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EMM Procedure 4. Service Request

Table of Contents

This document, as the fourth of the EMM Procedure series, will describe the service request procedure as defined as EMM Case 4 in our technical document, "Eleven EMM Cases in an EMM Scenario". This procedure is used when a UE, initially attached to the network but staying inactive in Idle state, wishes to use LTE services again when there is new traffic. We will discuss how E-UTRAN resources are allocated to the UE again through this procedure, establishing an ECM connection (RRC + S1 signaling connections) in the control plane, and an E-RAB (DRB + S1 bearer) in the user plane. We will also look into how information elements in EPS entities are different before and after the procedure.

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Index	Topic	Document Title	Document presented here
1	Network Architecture	LTE Network Architecture: Basic	
2	Identification	LTE Identification I: UE and ME Identifiers	
3		LTE Identification II: NE and Location Identifiers	
4		LTE Identification III: EPS Session/Bearer Identifiers	
5	Security	LTE Security I: LTE Security Concept and LTE Authentication	
6		LTE Security II: NAS and AS Security	
7	QoS	LTE QoS: SDF and EPS Bearer QoS	
8	EMM	LTE EMM and ECM States	
9		Eleven EMM Cases in an EMM Scenario	
10		LTE EMM Procedure 1. Initial Attach - Part 1. Cases of Initial Attach	
11		LTE EMM Procedure 1. Initial Attach - Part 2. Call Flow of Initial Attach	
12		LTE EMM Procedure 2. Detach	
13		LTE EMM Procedure 3. S1 Release	
14		**LTE EMM Procedure 4. Service Request**	**O**
15		LTE EMM Procedure 5. Periodic TAU	
16		LTE EMM Procedure 6. Handover without TAU - Part 1. Overview of LTE Handover	
17		LTE EMM Procedure 6. Handover without TAU - Part 2. X2 Handover	
18		LTE EMM Procedure 6. Handover without TAU - Part 3. S1 Handover	
19		LTE EMM Procedure 7. Cell Reselection without TAU	
20		LTE EMM Procedure 8 & 9. Handover and Cell Reselection with TAU	
21		LTE EMM Procedure 10 & 11. Move to Another City and Attach	
22	PCC	LTE Policy and Charging Control (PCC)	
23	Charging	LTE Charging I: Offline	
24		LTE Charging II: Online (TBD)	
25	IP Address Allocation	LTE IP Address Allocation Schemes I: Basic	
26		LTE IP Address Allocation Schemes II: A Case for Two Cities	

Abbreviations

AKA	Authentication and Key Agreement
AMBR	Aggregated Maximum Bit Rate
APN	Access Point Name
ARP	Allocation Retention Priority
AS	Access Stratum
ASME	Access Security Management Entity
C-RNTI	Cell Radio Network Temporary Identifier
CSG	Closed Subscriber Group
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
EPS-AKA	Evolved Packet System – Authentication and Key Agreement
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
IMSI	International Mobile Subscriber Identity
KSI	Key Set Identifier
LTE	Long Term Evolution
MAC	Message Authentication Code
MME	Mobility Management Entity
NAS	Non Access Stratum
O&M	Operation and Maintenance
PCC	Policy and Charging Control
PCRF	Policy and Charging Rule Function
P-GW	Packet Data Network Gateway
QCI	QoS Class Identifier
RRC	Radio Resource Control
S1AP	S1 Application Protocol
SDF	Service Data Flow
S-GW	Serving Gateway
SPR	Subscriber Profile Repository
S-TMSI	SAE Temporary Mobile Subscriber Identity
TAI	Tracking Area Identity
TEID	Tunnel End Point Identifier
TFT	Traffic Flow Template
UE	User Equipment
UL	Uplink
USIM	Universal Subscriber Identity Module

I. Introduction

This document describes the service request procedure defined as EMM Case 4 in our technical document, "Eleven EMM Cases in an EMM Scenario" [1]. This procedure is performed when an inactive UE in Idle state wishes to get activated to handle traffic when there is new traffic. New user traffic can be uplink traffic from UE or downlink traffic from the network to UE. The UE's E-UTRAN resources (allocated by eNB) have been released, and the UE has been in ECM/RRC-Idle state. Thus, in order for the UE to receive or send user traffic, DL or UL, it needs to transmit to ECM/RRC-Connected state through the service request procedure so that E-UTRAN resources can be allocated again.

This document explains the service request procedure in an LTE network. Chapter II categorizes different cases of service request depending on where new traffic is generated. Chapter III and IV describe distinct procedures required in each service request case. Finally, Chapter V summarizes how information elements in EPS entities are different before and after the procedure.

II. Cases of Service Request

When a UE is still registered at a network, but its S1 connection is released due to inactivity, the UE has no radio resources available. That is, the UE is in **EMM-Registered**, but **ECM-Idle** state. If, at this time, new traffic is generated from the UE, or from the network to the UE, the UE requests the network for services, transmitting to **ECM-Connected** state. Then an ECM connection (RRC + S1 signaling connections) and E-RAB (DRB + S1 bearer) are setup in the control and user planes, respectively, allowing the UE to receive or send traffic. In case the network is sending out traffic to a UE, it first informs the UE of such intent so that the user can request for services.

When the UE has new traffic to send, or learns about the network's intent to send new traffic, it sends the MME a **Service Request** message, transmitting to **ECM/RRC-Connected** state. Then the UE, by using the allocated radio and network resources, can receive or send traffic. Service requests can be triggered by a UE or by a network, and can be categorized as follows depending on where the new traffic is generated:

- **Service Request Case 1: UE-triggered New Traffic**
  When there is uplink data to be sent from UE to the network
- **Service Request Case 2: Network-triggered New Traffic**
  When there is downlink data to be sent from the network to UE

Figure 1 shows the connections established in the user and control planes, and the states of UE and MME, before and after the service request is made. Before the service request, the user is in **EMM-Registered** and **ECM/RRC-Idle** state. Thus, only the resources allocated by EPC are kept unreleased while those allocated by E-UTRAN are already released. In the control plane, S5 GTP-C and S11 GTP-C tunnels remain active while the ECM connection is lost. In the user plane, the S5 bearer and the uplink S1 bearer are kept active while the downlink S1 bearer and the DRB are released.

