

# Network Architecture

Sudeep Palat and Philippe Godin

## 2.1 Introduction

As mentioned in the preceding chapter, LTE has been designed to support only packet-switched services, in contrast to the circuit-switched model of previous cellular systems. It aims to provide seamless Internet Protocol (IP) connectivity between User Equipment (UE) and the Packet Data Network (PDN), without any disruption to the end users' applications during mobility. While the term 'LTE' encompasses the evolution of the radio access through the Evolved-UTRAN (E-UTRAN), it is accompanied by an evolution of the non-radio aspects under the term 'System Architecture Evolution' (SAE) which includes the Evolved Packet Core (EPC) network. Together LTE and SAE comprise the Evolved Packet System (EPS).

EPS uses the concept of *EPS bearers* to route IP traffic from a gateway in the PDN to the UE. A bearer is an IP packet flow with a defined Quality of Service (QoS) between the gateway and the UE. The E-UTRAN and EPC together set up and release bearers as required by applications.

In this chapter, we present the overall EPS network architecture, giving an overview of the functions provided by the Core Network (CN) and E-UTRAN. The protocol stack across the different interfaces is then explained, along with an overview of the functions provided by the different protocol layers. Section 2.4 outlines the end-to-end bearer path including QoS aspects and provides details of a typical procedure for establishing a bearer. The remainder of the chapter presents the network interfaces in detail, with particular focus on the E-UTRAN interfaces and the procedures used across these interfaces, including those for the support of user mobility. The network elements and interfaces used solely to support broadcast services are covered in Chapter 14.

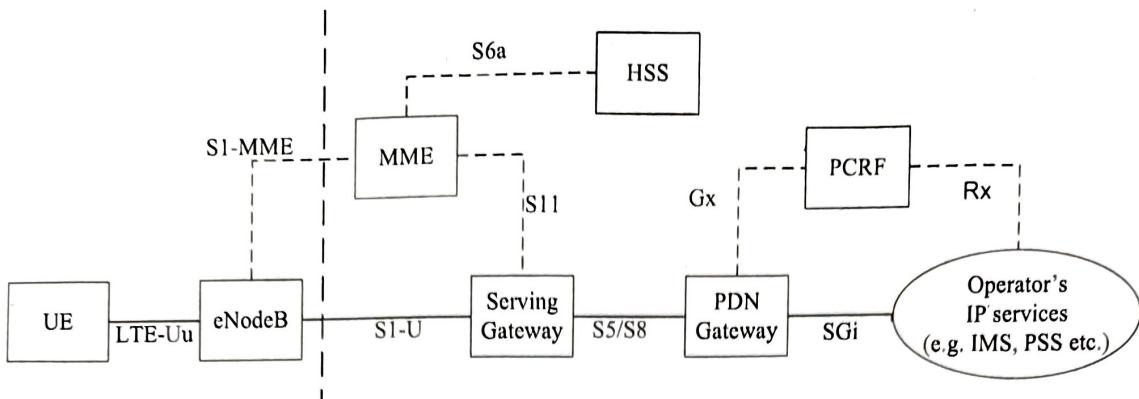


Figure 2.1 The EPS network elements.

## 2.2 Overall Architectural Overview

EPS provides the user with IP connectivity to a PDN for accessing the Internet, as well as for running services such as Voice over IP (VoIP). An EPS bearer is typically associated with a QoS. Multiple bearers can be established for a user in order to provide different QoS streams or connectivity to different PDNs. For example, a user might be engaged in a voice (VoIP) call while at the same time performing web browsing or File Transfer Protocol (FTP) download. A VoIP bearer would provide the necessary QoS for the voice call, while a best-effort bearer would be suitable for the web browsing or FTP session.

The network must also provide sufficient security and privacy for the user and protection for the network against fraudulent use.

This is achieved by means of several EPS network elements which have different roles. Figure 2.1 shows the overall network architecture including the network elements and the standardized interfaces. At a high level, the network is comprised of the CN (EPC) and the access network (E-UTRAN). While the CN consists of many logical nodes, the access network is made up of essentially just one node, the evolved NodeB (eNodeB), which connects to the UEs. Each of these network elements is inter-connected by means of interfaces which are standardized in order to allow multivendor interoperability. This gives network operators the possibility to source different network elements from different vendors. In fact, network operators may choose in their physical implementations to split or merge these logical network elements depending on commercial considerations. The functional split between the EPC and E-UTRAN is shown in Figure 2.2. The EPC and E-UTRAN network elements are described in more detail below.

### 2.2.1 The Core Network

The CN (called EPC in SAE) is responsible for the overall control of the UE and establishment of the bearers. The main logical nodes of the EPC are:

- PDN Gateway (P-GW);
- Serving Gateway (S-GW);
- Mobility Management Entity (MME).

