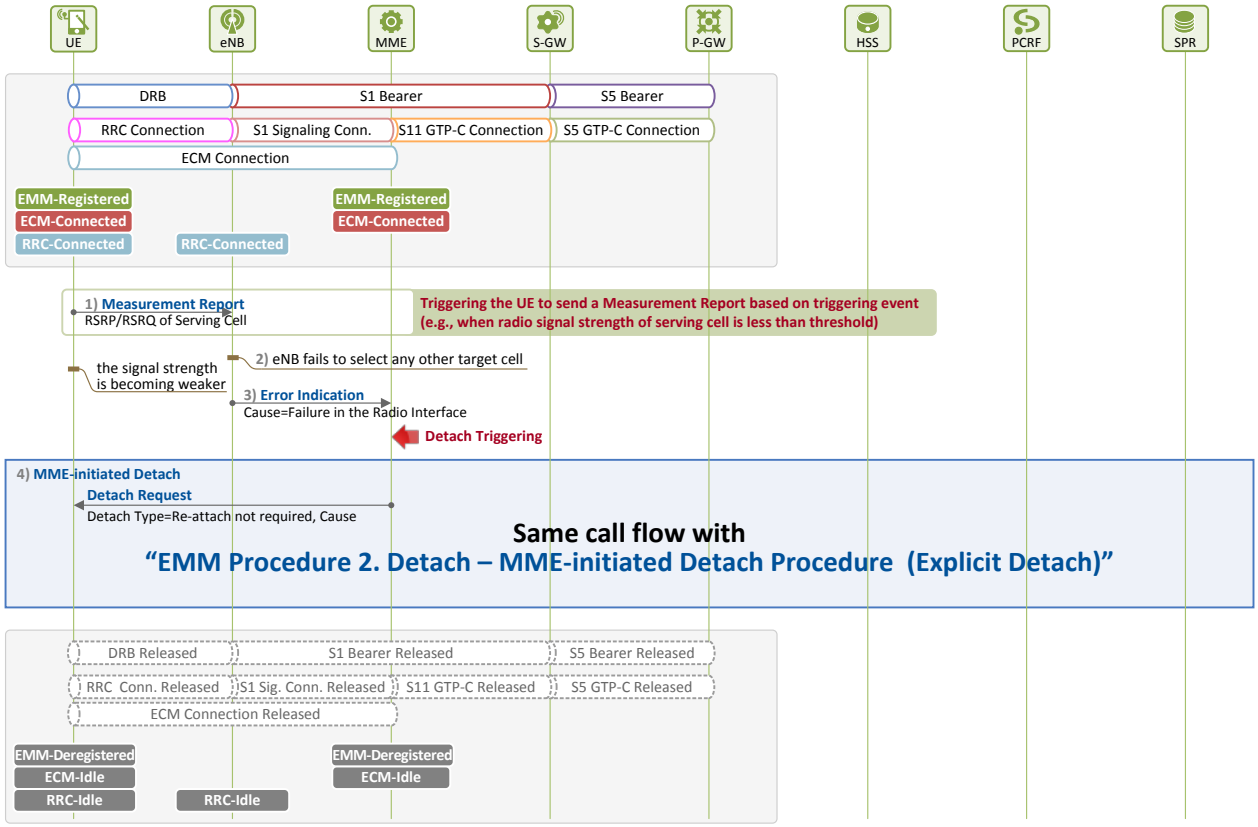
In EMM Case 11, UE attaches the network again as it moves into an LTE coverage after arriving in City 2. Unlike the case in the previous document [3], the network (Old MME) has already had the UE context when the UE attaches the network (New MME). The UE makes initial attach to the network (New MME) using the UE ID (Old GUTI) that was assigned by the network (Old MME). By that, it transits from Detach state (**EMM-Deregistered, ECM-Idle, RRC-Idle**) to Connected state (**EMM-Registered, ECM-Connected, RRC-Connected**).

This document is organized as follows: Chapter II and III will describe the EMM Case 10 and 11 procedures, respectively. And Chapter IV will explain how information elements in EPS entities are different before and after each procedure.

