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# LTE EMM and ECM States

January 23, 2013

(Last Updated: September 20, 2013)

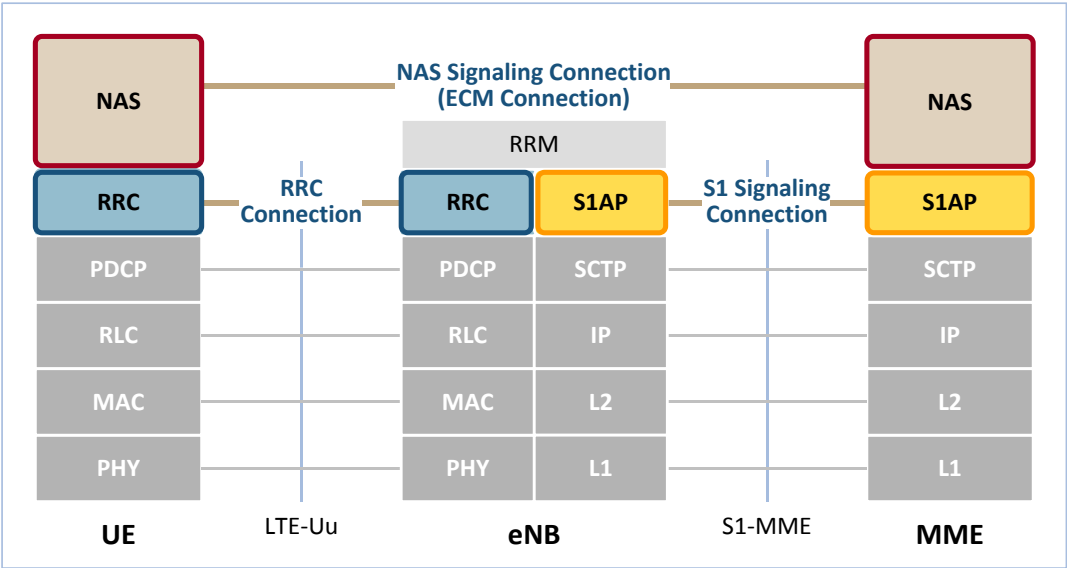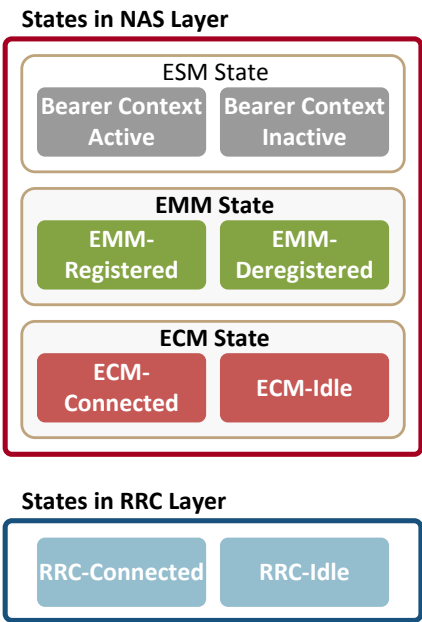**NMC Consulting Group (tech@netmanias.com)**