After the service request, the UE, now with the allocated E-UTRAN resources, is in **EMM-Registered** and **ECM/RRC-Connected**. Also, we can see all of the bearers and connections in the EPS bearer (i.e. DRB, S1

bearer and S5 bearer) and the signaling connection (i.e. ECM connection, S11 GTP-C and S5 GTP-C tunnels) are now established to support traffic delivery between the UE and the network (UE through P-GW).

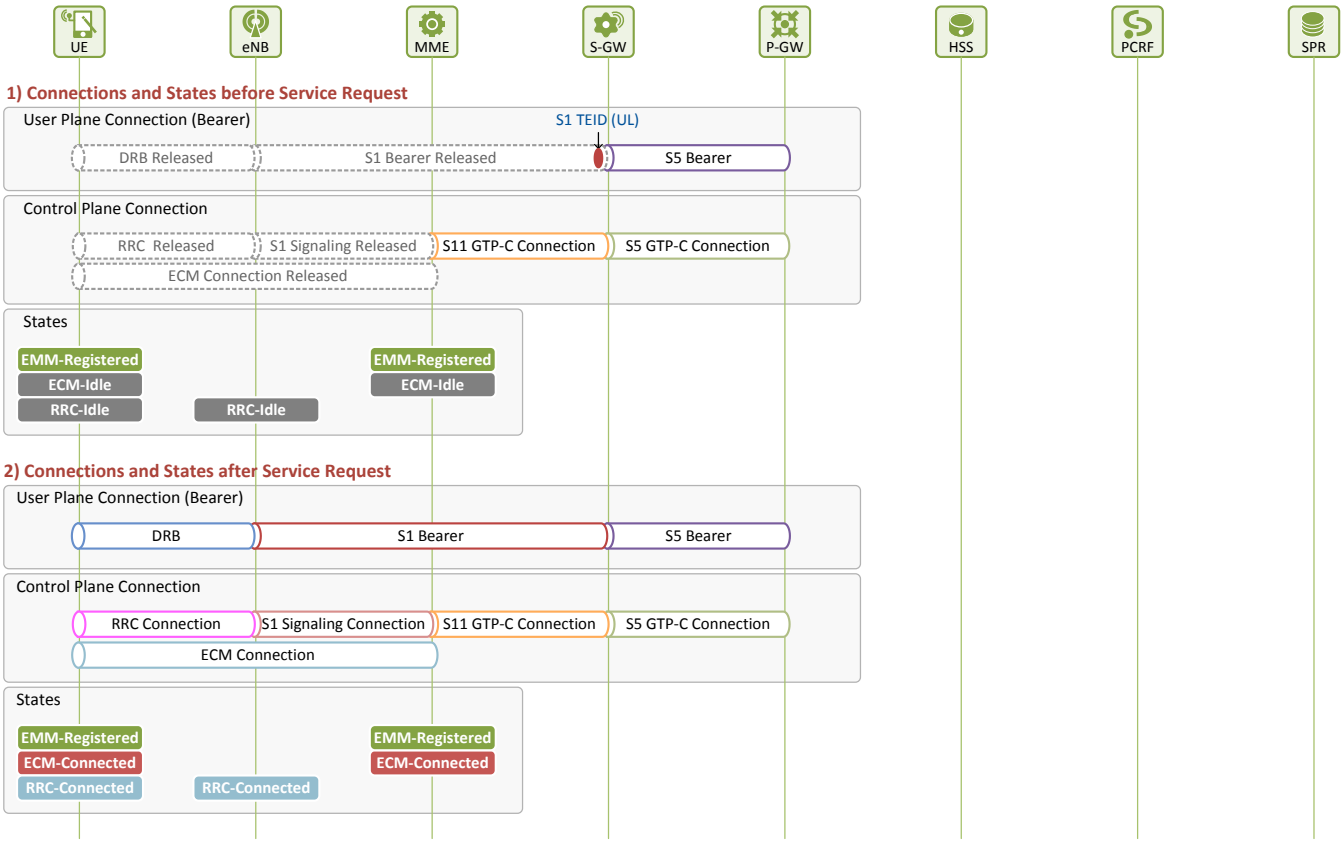

Figure 1. Connections and States before/after Service Request

III. UE-triggered Service Request

Figures 2 and 3 illustrate procedures for a UE-triggered service request caused by uplink traffic from UE. The NAS layer at the UE indicates to the MME that the UE has data to send out by sending a **Service Request** message. As a result, resources required for data transmission are allocated from the network. As the UE has stayed registered at the network, its NAS security context (K_{NASenc}, K_{NASint}, etc.) is kept valid at the UE and MME. With the context, the UE can send the **Service Request** as encrypted with the encryption key (K_{NASenc}), and integrity-protected with the integrity key (K_{NASint}). When the MME receives the message, it determines whether to perform authentication procedures for the user or not through integrity check and decryption of the message, and then the eNB establishes an E-RAB.