II. EMM Case 10. Move to Another City

2.1 Moving in Connected State

In Figure 2, we can see how UE, while using services in City 1, is detached from the network as it moves out of the LTE coverage.



[1] Generally, in an "out of coverage" situation, UE experiences implicit detach [1] due to lost RRC connection. However, here explicit detach [2] was assumed in the EMM Case 10 as the EMM Case 11 presented here concerns initial attach using Old GUTI.

Figure 2. Move to Another City in "Connected" State

1) [UE → eNB] Measurement Report

As the UE leaves City 1, the signal strength received from the serving cell gets weaker. In case A2 event has been activated, the UE sends a **Measurement Report** message to eNB, informing the signal strength of the serving cell.

2) [eNB] No Neighbor Cell to Hand Over to

The eNB finds no neighbor cell to hand the UE over to.

3) [eNB → MME] Error Indication

Due to the worsening communication quality, delivery fails over the radio interface. The eNB informs the MME of such failure by sending an **Error Indication (**Cause=Failure in the Radio Interface[2]**)** message (if the eNB finds it hard to maintain the minimum quality required for communication with the UE, it may send the MME an **UE Context Release Request** message).

If the UE loses the RRC connection due to poor communication quality, the UE attempts RRC connection re-establishment. If the quality degradation is temporary, the RRC connection is re-established allowing for normal radio communication. In such case, service provision is not interrupted. If the degradation persists, the RRC connection re-establishment will continue to fail, causing the connection to be lost eventually.

It is assumed here that i) the eNB sends an **Error Indication** to the MME while the RRC connection with the UE is still valid, and ii) the MME decides to detach the UE because the current serving cell of the UE is located near the city border, and has no neighbor cell to hand over to. So, the MME triggers a detach procedure.

4) MME-initiated Detach

The MME performs a detach procedure by sending the UE a **Detach Request** message. Here the procedure is the same as the "MME-initiated Explicit Detach procedure" explained in our previous document [2][3]. The MME stores the UE's GUTI and NAS security context, terminates the EPS session, releases the S1 signaling, and transits to Detach state (**EMM-Deregistered, ECM-Idle**). The UE stores its GUTI and NAS security context, deletes the EPS bearer context, and then transits to Detach state (**EMM-Deregistered, ECM-Idle, RRC-Idle**).

2.2 Moving in Idle State

UE performs periodic TAU to report its location to the network periodically while it stays in Idle state (see the previous document [5] for details). When there is an incoming call/packet for the UE, MME does not know whether the UE is reachable or not if it is in Idle state. For this reason, UE in Idle state periodically reports its location even while staying in a TA in the TAI list so that the network can see whether the UE is reachable or not. To this end, MME has a TAU timer (T3412), mobile reachable timer, and implicit detach timer. The TAU

[2] This cause value is used here just as an example. Other possible values include "Radio connection with UE lost" (see 3GPP TS 36.413 [4]).

[3] An implicit detach procedure may be performed instead if the MME believes the RRC connection between the UE and eNB is lost.

timer (T3412) value is forwarded to UE through an **Attach Accept** message when the UE makes initial attach to the network, or through a **TAU Accept** message when the UE makes a TAU request.
A TAU timer (T3412) defaults to 54 minutes [4]. If MME sets this value to "0", UE deactivates the TAU timer, and does not perform periodic TAU (Wouldn't it be used for M2M communications?). The TAU timer in UE is activated when the UE transits from Connected state (**EMM-Registered, ECM-Connected, RRC-Connected**) to Idle state (**EMM-Registered, ECM-Idle, RRC-Idle**). When the timer expires, the UE transits to Connected state to send MME a **TAU Request** message informing it is reachable, and then transits back to Idle state, restarting the TAU timer. The UE stops the timer if it transits from Idle to Connected state, or if it is detached from the network.
If the TAU timer that MME set for the UE expires, the MME shortly receives a **TAU Request** message[4], through which it keeps track of the UE's location. Then, it re-allocates a new TAI list if needed, and then re-starts the TAU timer. That is, the network checks whether the UE is reachable or not at least at the end of every TAU timer cycle, and sets Paging Proceed Flag to "1", indicating the UE is reachable.