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# Type of EMM Procedures

- EMM Common Procedure: Procedures which can always be initiated whilst a NAS signalling connection exists
- EMM Specific Procedure: Procedures related to user mobility (Registration and Location Update)
- EMM Connection Management Procedure: Procedures related to establishing a NAS signalling connection
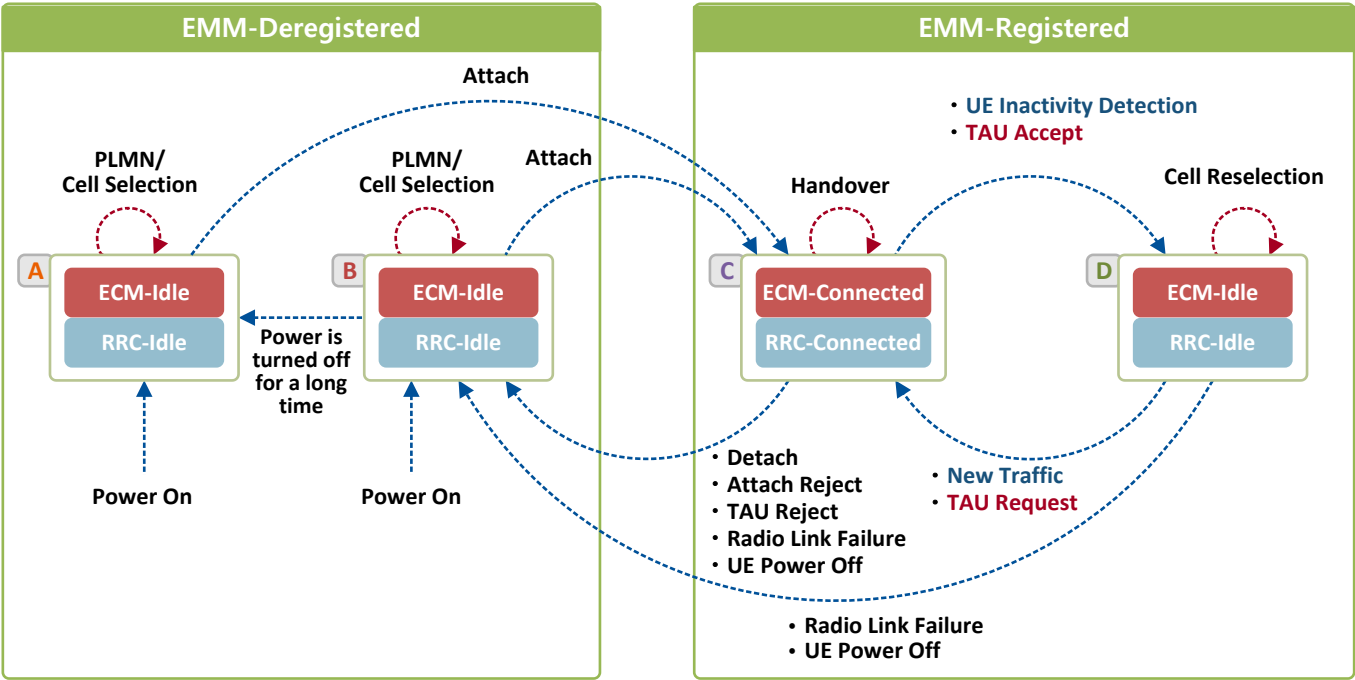
## Types of EMM Procedures

| Type | EMM Procedures | Initiator | The initiator will: |
|---|---|---|---|
| EMM Common Procedure | GUTI Allocation | Network | Allocate a GUTI and provide a new TAI list to a UE. |
| | Authentication | Network | Through EPS-AKA procedure, perform mutual authentication between user and network, and agree on a key $K_{ASME}$. |
| | Security Mode Control | Network | Initialize NAS signalling security between UE and MME with EPS NAS keys and EPS security algorithms. |
| | Identification | Network | Request a UE for IMSI or IMEI. |
| | EMM Information | Network | Support network identity and time zone (NITZ). Network optionally sends network name and time information to a UE. |
| EMM Specific Procedure | Attach | UE | Attach IMSI in network, and establish an EMM context and a default bearer. |
| | Detach | UE or Network | Detach the IMSI in the network, to release an EMM context and all bearers. |
| | Tracking Area Update | UE | At normal TAU, have the network update the registration of the actual TA of a UE.<br>At periodic TAU, periodically notify the availability of the UE. |
| EMM Connection Management Procedure | Service Request | UE | Establish a secure connection to network, and request resource reservation for sending data. |
| | Paging | Network | Request a NAS signalling connection establishment, and prompt UE to re-attach . |
| | Transport of NAS Message | UE or Network | |