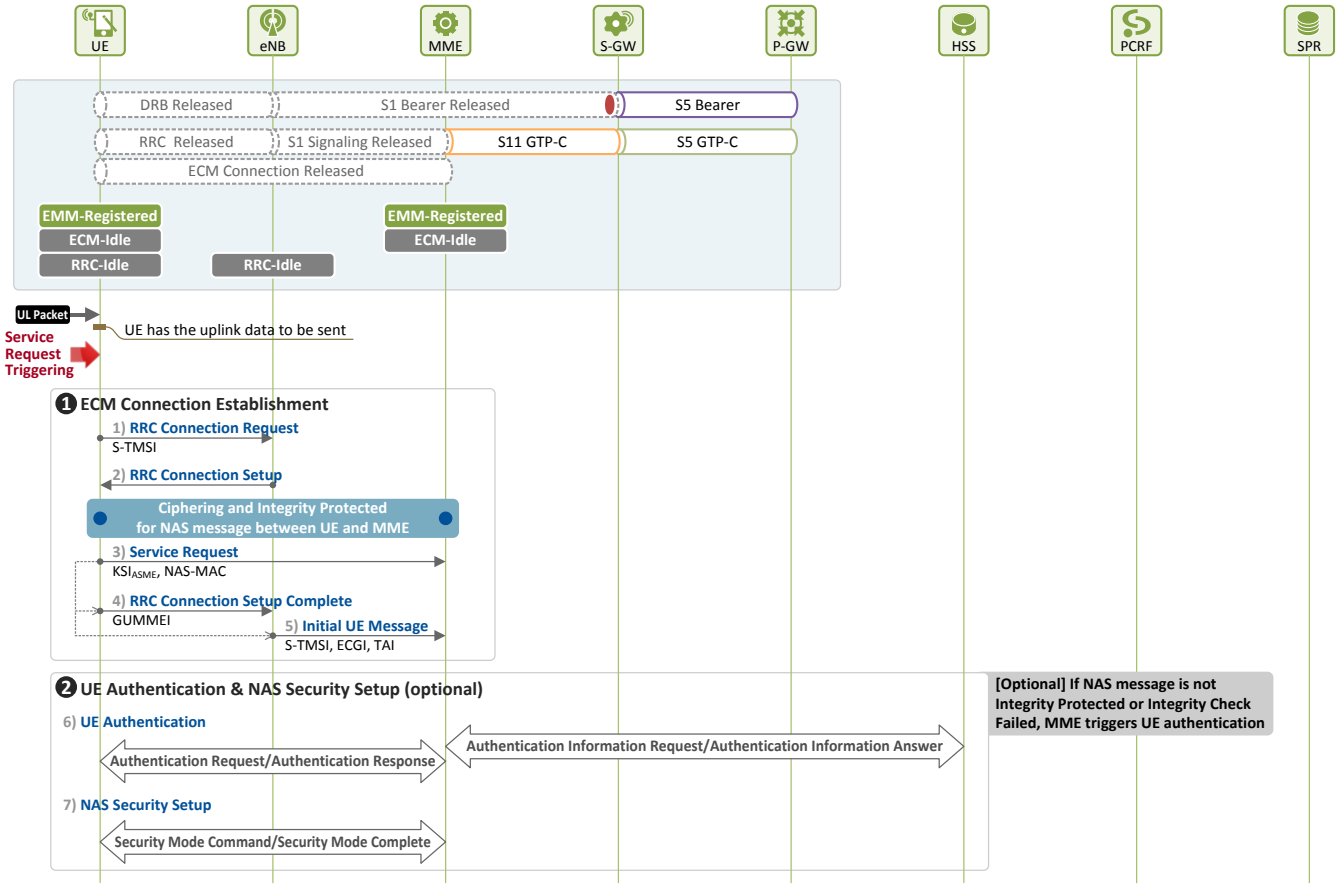

Figure 2. Procedures for UE-triggered Service Request (1)

1 ECM Connection Establishment

When there is new traffic to send out, the UE sends the MME a **Service Request** message to establish an ECM connection. The **Service Request** message is delivered to the MME, through RRC connection established over radio link, and then through S1 signaling connection established between the eNB and the MME. In this document, we assume that a valid GUTI and NAS security context are kept at the UE and MME.

1), 2) [UE – eNB] RRC Connection Setup

The NAS layer at the UE provides the RRC layer with S-TMSI. Then the RRC layer, by using this S-TMSI as a UE ID, sends a **RRC Connection Request** message to the eNB to set up RRC connection. The eNB returns a **RRC Connection Setup** message to the UE (see our document, Initial Attach [2] for more information).

3), 4), 5) [UE → MME] ECM Connection Setup Request

The NAS layer at the UE sends a **Service Request** message to the MME to set up an ECM connection. The NAS security context associated with the UE has already been stored at the UE and MME. Thus, the message includes the NAS base key identifier (KSI_{ASME}), and is sent encrypted with the encryption key K_{NASenc} and integrity-protected with the integrity key (NAS_{int}). This **Service Request** message is delivered to the eNB as included in a **RRC Connection Setup Complete** message over the radio link between the UE and eNB. Then it is sent as included in a S1AP message, **Initial UE Message**, from the eNB to the MME. At this time, the eNB allocates eNB UE S1AP ID, and includes it in the **Initial UE**

Message sent to the MME. Upon receiving the **Initial UE Message**, the MME allocates MME S1AP UE ID, and establishes an S1 signaling connection between the eNB and itself.

❷ UE Authentication and NAS Security Setup (Optional)

6) [UE – MME – HSS] UE Authentication

After receiving the **Service Request** message from the UE, the MME performs integrity check on NAS-MAC. If the check passes, the MME can use the current NAS security context in transmitting NAS messages, without having to authenticate the UE again. However, if it fails, the MME performs authentication procedures for the UE through EPS-AKA[1].

7) [UE – MME] NAS Security Setup

When the authentication is completed, both the UE and the MME generate the NAS security keys (K_{NASenc}, K_{NASint}) to be used in delivering NAS messages, through the NAS security setup procedure.