If the UE has any problem (for example, if it is within a shadowing area at the time of T3412 timer expiration, and hence not reachable), it cannot make a TAU request required upon the expiration of T3412, and hence fails to inform MME of its location. UE is required to re-attempt when a TAU request is failed. So, if the UE gets out of the shadowing area soon after, then the re-attempted TAU request can be made successfully. However, if it stays in the shadowing area, then any further TAU requests will continue to fail.

A mobile reachable timer is used by the network to check whether UE is reachable or not. Compared to the TAU timer (T3412), it has a slightly higher value, defaulting to "T3412 + 4 minutes". The timer starts when the ECM connection with UE is released (e.g. if UE transits to Idle state), and stops when a new ECM connection is established (e.g. if UE sends a **TAU Request** message to MME).

When the mobile reachable timer expires, MME knows UE is **out of the LTE coverage**, but does not know for how long the out of the coverage status has lasted. So, instead of deleting the UE's context right away, the MME clears the PPF flag and starts the implicit detach timer. When the PPF flag is cleared, the UE is **locally detached**. That is, while the implicit detach timer runs, the network still keeps the UE context undeleted, but the MME does not page the UE (of course because it does not know where the UE is). Even when S-GW sends the MME a **Downlink Data Notification** message upon arrival of a call/packet destined to the UE, the MME declines the message.

When the UE sends a NAS message, establishing an ECM connection, the implicit detach timer stops. If the MME is unable to locate the UE before the implicit detach timer is expired, it believes the UE has **long been out of the LTE coverage**, and thus detaches the UE from the network. Now, the UE context is deleted in the network.

Figure 3 illustrates how UE that has been camping on the serving cell in City 1 is detached from the network as it moves out of the LTE coverage.

[4] The context of the UE that is making a TAU request is received through S1 interface if the UE is residing in the areas managed by the MME. However, if the UE is moving to an area managed by other MME, then the context is received through S10 interface from the other MME.