# EMM/ECM/RRC State

**States in NAS Layer**

ESM State
| Bearer Context Active | Bearer Context Inactive |

**EMM State**
| EMM-Registered | EMM-Deregistered |

**ECM State**
| ECM-Connected | ECM-Idle |

**States in RRC Layer**
| RRC-Connected | RRC-Idle |

| NAS | **NAS Signaling Connection (ECM Connection)** | NAS |

RRM

| RRC | **RRC Connection** | RRC | S1AP | **S1 Signaling Connection** | S1AP |

| PDCP | | PDCP | SCTP | | SCTP |
| RLC | | RLC | IP | | IP |
| MAC | | MAC | L2 | | L2 |
| PHY | | PHY | L1 | | L1 |

**UE**  LTE-Uu  **eNB**  S1-MME  **MME**

| Layer | State | Entity | Description |
|-------|-------|--------|-------------|
| EMM | EMM-Deregistered | UE, MME | UE is not attached to any LTE network and no EMM context has been established in the UE and MME. The MME does not know the current location of the UE, but may have tracking area (TA) information last reported by the UE. |
| | EMM-Registered | UE, MME | UE has been attached to the LTE network and an IP address has been assigned to the UE. An EMM Context has been established and a default EPS bearer context has been activated in the UE and MME. The MME knows the current location of UE with an accuracy of a cell or, at least, a tracking area. |
| ECM | ECM-Idle | UE, MME | No NAS signalling connection (ECM connection) is established yet. The UE has not been assigned physical resources, i.e. radio resources (SRB/DBR) and network resources (S1 bearer/S1 signalling connection) yet. |
| | ECM-Connected | UE, MME | A NAS signalling connection (ECM connection) is established. The UE has been assigned physical resources, i.e. radio resources (SRB/DRB) and network resources (S1 bearer/S1 signalling connection). The ECM connection consists of an RRC connection and an S1 signalling connection. |
| RRC | RRC-Idle | UE, eNB | No RRC is established yet. |
| | RRC-Connected | UE, eNB | An RRC connection has been established. |

# EMM State Transition



| Case | State | User Experience (Example) |
|------|-------|---------------------------|
| **A** | EMM-Deregistered + ECM-Idle + RRC-Idle | • When a UE is switched on for the first time after subscription<br>• When a UE is switched on after staying turned off for a long time<br>• No UE context in the UE and MME. |
| **B** | EMM-Deregistered + ECM-Idle + RRC-Idle | • When a UE is switched on within a certain period of time after being turned off<br>• When ECM connection is lost during communication due to radio link failure<br>• Some UE context from the last attach can still be stored in the UE and MME (e.g., to avoid running an AKA procedure during every Attach procedure). |
| **C** | EMM-Registered + ECM-Connected + RRC-Connected | • When a UE is attached to network (an MME) and is using services (e.g., Internet, VoD, Live TV ..)<br>• The mobility of a UE is handled by a handover procedure. |
| **D** | EMM-Registered + ECM-Idle + RRC-Idle | • When a UE is attached to network (an MME), but not using any service<br>• The mobility of a UE is handled by a cell reselection procedure. |

# EMM Features (1) – UE Location Information

## UE Location Information Set in Each EPS Entity

| Case | State | UE | eNB | S-GW | P-GW | MME | HSS | PCR | SPR |
|------|-------|----|----|------|------|-----|-----|-----|-----|
| A | EMM-Deregistered + ECM-Idle + RRC-Idle | - | - | - | - | - | - | - | - |
| B | EMM-Deregistered + ECM-Idle + RRC-Idle | Last Visited TAI | - | - | - | TAI of Last TAU | MME ID | - | - |
| C | EMM-Registered + ECM-Connected + RRC-Connected | ECGI, TAI | ECGI, TAI | ECGI, TAI of Last TAU | ECGI, TAI of Last TAU | ECGI, TAI of Last TAU | MME ID | ECGI | - |
| D | EMM-Registered + ECM-Idle + RRC-Idle | - | - | TAI of Last TAU | TAI of Last TAU | TAI of Last TAU | MME ID | TAI of Last TAU | - |