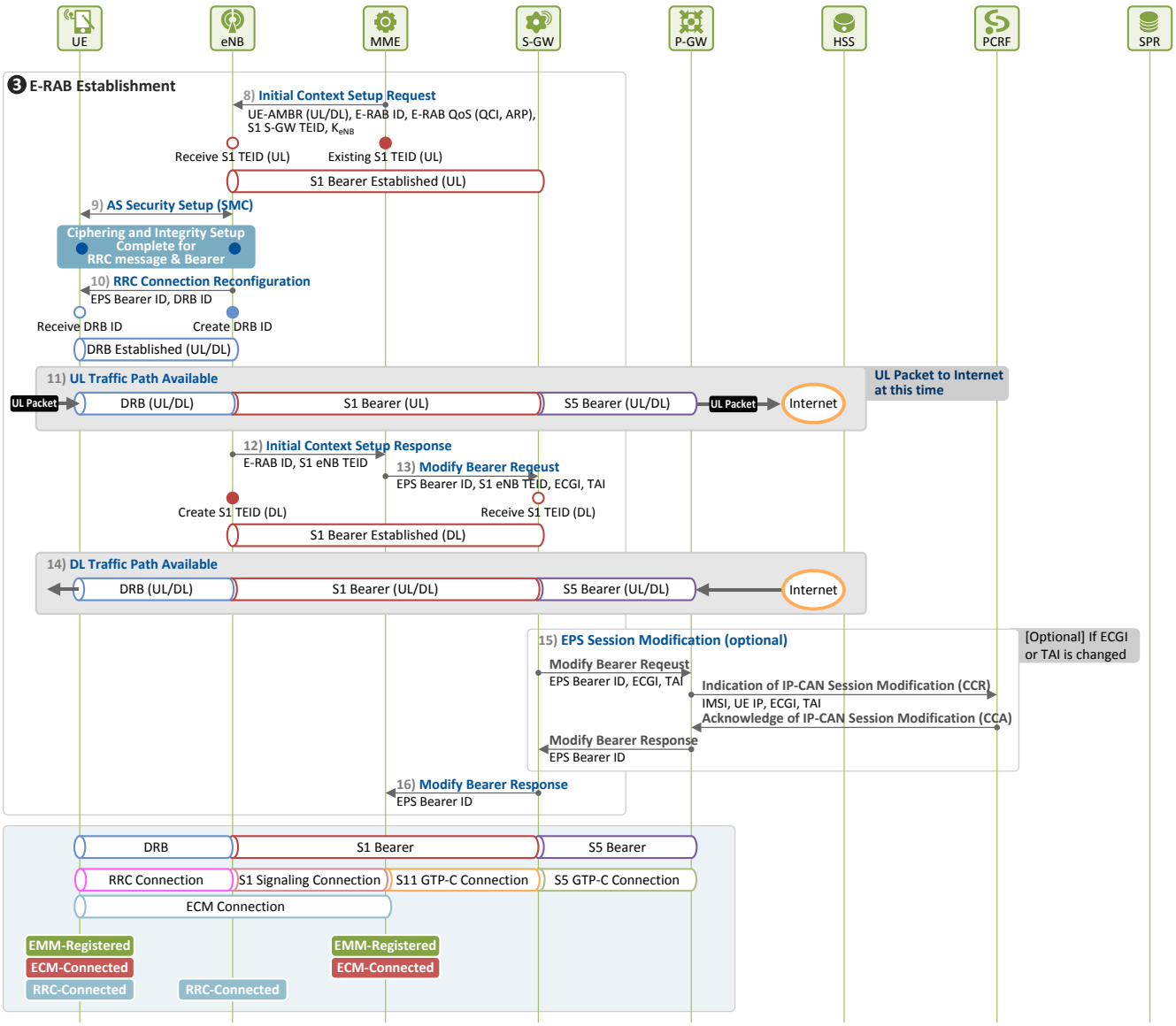

Figure 3. Procedures for UE-triggered Service Request (2)

[1] MME obtains authentication vectors for UE from HSS, and performs user authentication with the UE on behalf of the HSS. See our LTE Security document [3] for detailed procedures.

❸ E-RAB Establishment

After receiving the **Service Request** message from the UE, the MME has the eNB establish a DRB and a downlink S1 bearer through E-RAB establishment procedures.

8) [eNB ← MME] Requesting E-RAB Establishment

Upon receiving the **Service Request** message from the UE, the MME realizes that an E-RAB has to be established. So, it sends the eNB an **Initial Context Setup Request** message so that the eNB can set up an S1 bearer with the S-GW, and a DRB with the UE. At this time, the message includes the following information:

Initial Context Setup Request (E-RAB ID, K_{eNB}, S1 S-GW TEID, MME UE S1AP ID)

- **E-RAB ID**
- **K_{eNB}**: the AS Security base key that enables eNB to set up AS Security with UE
- **S1 S-GW TEID**: identifies the uplink S1 bearer connected to S-GW for eNB
- **MME UE S1AP ID**: identifies the S1 signaling connection to MME for eNB

9) [UE – eNB] AS Security Setup

After receiving the **Initial Context Setup Request** message from the MME, the eNB realizes that DRB and S1 bearer setup has to be performed in order for user traffic to be delivered. Before establishing a DRB, the eNB performs AS security setup procedures for secured communication with the UE through the SRB and DRB over the radio link (see our "LTE Security" document [3] for more information). The UE and the eNB derive K_{RRCint}/K_{RRCenc} to be used for integrity/encryption, and K_{UPenc} to be used for user traffic encryption, through the AS security setup procedures.

After the AS security setup is completed successfully, RRC messages to be delivered through the radio link are sent encrypted and integrity-protected, and user traffic is sent encrypted. Next, the eNB begins DRB establishment.

10) [UE ← eNB] DRB Establishment

The eNB allocates a DRB ID to create a DRB, an EPS bearer over the radio link, and sends a **RRC Connection Reconfiguration** message to the UE after configuring DRB QoS parameters for the message based on E-RAB QoS received from the MME. The UE, upon receiving the **RRC Connection Reconfiguration** message from the eNB, generates a DRB and SRB2.

11) UL Traffic Path Available

Once a DRB is generated after Step 10), an uplink EPS bearer is set up from the UE all the way through the P-GW, allowing delivery of UE-generated uplink traffic.

12) 13) & 16) [eNB → S-GW] Setting up Downlink S1 Bearer

In Step 12), the eNB allocates a downlink S1 TEID (S1 eNB TEID) for the S1 bearer, and forwards to the MME by including the ID in an **Initial Context Setup Response** message to be sent as a response to the **Initial Context Setup Request** it received in Step 8). In Step 13), the MME delivers an S1 eNB TEID as included in a **Modify Bearer Request** message to the S-GW, which establishes a downlink S1 bearer using the information. Then in Step 16), the S-GW informs the MME the establishment of the downlink S1 bearer through a **Modify Bearer Response** message.

14) DL Traffic Path Available

Once Step 13) is performed, a downlink S1 GTP-U tunnel from the S-GW to the eNB is created,

completing establishment of a downlink EPS bearer (all the bearers in the downlink) from the P-GW through the UE. This allows delivery of downlink traffic to the UE.