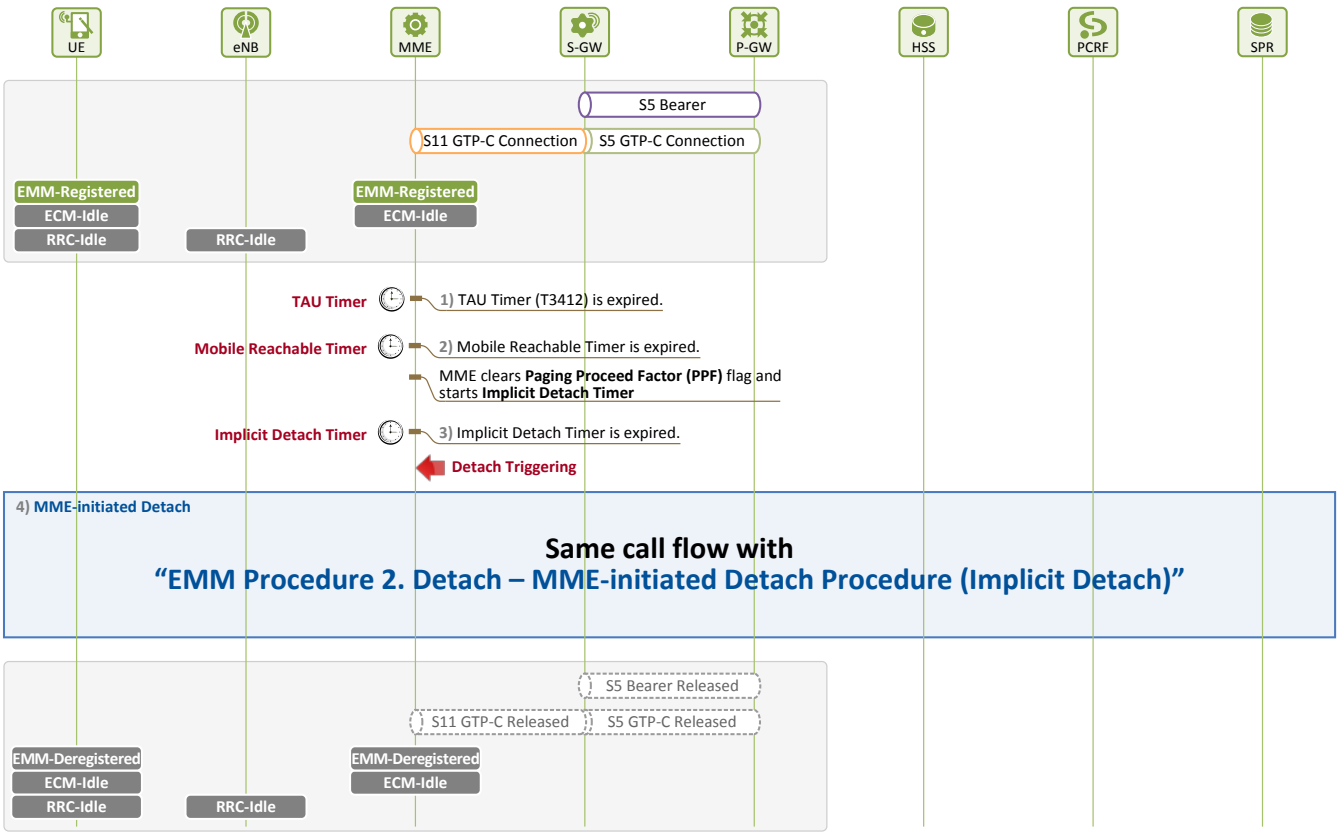


Figure 3. Move to Another City in "Idle" State

1) [MME] TAU Timer (T3412) Expiry

The TAU timer set for UE is expired. The MME has not received a **TAU Request** message from the UE, and must check whether the UE is reachable or not.

2) [MME] Mobile Reachability Timer Expiry

The UE's mobile reachable timer is also expired. The MME, believing the UE is in the "out of coverage" status, clears the PPF flag and starts the implicit detach timer. The resources allocated to the UE (e.g. EPS bearer, security context, etc.) are kept valid, but the MME does not page the UE.

3) [MME] Mobile Implicit Timer Expiry

The UE's implicit detach timer is expired. The MME, believing the UE has long been "out of the coverage", decides to implicitly detach the UE from the network.

4) [eNB, MME, S-GW, P-GW, PCRF] UE Detached

The MME initiates an implicit detach procedure. This procedure is the same as the "MME-initiated Implicit Detach procedure" explained in the previous document [2]. The allocated resources and context of the UE are deleted.

III. EMM Case 11. Initial Attach in Another City

Now, this chapter describes how the traveling UE, as it moves back into the LTE coverage in City 2, selects a new cell, and performs initial attach, thereby transiting from Detach state (**EMM-Deregistered, ECM-Idle, RRC-Idle**) to Connected state (**EMM-Registered, ECM-Connected, RRC-Connected**). We assume that the UE was detached from the network in City 1 through an MME-initiated explicit detach procedure, and thus the Old GUTI and NAS security context are all kept valid at UE and the network (MME1).

Figure 4 shows the type of initial attach and function blocks involved in the UE's initial attach in City 2. The initial attach type here is the same as "Attach Case 5: Known UE, MME Changed" (Attach to New MME with Old GUTI) discussed in our previous document [6]. That is, as the UE detached from the network successfully, both UE and network (Old MME) have kept the Old GUTI and NAS security context valid, and the UE is making initial attach to a new MME using them. The UE sends an **Attach Request** message by using the Old GUTI instead of IMSI as its ID. The message is sent integrity protected with the NAS integrity key (K_{NASint}). The new MME (New MME) forwards the message to the old MME (Old MME) so that it can run an integrity check.