# EMM Features (2) – EPS Bearer and NAS Signalling Connection Information

## EPS Bearer and NAS Signalling Connection Information

| Case | State | EPS Bearer | | | NAS Signalling Connection (= ECM Connection) | | S11 Signalling Conn. (MME – SGW) | S5 Signalling Conn. (SGW – PGW) |
|------|-------|------------|--|--|-----------------------------------------------|--|----------------------------------|----------------------------------|
| | | Radio Bearer (UE – eNB) | S1 Bearer (eNB – SGW) | S5 Bearer (SGW – PGW) | RRC Conn. (UE – eNB) | S1 Conn. (eNB – MME) | | |
| A | EMM-Deregistered + ECM-Idle + RRC-Idle | - | - | - | - | - | - | - |
| B | EMM-Deregistered + ECM-Idle + RRC-Idle | - | - | - | Established | Established | - | - |
| C | EMM-Registered + ECM-Connected + RRC-Connected | Established | Established | Established | Established | Established | Established | Established |
| D | EMM-Registered + ECM-Idle + RRC-Idle | - | - | Established | - | - | Established | Established |
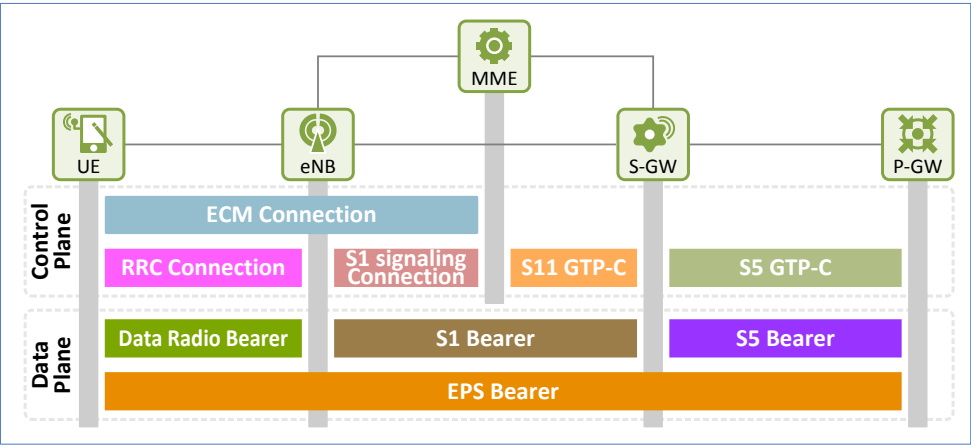


State C (EMM-Registered + ECM-Connected + RRC-Connected)
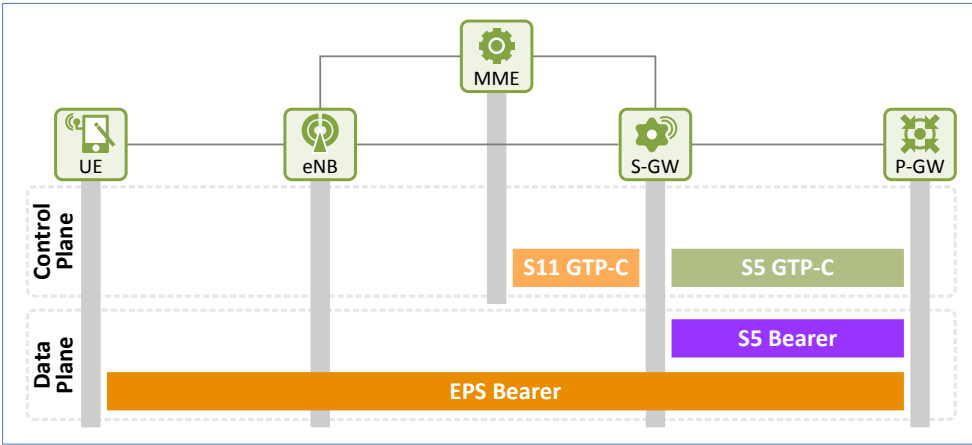
State D (EMM-Registered + ECM-Idle + RRC-Idel)