15) Modifying EPS Session (UE Location Registration)

In case the UE's current cell (ECGI) or TA has been changed at the time of service request, the S-GW sends the P-GW to inform such change. Then, the P-GW reports the same to the PCRF through EPS session medication procedure.[2]

IV. Network-triggered Service Request

Figures 4 and 5 display procedures for a network-triggered service request procedure. This type of request is made when the network has downlink traffic to deliver to a UE in Idle state. The MME does not know the location of a UE which is in Idle state. So, it has to inform it has traffic to send to the UE through paging procedures, so that the bearer (E-RAB) resources that have been released can be established again.

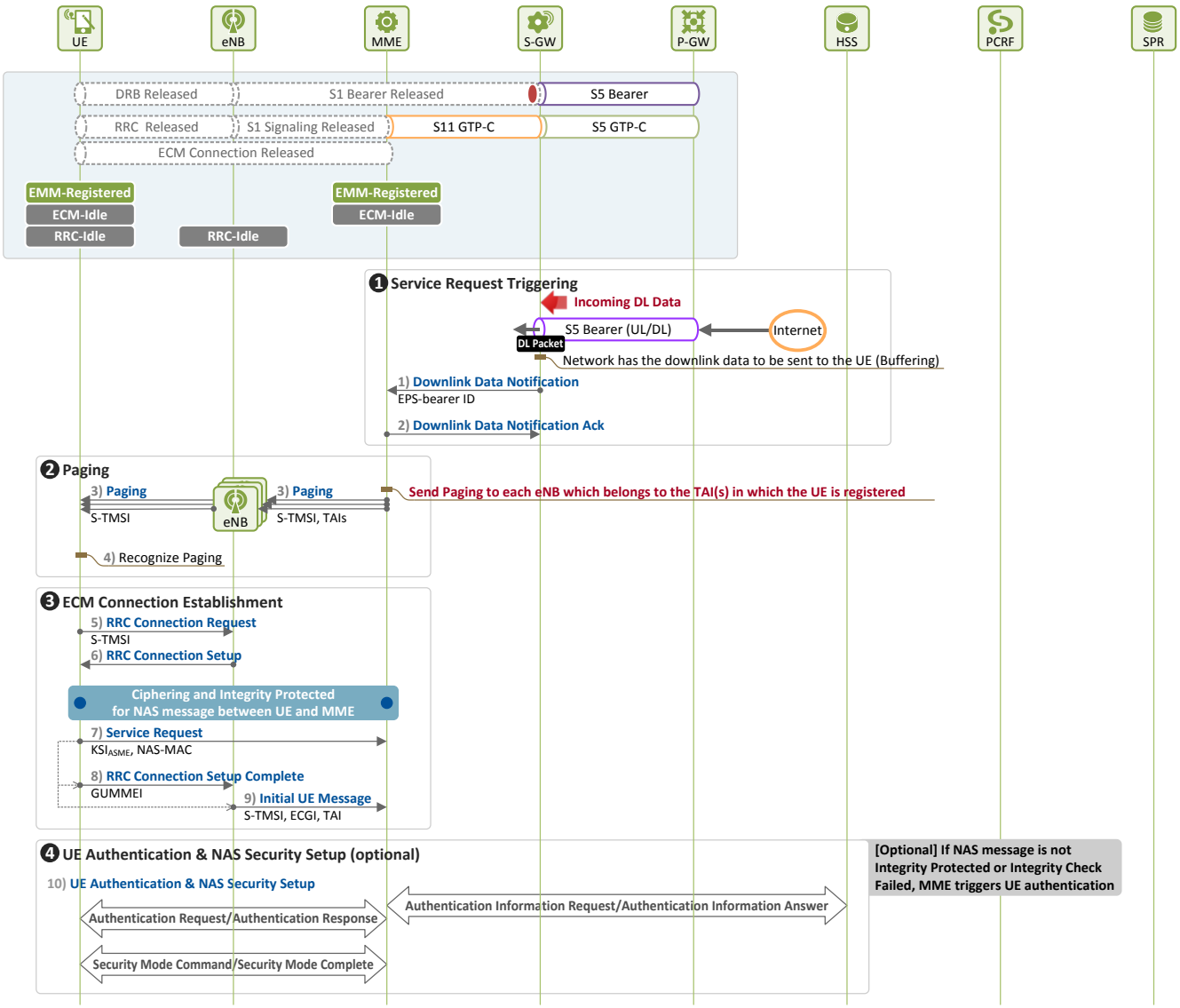

Figure 4. Procedures for Network-triggered Service Request (1)

[2] 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 [2].

❶ **Service Request Triggering**

If the S-GW receives downlink data packets from the P-GW through the S5 bearer, but cannot send them on to the eNB because the downlink S1 bearer is released (i.e. the S-GW does not have an S1 eNB TEID), it buffers the packets, and finds out at which MME the UE is registered.

Then, the S-GW sends a **Downlink Data Notification** message to the MME to inform signaling connections and bearers need to be established for the UE.

❷ **Paging**

The MME knows the UE is located in one of its TAs, but does not know in which cell the UE is. So, the MME sends a **Paging** message to all the eNBs in the TA the UE was in last time. The eNBs then broadcast the received **Paging** message, through its PCH (Paging Channel), so that the UE can receive it during its regular monitoring on the PCH.

❸ **ECM Connection Establishment**

Becoming aware of incoming traffic, the UE sends a **Service Request** message, to establish an ECM connection. The procedure for ECM connection establishment begins when the UE accesses a cell through the radio access channel, and then sends an **RRC Connection Request** message to establish an RRC connection. It is performed as illustrated in Figure 2 (see detailed description given under Figure 2 for more information about ECM connection establishment).

❹ **UE Authentication and NAS Security Setup (Optional)**

The MME, upon receiving the **Service Request** message from the UE, performs UE authentication procedures through EPS-AKA, and generates NAS security keys (NAS_{int}, NAS_{enc}) through NAS security setup procedures if the integrity check on NAS-MAC failed (see our LTE Security document [3] for detailed procedures).