In this document, it is assumed the integrity check in the Old MME succeeded. The New MME, after obtaining the UE context including IMSI from the Old MME, performs location update and EPS session establishment procedures. If the integrity check in the Old MME fails, the Old MME sends an error message to the New MME, which then obtains IMSI from the UE and performs user authentication, NAS security setup, location update and then EPS session establishment.

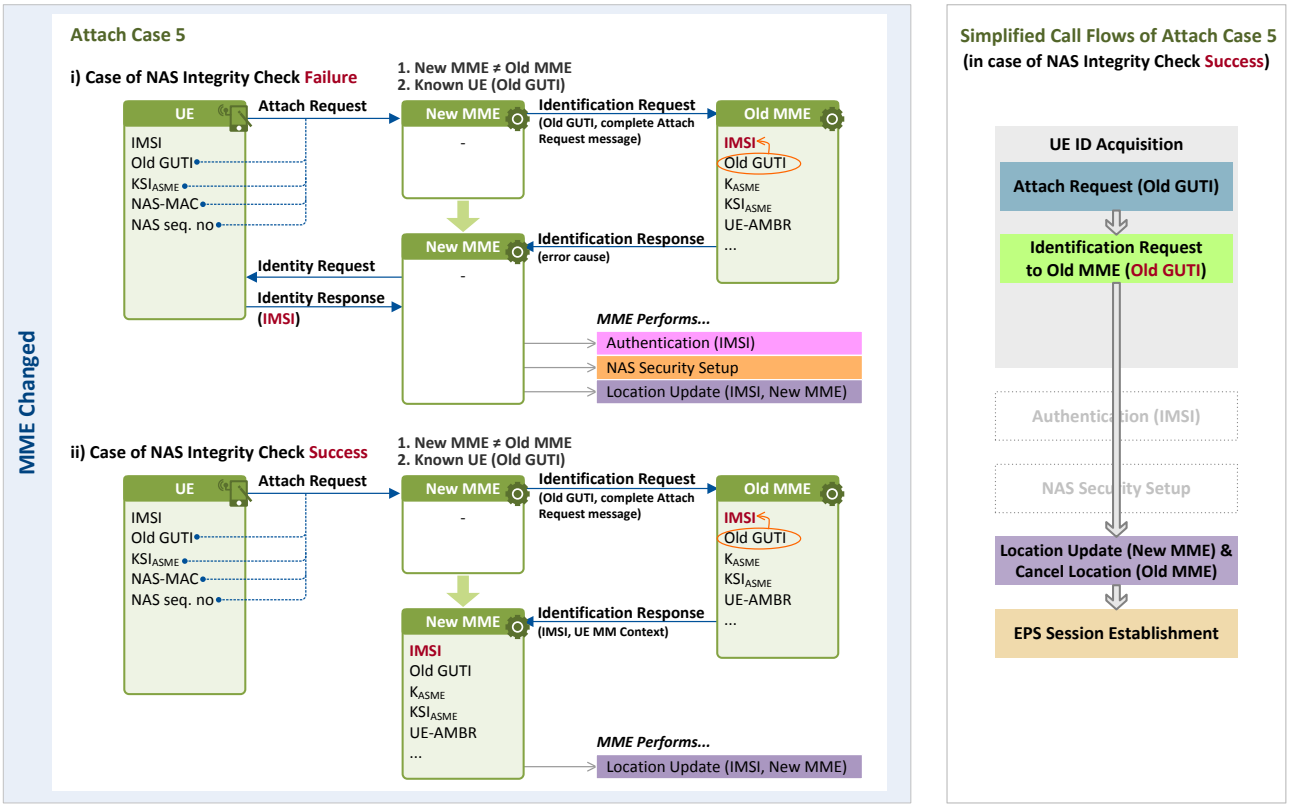


Figure 4. Attach Case 5: Attach to New MME with Old GUTI [6]

Figure 5 is an illustration showing how the UE performs initial attach to the New MME (MME2) in City 2, using its Old GUTI.

