4G LTE-Network Architecture Implementation in Testbed with OpenAirInterface and D2D-Communication

Ilias Chatzistefanidis[1]
ichatsist@uth.gr
iliasece16@gmail.com

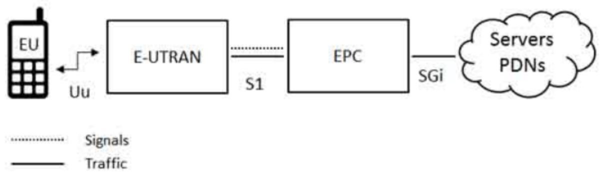

Fig. 1. EPS's high-level Architecture

***Abstract*— erere**

I. INTRODUCTION

Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements. LTE is the upgrade path for carriers with both GSM/UMTS networks and CDMA2000 networks. The standard is the next major step in mobile radio communications, and is introduced in 3rd Generation Partnership Project (3GPP). is specified in its Release 8 document series, with minor enhancements described in Release 9.

LTE covers the radio access network, air interface and mobile, while the System Architecture Evolution (SAE), covers the core network. Officially, the whole system is known as the evolved packet system (EPS). The high-level architecture of the evolved packet system (EPS) consists of three main components, namely the user equipment (UE), the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core (EPC) as shown in Fig 1.

Device-to-Device (D2D) communication in cellular networks is defined as direct communication between two mobile users without traversing the Base Station (BS) or core network. D2D communication is generally non-transparent to the cellular network and it can occur on the cellular frequencies (i.e., inband) or unlicensed spectrum (i.e., outband).

In a traditional cellular network, all communications must go through the BS even if communicating parties are in range for proximity-based D2D communication. Communication through BS suits conventional low data rate mobile services such as voice call and text messaging in which users are seldom close enough for direct communication. However, mobile users in today's cellular networks use high data rate services (e.g., video sharing, gaming, proximity-aware social networking) in which they could potentially be in range for direct communications (i.e., D2D). Hence, D2D communications in such scenarios can greatly increase the spectral efficiency of the network. The advantages of D2D communications go beyond spectral efficiency; they can potentially improve throughput, energy efficiency, delay, and fairness.

OpenAirInterface (OAI) wireless technology platform is a flexible platform towards an open LTE ecosystem. The platform offers an open-source software-based implementation of the LTE system spanning the full protocol stack of 3GPP standard both in E-UTRAN and EPC. It can be used to build and customize a LTE base station (OAI eNB), a user equipment (OAI UE) and a core network (OAI EPC) on a PC. The OAI eNB can be connected either to a commercial UEs or OAI UEs to test different configurations and network setups and monitor the network and mobile device in real-time.

In this paper we delve into the assistance of the OAI in the implementation of a real EPS topology in our University's testbed. The structure of the paper is as follows:
Related Work: We mention interesting and important related published work.
EPS Architecture Explanation: Detailed theoretical analysis on every component of EPS Topology.
Simple EPS Topology in Testbed: Explanation of testbed's topology and a step-by-step configuration of software using OAI.
D2D-Communication: As a step forward, we describe how OAI could assist achieving 1D2D-communication on our testbed.
Conclusions: In conclusion, we summarize our results and thoughts and we evaluate the usability of the OpenAirInterfeace
Future Work: In this section, we propose ideas to expand our work for further research around OAI and whole EPS structure.

II. RELATED WORK

Some related work to ours is listed below:

*This work was not supported by any organization

[1]I. Chatzistefanidis is with Department of Electrical and Computer Engineering, University of Thessaly, Volos, Greece

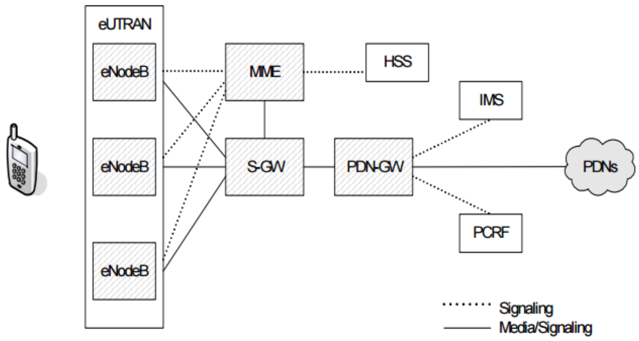

Fig. 2. LTE Network Analytical Architecture

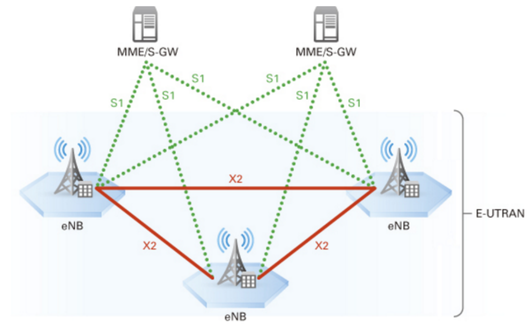

Fig. 3. E-UTRAN composition of eNBs

- Ronit Nossenson in paper "Long-Term Evolution Network Architecture" provides a technological overview of the System Architecture Evolution (SAE) of LTE networks providing a basic knowledge on 4G cellular network structure, entities responsibilities and protocol stack.