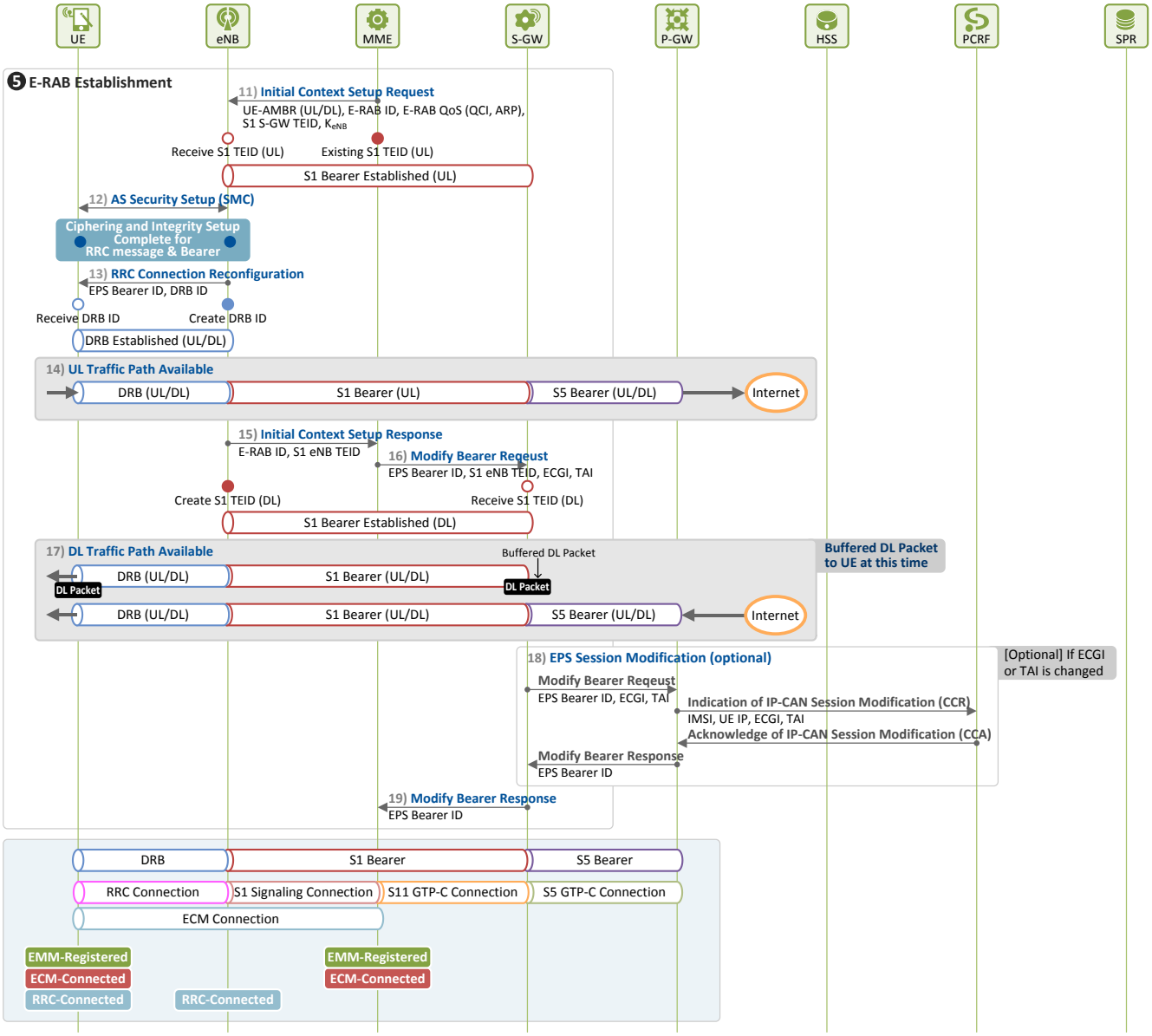

Figure 5. Procedures for Network-triggered Service Request (2)

❺ E-RAB Establishment

After receiving the **Service Request** message from the UE, the MME establishes a DRB and downlink S1 bearer through E-RAB establishment procedures. Then, it is ready to receive data packets form the S-GW. The detailed procedures are the same as seen in Figure 3.

V. EPS Entity Information: Before/After Service Request

This chapter looks into how information elements in the EPS entities are changed before and after the service request. All the information elements are categorized into UE ID, UE Location, Security, and EPS Session/Bearer information.

5.1 Before Service Request

As explained in the EMM scenario document [1], before a service request is triggered, a UE transits from Active state to **EMM-Registered** and **ECM/RRC-Idle** state through S1 release. Therefore, all the information in the EPS entities after S1 release remain the same until the service request procedure is performed [4]. 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 service request is triggered are marked in black.