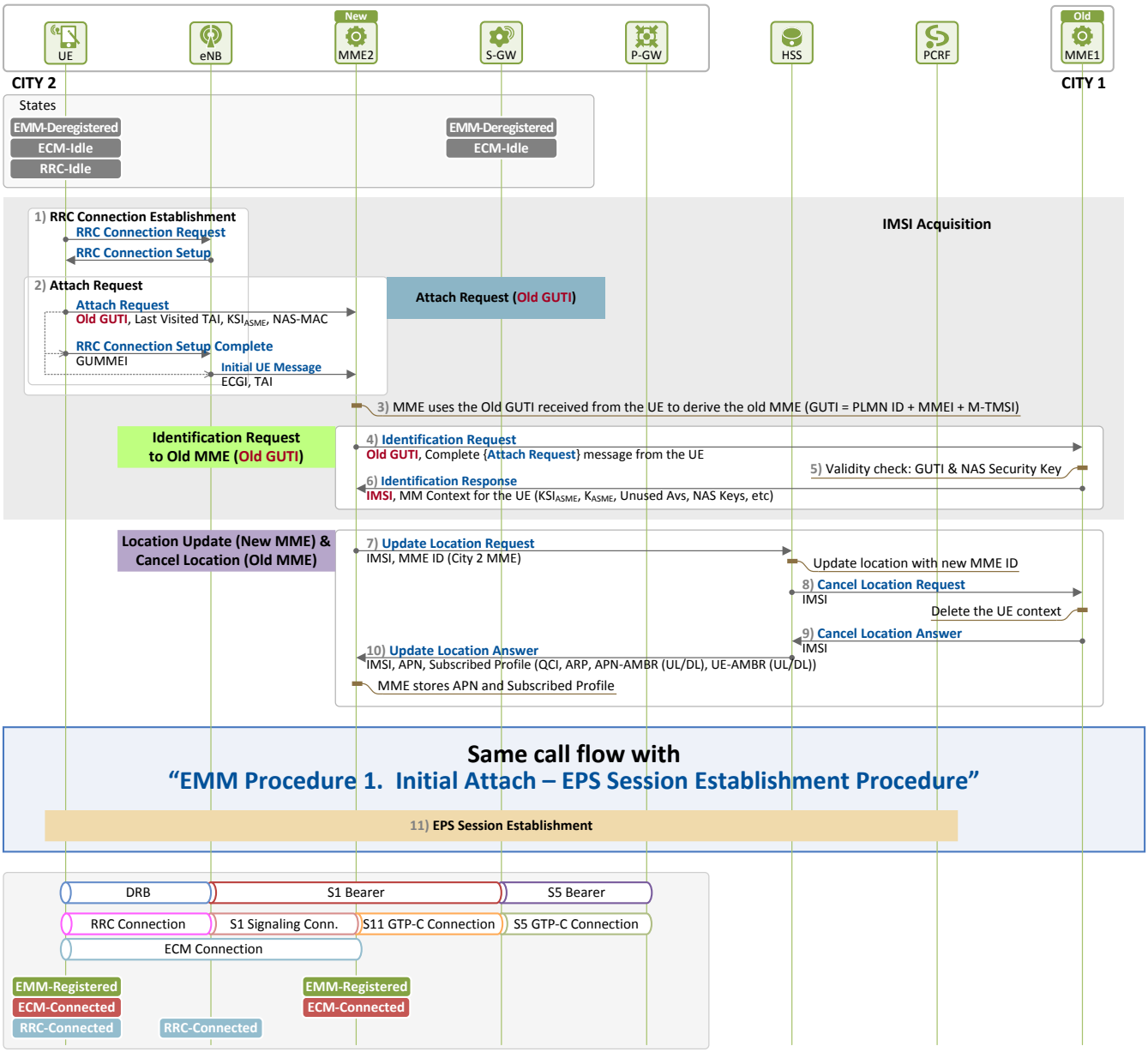


Figure 5. Initial Attach in Another City

1) [UE, eNB] Establishing RRC Connection

Once entering City 2, the UE detects LTE signal, selects a new cell, and requests eNB for an RRC connection. As a result, an RRC connection is established.