# EMM Features (3) – Mobility Information

## Features Related to User Mobility

| Case | State | Mobility | Tracking Area Update | Paging |
|------|-------|----------|----------------------|--------|
| A | EMM-Deregistered + ECM-Idle + RRC-Idle | • PLMN/Cell Selection | - | - |
| B | EMM-Deregistered + ECM-Idle + RRC-Idle | • PLMN/Cell Selection | - | - |
| C | EMM-Registered + ECM-Connected + RRC-Connected | • Handover:<br>- Intra-eNB handover<br>- X2 Handover<br>- S1 Handover | • TAU when TA is changed | - |
| D | EMM-Registered + ECM-Idle + RRC-Idle | • Cell Reselection | • TAU when TA is changed<br>• Periodic TAU | • Paging Control |

# EMM Features (4) – UE ID Information

## UE IDs Set in Each EPS Entity

| Case | State | UE | eNB | S-GW | P-GW | MME | HSS | PCR | SPR |
|------|-------|-----|-----|------|------|-----|-----|-----|-----|
| A | EMM-Deregistered + ECM-Idle + RRC-Idle | IMSI | - | - | - | - | IMSI | - | IMSI |
| B | EMM-Deregistered + ECM-Idle + RRC-Idle | IMSI, GUTI | - | - | - | IMSI, GUTI | IMSI | - | IMSI |
| C | EMM-Registered + ECM-Connected + RRC-Connected | IMSI, GUTI, UE IP addr., C-RNTI | C-RNTI, eNB/MME UE S1AP ID, Old/New eNB UE X2AP ID | IMSI | IMSI, UE IP addr. | IMSI, GUTI, UE IP addr., eNB/MME UE S1AP ID | IMSI | IMSI, UE IP addr. | IMSI |
| D | EMM-Registered + ECM-Idle + RRC-Idle | IMSI, GUTI, UE IP addr. | - | IMSI | IMSI, UE IP addr. | IMSI, GUTI, UE IP addr. | IMSI | IMSI, UE IP addr. | IMSI |

# EPS Entity Information Set in State A

**State A: EMM-Deregistered + ECM-Idle + RRC-Idle**

| UE | eNB | S-GW | P-GW | MME | HSS | PCRF | SPR |
|---|---|---|---|---|---|---|---|
| IMSI | - | - | - | - | IMSI | - | IMSI |
| LTE K | - | - | - | - | LTE K | - | - |
| APN | - | - | - | - | Default APN | - | - |
| - | - | - | - | - | EPS QoS Subscribed Profile | - | - |
| - | - | - | - | - | - | - | Access Profile |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |

# EPS Entity Information Set in State B

**State B: EMM-Deregistered + ECM-Connected + RRC-Connected**

| UE | eNB | S-GW | P-GW | MME | HSS | PCRF | SPR |
|---|---|---|---|---|---|---|---|
| IMSI | - | - | - | IMSI | IMSI | - | IMSI |
| LTE K | - | - | - | - | LTE K | - | - |
| APN | - | - | - | Default APN | Default APN | - | - |
| - | - | - | - | EPS QoS Subscribed Profile | EPS QoS Subscribed Profile | - | - |
| - | - | - | - | - | - | - | Access Profile |
| GUTI | - | - | - | GUTI | - | - | - |
| Last Visited TAI | - | - | - | TAI of Last TAU | - | - | - |
| NAS Security Context | - | - | - | NAS Security Context | - | - | - |
| - | - | - | - | - | MME ID | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | Used UE-AMBR (UL/DL) | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |

# EPS Entity Information Set in State C

## State C: EMM-Registered + ECM-Connected + RRC-Connected

| UE | eNB | S-GW | P-GW | MME | HSS | PCRF | SPR |
|---|---|---|---|---|---|---|---|
| IMSI | - | IMSI | IMSI | IMSI | IMSI | IMSI | IMSI |
| LTE K | - | - | - | - | LTE K | - | - |
| APN in Use | - | - | APN in Use | APN in Use | Default APN | APN in Use | - |
| - | - | - | - | EPS QoS Subscribed Profile | EPS QoS Subscribed Profile | - | - |
| - | - | - | PCC Rule | - | - | PCC Rule | Access Profile |
| GUTI | - | - | - | GUTI | - | - | - |
| TAI | TAI | TAI of Last TAU | TAI of Last TAU | TAI of Last TAU | - | TAI of Last TAU | - |
| NAS Security Context | - | - | - | NAS Security Context | - | - | - |
| - | - | - | - | - | MME ID | - | - |
| TAL List | - | - | - | TAI List | - | - | - |
| UE IP address | - | - | UE IP address | UE IP address | - | UE IP address | - |
| C-RNTI | C-RNTI | - | - | - | - | - | - |
| ECGI | ECGI | ECGI | ECGI | ECGI | - | ECGI | - |
| AS Security Context | AS Security Context | - | - | - | - | - | - |
| - | Used UE-AMBR (UL/DL) | - | - | Used UE-AMBR (UL/DL) | - | - | - |
| Used APN-AMBR (UL) | - | - | Used APN-AMBR (UL/DL) | Used APN-AMBR (UL/DL) | - | - | - |
| 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 (DL/UL) | S1-TEID (DL/UL) | - | S1-TEID (DL/UL) | - | - | - |
| - | | S5-TEID (DL/UL) | S5-TEID (DL/UL) | S5-TEID (DL/UL) | - | - | - |
| TFT(UL) | - | - | TFT(UL/DL) | - | - | - | - |
| QCI | QCI | QCI | QCI | QCI | - | - | - |
| - | ARP | ARP | ARP | ARP | - | - | - |
| - | eNB UE S1AP ID | - | - | eNB UE S1AP ID | - | - | - |
| - | MME UE S1AP ID | - | - | MME UE S1AP ID | - | - | - |
| - | eNB UE X2AP ID | - | - | - | - | - | - |

# EPS Entity Information Set in State D

### State D: EMM-Registered + ECM-Idle + RRC-Idle

| UE | eNB | S-GW | P-GW | MME | HSS | PCRF | SPR |
|---|---|---|---|---|---|---|---|
| IMSI | - | IMSI | IMSI | IMSI | IMSI | IMSI | IMSI |
| LTE K | - | - | - | - | LTE K | - | - |
| APN in Use | - | - | APN in Use | APN in Use | Default APN | APN in Use | - |
| - | - | - | - | EPS QoS Subscribed Profile | EPS QoS Subscribed Profile | - | - |
| - | - | - | PCC Rule | - | - | PCC Rule | Access Profile |
| GUTI | - | - | - | GUTI | - | - | - |
| TAI | TAI | TAI of Last TAU | TAI of Last TAU | TAI of Last TAU | - | TAI of Last TAU | - |
| NAS Security Context | - | - | - | NAS Security Context | - | - | - |
| - | - | - | - | - | MME ID | - | - |
| TAL List | - | - | - | TAI List | - | - | - |
| UE IP address | - | - | UE IP address | UE IP address | - | UE IP address | - |
| C-RNTI | C-RNTI | - | - | - | - | - | - |
| ECGI | ECGI | ECGI | ECGI | ECGI | - | ECGI | - |
| AS Security Context | AS Security Context | - | - | - | - | - | - |
| - | Used UE-AMBR (UL/DL) | - | - | Used UE-AMBR (UL/DL) | - | - | - |
| Used APN-AMBR (UL) | - | - | Used APN-AMBR (UL/DL) | Used APN-AMBR (UL/DL) | - | - | - |
| 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 (DL/UL) | S1-TEID (DL/UL) | - | S1-TEID (DL/UL) | - | - | - |
| - | | S5-TEID (DL/UL) | S5-TEID (DL/UL) | S5-TEID (DL/UL) | - | - | - |
| TFT(UL) | - | - | TFT(UL/DL) | - | - | - | - |
| QCI | QCI | QCI | QCI | QCI | - | - | - |
| - | ARP | ARP | ARP | ARP | - | - | - |
| - | eNB UE S1AP ID | - | - | eNB UE S1AP ID | - | - | - |
| - | MME UE S1AP ID | - | - | MME UE S1AP ID | - | - | - |
| - | eNB UE X2AP ID | - | - | - | - | - | - |