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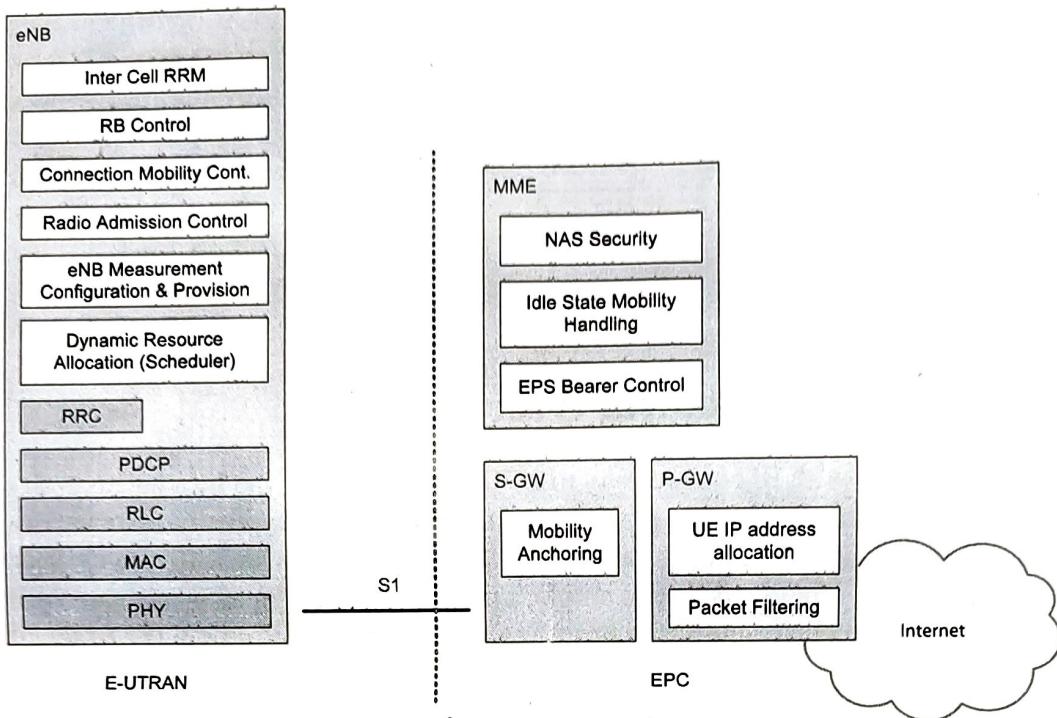


Figure 2.2 Functional split between E-UTRAN and EPC. Reproduced by permission of © 3GPP.

In addition to these nodes, EPC also includes other logical nodes and functions such as the Home Subscriber Server (HSS) and the Policy Control and Charging Rules Function (PCRF). Since the EPS only provides a bearer path of a certain QoS, control of multimedia applications such as VoIP is provided by the IP Multimedia Subsystem (IMS) which is considered to be outside the EPS itself.

The logical CN nodes (specified in [1]) are shown in Figure 2.1 and discussed in more detail in the following.

- **PCRF.** It is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF) which resides in the P-GW. The PCRF provides the QoS authorization (QoS class identifier and bitrates) that decides how a certain data flow will be treated in the PCEF and ensures that this is in accordance with the user's subscription profile.
- **Home Location Register (HLR).** The ~~Home Location Register~~ <sup>Home Subscribers Server HSS</sup> contains users' SAE subscription data such as the EPS-subscribed QoS profile and any access restrictions for roaming (see Section 2.2.3). It also holds information about the PDNs to which the user can connect. This could be in the form of an Access Point Name (APN) (which is a label according to DNS<sup>1</sup> naming conventions describing the access point to the PDN), or a PDN Address (indicating subscribed IP address(es)). In addition the HLR holds dynamic information such as the identity of the MME to which the user is currently attached

<sup>1</sup>Domain Name System.

*HSS*

or registered. The ~~HLR~~<sup>HSS</sup> may also integrate the Authentication Centre (AuC) which generates the vectors for authentication and security keys.