2) [UE, New MME] Requesting Initial Attach to New MME using Old GUTI

The UE sends an **Attach Request (Old GUTI, Last Visited TAI, KSI_{ASME}, NAS-MAC)** to the network (MME2), by using the Old GUTI allocated by MME1 in City 1 as its ID. The message is integrity protected with the K_{NASint} key first, and sent through the **RRC Connection Setup Complete** message over the radio interface

(LTE-Uu interface) and then through the **Initial UE Message (ECGI, TAI)** over S1 interface.

3) [New MME] Identifying Old MME

MME2 checks the location of the UE from the received **Initial UE Message**, and learns from the Old GUTI that it was allocated by MME1.[5]

Next, MME2 checks if the Old GUTI is still valid through communication with MME1 over S10 interface, and obtains the UE context stored at MME1.

4) ~ 6) [Old MME, New MME] Obtaining UE Context from Old MME

4) The New MME (MME2) includes the **Attach Request** message that it received and the Old GUTI in the **Identification Request (Old GUTI, Complete {Attach Request} message from UE)** message, and sends the message to the Old MME (MME1).

5) When receiving the message from the New MME (MME2), the Old MME (MME1) knows that the GUTI was allocated by itself, and then performs integrity check on the **Attach Request** message sent by the UE, by using the UE security context it has kept. The check succeeds.

6) As the integrity check succeeded, the Old MME (MME1) sends the New MME (MME2) the UE context[6] through the **Identification Response (IMSI, UE-AMBR, UE Security Context (K_{ASME}, KSI_{ASME}, Unused AVs, NAS Keys, etc))** message. The new MME (MME2) obtains the UE context.

7) ~ 10) [Old MME, New MME, HSS] Location Information Updated at New MME, and Deleted at Old MME

7) The MME2, now with the valid UE context, sends the **Update Location Request (IMSI, MME ID=MME2)** message to HSS in order to register the UE with the network (MME2). This way, it informs the HSS that the UE with the IMSI has been registered with MME2. The HSS updates the UE's new location accordingly.

8) The HSS sends MME1 the **Cancel Location Request (IMSI)** message asking MME1 to delete the UE context. MME1 deletes the UE context as requested.

9) MME1 informs the HSS that the UE context is deleted, by sending the **Cancel Location Response (IMSI)** message.

10) The HSS provides MME2 with the subscription profile information of the UE, including subscription QoS information, by sending the **Update Location Answer (IMSI, APN, Subscribed Profile (QCI, ARP, APN-AMBR (UL/DL), UE-AMBR (UL/DL))** message, so that MME2 can establish an EPS session.

11) [New MME] Establishing EPS Session

MME2 establishes an EPS session by using the UE context received from MME1, and the subscription profile received from the HSS. The establishment procedure at this time is the same as the "EPS Session

[5] As GUTI consists of MME ID and M-TMSI, MME2 can tell which MME has assigned the Old GUTI (see the previous document [7]).

[6] For information about the UE context kept by MME, see 3GPP TS 23.401 [8] 5.7.2.

Establishment procedure" explained in the previous document [3].

IV. EPS Entity Information

The Information elements stored in the EPS entities before and after the “move to Another City” procedure in EMM Case 10 are as follows:

- Before
  - If UE is in Connected state, the same information elements kept after the initial attach procedure [3] are stored.
  - If UE is in Idle state, the same information elements kept after the S1 release procedure [9] are stored.
- After
  - UE is detached from the network. The information elements stored in EPS entities are the same as those kept after the detach procedure [4].

The Information elements stored in the EPS entities before and after the “initial attach in another city” procedure in EMM Case 11 are as follows:

- Before: UE is detached from the network. The same information elements kept after the detach procedure [2] are stored.
- After: UE is attached to the network. The same information elements kept after the initial attach procedure [3] are stored.