# References and Abbreviations

[1] 3GPP TS 24.301, "Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3".

[2] Netmanias Technical Document, "LTE Network Architecture", December 2012,
http://www.netmanias.com/bbs/view.php?id=techdocs&no=52

[3] Netmanias Technical Document, "LTE Security II", August 2012 ,
http://www.netmanias.com/bbs/view.php?id=techdocs&no=66

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

## Abbreviations

| | | | | |
|---|---|---|---|---|
| AMBR | : Aggregated Maximum Bit Rate | | MBR | : Maximum Bit Rate |
| APN | : Access Point Name | | MME | : Mobility Management Entity |
| ARP | : Allocation and Retention Priority | | NAS | : Non Access Stratum |
| AS | : Access Stratum | | PCC | : Policy and Charging Control |
| C-RNTI | : Cell Radio Network Temporary Identifier | | PCRF | : Policy and Charging Rule Function |
| DRB | : Data Radio Bearer | | PDCP | : Packet Data Convergence Protocol |
| ECGI | : E-UTRAN Cell Global Identifier | | P-GW | : Packet Data Network Gateway |
| ECM | : EPS Connection Management | | PLMN | : Public Land Mobile Network |
| EMM | : EPS Mobility Management | | QCI | : QoS Class Identifier |
| eNB | : Evolved Node B | | RLC | : Radio Link Control |
| EPS | : Evolved Packet System | | RRC | : Radio Resource Control |
| E-RAB | : E-UTRAN Radio Access Bearer | | S1AP | : S1 Application Protocol |
| ESM | : EPS Session Management | | S-GW | : Serving Gateway |
| E-UTRAN | : Evolved Universal Terrestrial Radio Access Network | | SPR | : Subscriber Profile Repository |
| GBR | : Guaranteed Bit Rate | | TAI | : Tracking Area identity |
| GUTI | : Globally Unique Temporary Identifier | | TAU | : Tracking Area Update |
| HSS | : Home Subscriber Server | | TFT | : Traffic Flow Template |
| IMSI | : Serving Gateway | | UE | : User Equipment |
| LTE | : Subscriber Profile Repository | | X2AP | : X2 Application Protocol |
| MAC | : Medium Access Control | | | |

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| 3 | Identification | LTE Identification II: NE and Location Identifier | |
| 4 | | LTE Identification III: EPS Session/Bearer Identifier | |
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# Netmanias Research and Consulting Scope

| | | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Services** | eMBMS/Mobile IPTV | | | | | | | | | | | | | | ■ | ■ |
| | CDN/Mobile CDN | | | | | | | | | | | | | ■ | ■ | ■ |
| | Transparent Caching | | | | | | | | | | | | | ■ | ■ | ■ |
| | BSS/OSS | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ |
| | Cable TPS | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Voice/Video Quality | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | IMS | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Policy Control/PCRF | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | IPTV/TPS | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Mobile Network** | LTE | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ |
| | Mobile WiMAX | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
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| | LTE Backaul | | | | | | | | | | | | | ■ | ■ | ■ |
| **Wireline Network** | Data Center Migration | | | | | | | | | | | | | ■ | ■ | ■ |
| | Carrier Ethernet | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | FTTH | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Data Center | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Metro Ethernet | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | MPLS | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | IP Routing | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

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