- **P-GW.** The P-GW is responsible for IP address allocation for the UE, as well as QoS enforcement and flow-based charging according to rules from the PCRF. The P-GW is responsible for the filtering of downlink user IP packets into the different QoS based bearers. This is performed based on Traffic Flow Templates (TFTs) (see Section 2.4). The P-GW performs QoS enforcement for Guaranteed Bit Rate (GBR) bearers. It also serves as the mobility anchor for inter-working with non-3GPP technologies such as CDMA2000 and WiMAX networks (see Section 2.2.4 and Chapter 13 for more information about mobility).
- **S-GW.** All user IP packets are transferred through the S-GW, which serves as the local mobility anchor for the data bearers when the UE moves between eNodeBs. It also retains the information about the bearers when the UE is in idle state (known as ECM-IDLE, see Section 2.2.1.1) and temporarily buffers downlink data while the MME initiates paging of the UE to re-establish the bearers. In addition, the S-GW performs some administrative functions in the visited network such as collecting information for charging (e.g. the volume of data sent to or received from the user), and legal interception. It also serves as the mobility anchor for inter-working with other 3GPP technologies such as GPRS and UMTS (see Section 2.2.4 and Chapter 13 for more information about mobility).
- **MME.** The MME is the control node which processes the signalling between the UE and the CN. The protocols running between the UE and the CN are known as the *Non-Access Stratum* (NAS) protocols.

The main functions supported by the MME are classified as:

**Functions related to bearer management.** This includes the establishment, maintenance and release of the bearers, and is handled by the session management layer in the NAS protocol.

**Functions related to connection management.** This includes the establishment of the connection and security between the network and UE, and is handled by the connection or mobility management layer in the NAS protocol layer.

NAS control procedures are specified in [1] and are discussed in more detail in the following section.

### 2.2.1.1 Non-Access Stratum (NAS) Procedures

The NAS procedures, especially the connection management procedures, are fundamentally similar to UMTS. The main change from UMTS is that EPS allows concatenation of some procedures to allow faster establishment of the connection and the bearers.

The MME creates a *UE context* when a UE is turned on and attaches to the network. It assigns a unique short temporary identity termed the SAE-Temporary Mobile Subscriber Identity (S-TMSI) to the UE which identifies the UE context in the MME. This UE context holds user subscription information downloaded from the HSS. The local storage of subscription data in the MME allows faster execution of procedures such as bearer

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establishment since it removes the need to consult the HSS every time. In addition, the UE context also holds dynamic information such as the list of bearers that are established and the terminal capabilities.

To reduce the overhead in the E-UTRAN and processing in the UE, all UE-related information in the access network can be released during long periods of data inactivity. This state is called EPS Connection Management IDLE (ECM-IDLE). The MME retains the UE context and the information about the established bearers during these idle periods.

To allow the network to contact an ECM-IDLE UE, the UE updates the network as to its new location whenever it moves out of its current Tracking Area (TA); this procedure is called a ‘Tracking Area Update’. The MME is responsible for keeping track of the user location while the UE is in ECM-IDLE.

When there is a need to deliver downlink data to an ECM-IDLE UE, the MME sends a paging message to all the eNodeBs in its current TA, and the eNodeBs page the UE over the radio interface. On receipt of a paging message, the UE performs a service request procedure which results in moving the UE to ECM-CONNECTED state. UE-related information is thereby created in the E-UTRAN, and the bearers are re-established. The MME is responsible for the re-establishment of the radio bearers and updating the UE context in the eNodeB. This transition between the UE states is called an idle-to-active transition. To speed up the idle-to-active transition and bearer establishment, EPS supports concatenation of the NAS and AS procedures for bearer activation (see also Section 2.4.1). Some inter-relationship between the NAS and AS protocols is intentionally used to allow procedures to run simultaneously rather than sequentially, as in UMTS. For example, the bearer establishment procedure can be executed by the network without waiting for the completion of the security procedure.

Security functions are the responsibility of the MME for both signalling and user data. When a UE attaches with the network, a mutual authentication of the UE and the network is performed between the UE and the MME/HSS. This authentication function also establishes the security keys which are used for encryption of the bearers, as explained in Section 3.2.3.1. The security architecture for SAE is specified in [2].

### 2.2.2 The Access Network

The Access Network of LTE, E-UTRAN, simply consists of a network of eNodeBs, as illustrated in Figure 2.3. For normal user traffic (as opposed to broadcast), there is no centralized controller in E-UTRAN; hence the E-UTRAN architecture is said to be flat.

The eNodeBs are normally inter-connected with each other by means of an interface known as X2, and to the EPC by means of the S1 interface – more specifically, to the MME by means of the S1-MME interface and to the S-GW by means of the S1-U interface.

The protocols which run between the eNodeBs and the UE are known as the *Access Stratum (AS)* protocols.

The E-UTRAN is responsible for all radio-related functions, which can be summarized briefly as:

- **Radio Resource Management.** This covers all functions related to the radio bearers, such as radio bearer control, radio admission control, radio mobility control, scheduling and dynamic allocation of resources to UEs in both uplink and downlink (see Chapter 13).