V. Closing

This document has discussed how UE moves out of the LTE coverage, and also how the UE makes initial attach to a new MME by using the Old GUTI. The scenario in this document was presented for the purposes of explaining a procedure of initial attach using an old GUTI, instead of IMSI. So, actual procedures in real cases of moving to another city may vary depending on how each operator configures the network, and implements the network nodes. The Korean LTE networks are nation-wide, and thus services are available anywhere in the country, unlike the cases presented in this document. So, LTE coverage hole(s) can be found anywhere with poor radio quality. Besides, there are neighbor cells, LTE or 2G/3G (e.g. CDMA2000, HSPA), everywhere. So, in real networks, UE performs a handover to a neighbor cell or cell reselection, instead of being detached from the network as seen in this document.

This document is the last of our EMM scenario series [1] that cover different EMM procedures in each EMM cases. Next documents will discuss other interesting topics.

References

[1] Netmanias Technical Document, "Eleven EMM Cases in an EMM Scenario", October 2013, http://www.netmanias.com/en/?m=view&id=techdocs&no=6002

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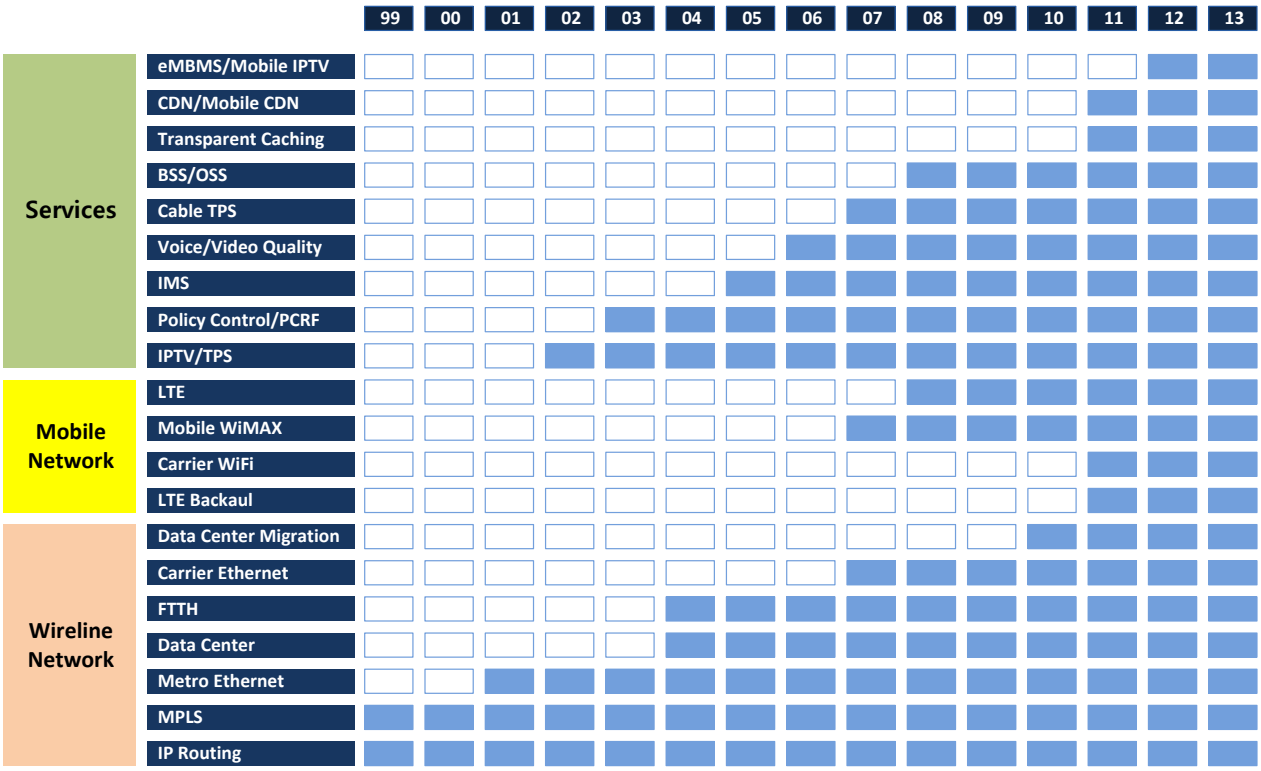

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