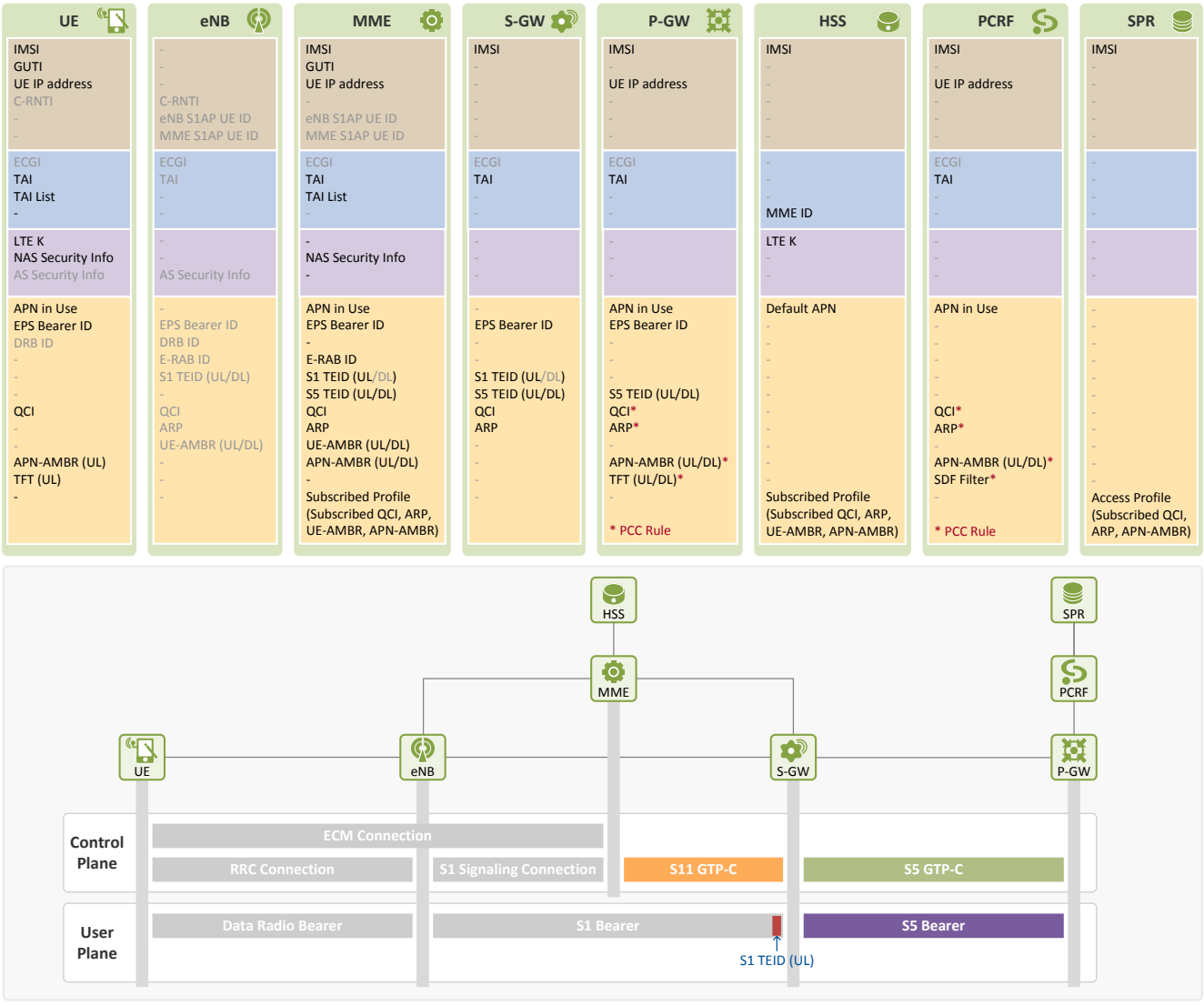

Figure 6. Information in EPS entities before Service Request

5.2 After Service Request

Once a service request is completed, a UE transits to **ECM/RRC-Connected** state, and an RRC connection/S1 signaling and E-RAB bearer (DRB + downlink S1 bearer) are established by E-UTRAN. As a result, all the information required for user traffic delivery between UE and P-GW is stored in EPS entities. Figure 7 lists information elements stored in each EPS entity after a service request is completed. These elements are the same as those stored after initial attach [2].

UE	eNB	MME	S-GW	P-GW	HSS	PCRF	SPR
IMSI	-	IMSI	IMSI	IMSI	IMSI	IMSI	IMSI
GUTI	-	GUTI	-	-	-	-	-
UE IP address	-	UE IP address	-	UP IP address	-	UE IP address	-
C-RNTI	C-RNTI	-	-	-	-	-	-
-	eNB S1AP UE ID	eNB S1AP UE ID	-	-	-	-	-
-	MME S1AP UE ID	MME S1AP UE ID	-	-	-	-	-
ECGI	ECGI	ECGI	ECGI	ECGI	-	ECGI	-
TAI	TAI	TAI	TAI	TAI	-	TAI	-
TAI List	-	TAI List	-	-	-	-	-
-	-	-	-	-	MME ID	-	-
LTE K	-	-	-	-	LTE K	-	-
NAS Security Info	-	NAS Security Info	-	-	-	-	-
AS Security Info	AS Security Info	-	-	-	-	-	-
APN in Use	-	APN in Use	-	APN in Use	Default APN	APN in Use	-
EPS Bearer ID	EPS Bearer ID	EPS Bearer ID	EPS Bearer ID	EPS Bearer ID	-	-	-
DRB ID	DRB ID	-	-	-	-	-	-
-	E-RAB ID	E-RAB ID	-	-	-	-	-
-	S1 TEID (UL/DL)	S1 TEID (UL/DL)	S1 TEID (UL/DL)	-	-	-	-
-	-	S5 TEID (UL/DL)	S5 TEID (UL/DL)	S5 TEID (UL/DL)	-	-	-
QCI	QCI	QCI	QCI	QCI*	-	QCI*	-
-	ARP	ARP	ARP	ARP*	-	ARP*	-
-	UE-AMBR (UL/DL)	UE-AMBR (UL/DL)	-	-	-	-	-
APN-AMBR (UL)	-	APN-AMBR (UL/DL)	-	APN-AMBR (UL/DL)*	-	APN-AMBR (UL/DL)*	-
TFT (UL)	-	-	-	TFT (UL/DL)*	-	SDF Filter*	
-	-	Subscribed Profile	-	-	Subscribed Profile	-	Access Profile
		(Subscribed QCI, ARP,			(Subscribed QCI, ARP,		(Subscribed QCI,
		UE-AMBR, APN-AMBR)		* PCC Rule	UE-AMBR, APN-AMBR)	* PCC Rule	ARP, APN-AMBR)

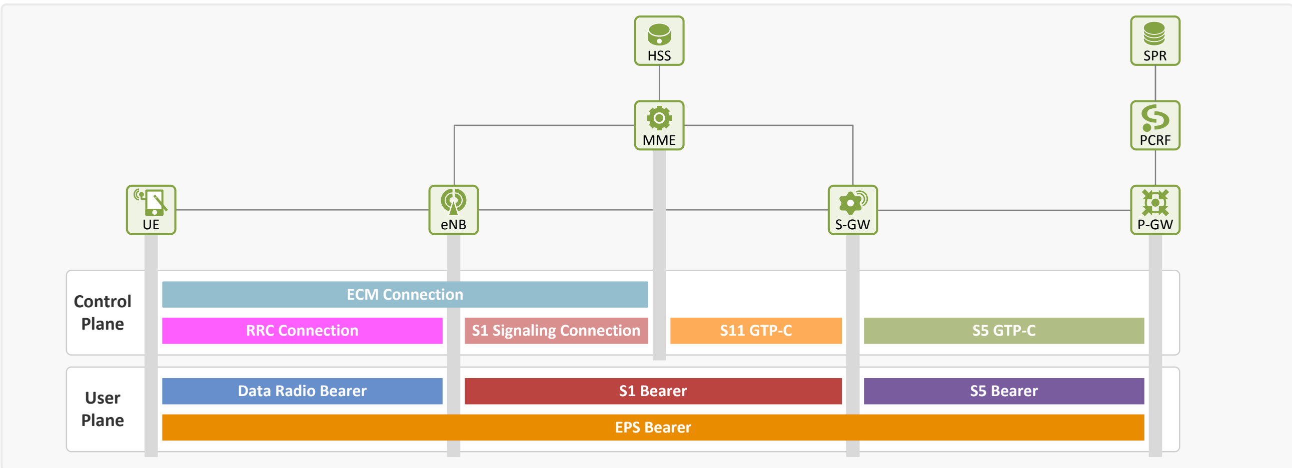

Figure 7. Information in EPS entities after Service Request

VI. Closing

In this document, we have learned the service request procedure ("EMM Case 4" in [1]) required for re-allocation of E-UTRAN (eNB) resources as new traffic arrives to a UE which has stayed in Idle state in the network it accessed. We have also summarized the user information elements that are stored in EPS entities when an end-to-end EPS bearer is established through a service request procedure. When a UE transits to Idle state while still being registered at the network, its EPC resources are kept, but E-UTRAN resources are released. Thus, a DRB has to be re-established as in attach request. However, in case of an S1 bearer, only a downlink S1 bearer needs to be re-established unlike attach request, allowing faster traffic delivery. The subsequent document will discuss procedures required when a UE in Idle state performs Tracking Area Updates (TAUs) regularly ("EMM Case 5: Periodic TAU" in [1]).

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

[2] Netmanias Technical Document, "LTE EMM Procedure 1. Initial Attach – Part 2. Call Flow of Initial Attach", January 2014, http://www.netmanias.com/en/?m=view&id=techdocs&no=6102

[3] Netmanias Technical Document, "LTE Security II: NAS and AS Security", August 2013, http://www.netmanias.com/en/?m=view&id=techdocs&no=5903

[4] Netmanias Technical Document, "LTE EMM Procedure 3. S1 Release", January 2014, http://www.netmanias.com/en/?m=view&id=techdocs&no=6110

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

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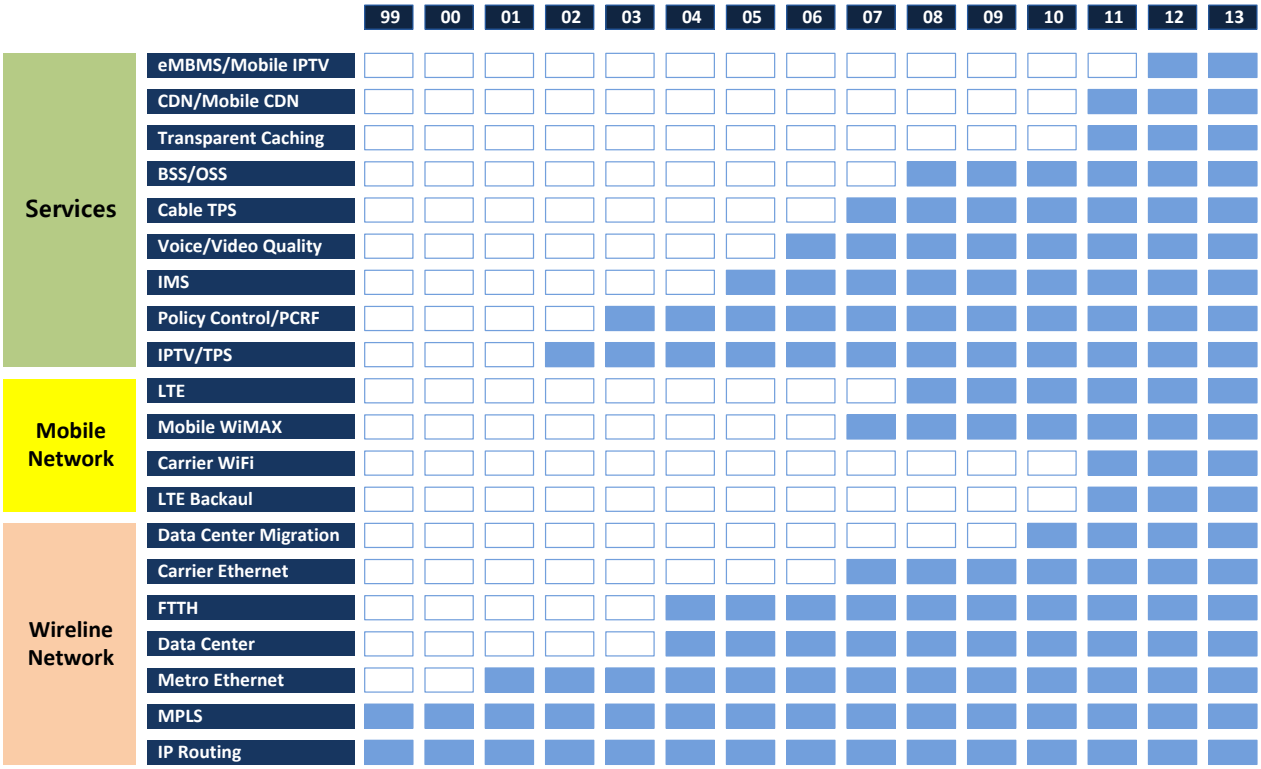

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