III. EPS Architecture Explanation

To start with, LTE High-level Network Architecture consists of three main parts:

- UE (User Equipment) ,
- E-UTRAN (Evolved UMTS Terrestrial Radio Access Network)
- EPC (Evolved Packet Core)

These parts are shown in Fig 1,2

A. UE

User Equipment provides the user interface to the end user. The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment (ME). The mobile equipment comprised of the following important modules:

- Mobile Termination (MT) : This handles all the communication functions.
- Terminal Equipment (TE) : This terminates the data streams.
- Universal Integrated Circuit Card (UICC) : This is also known as the SIM card for LTE equipments. It runs an application known as the Universal Subscriber Identity Module (USIM).

A USIM stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

B. E-UTRAN

The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called eNodeB or eNB. Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB.

LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB:

- The eBN sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.
- The eNB controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.

Each eNB connects with the EPC by means of the S1 interface and it can also be connected to nearby base stations by the X2 interface, which is mainly used for signalling and packet forwarding during handover as shown in Fig. 3.

C. EPC

Let's analize each of the components of EPC as shown in Figures 2 and 4:

1) HSS: The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.

2) P-GW: The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world ie. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node

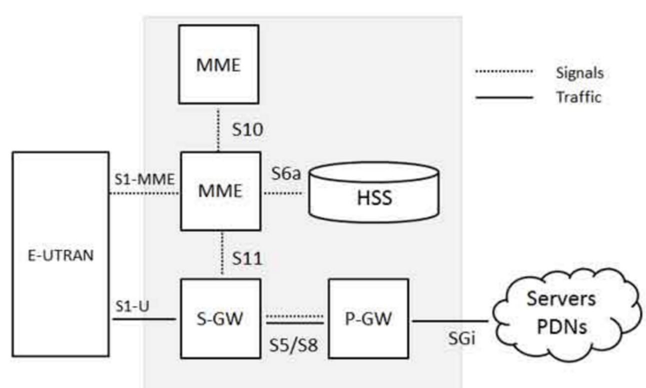

Fig. 4. EPC Analytical Architecture with Interfaces

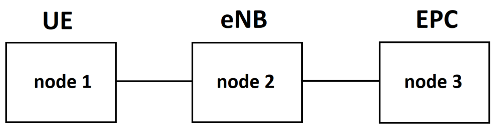

Fig. 5. Testbed's topology

(GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.

3) S-GW: The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.

4) MME: The mobility management entity (MME) controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server (HSS).

5) PCRF: The Policy Control and Charging Rules Function (PCRF) is a component which is shown in diagram 2 but 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 interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different networks.

IV. SIMPLE EPS TOPOLOGY IN TESTBED

For a simple LTE-Network topology implementation in our testbed we need only three nodes[1]. In the first we will configure a UE, in the second one eNB and in the third the EPC as shown in Fig. 5.

A. Hardware

We do not need any hardware with special properties. The only important things are:

- The eNB-node to be equipped with USRP[2]
- The UE-node to support LTE wireless technology

B. Software

The configuration will be done through OAI software. We use the openairinterface5G [3] repository.

C. Configuration

In the beginning, we should assign the correct IP addresses to the nodes.

1) eNB: In the configuration file of the eNB (openairinterface5g/targets/PROJECTS/GENERIC-LTE-EPC/CONF/enb.band7.tm1.usrpb210.conf) we change:

- *mme_ip_address* to the EPC's IP
- *ENB_IPV4_ADDRESS_FOR_S1_MME* and *ENB_IPV4_ADDRESS_FOR_S1_U* to the eNB's IP
- *ENB_INTERFACE_NAME_FOR_S1U* and *ENB_INTERFACE_NAME_FOR_S1_MME* to the interface that the nodes communicate.
- *mobile_country_code* and *mobile_network_code* depending on the IMSI of the UE-node (e.g IMSI = 460990010001045, *mobile_country_code*=460, *mobile_network_code*=99)

2) EPC:

- MME: In the configuration file of MME (/usr/local/etc/oai/mme.conf) we change:
  - *MME_INTERFACE_NAME_FOR_S1_MME* to the communication's interface (e.g. "eth1")
  - *MME_IPV4_ADDRESS_FOR_S1_MME* to IP of EPC
  - *GUMMEI_LIST* and *TAI_LIST* depending on IMSI of UE-node (e.g IMSI = 460990010001045, *MCC*=460, *MNC*=99)
- SP-GW: In the configuration file of SP-GW (/usr/local/etc/oai/spgw.conf) we change:
  - *SGW_INTERFACE_NAME_FOR_S1U_S12_S4_UP* to the communication's interface (e.g. "eth1")
  - *SGW_IPV4_ADDRESS_FOR_S1U_S12_S4_UP* to the EPC's IP
- HSS: In the configuration file of HSS (/usr/local/etc/oai/hss.conf) we change the *OPERATOR_key* to the appropriate one

We should, also, check if the certificates of the MME-HSS communication have not expired. If they did, we should replace them. Moreover, it is of great importance that we have the OpenAirInterface's database (oai_db) updated. This can be done with MySQL[4] as follows: "mysql -u root –password=... oai_db < clients_file"

3) UE: We should:

- activate the LTE-Dongle[5] USB
- access serial port with Minicom[6]
- obtain an IP address for DHCP client (wwan0 interface)

D. Execution of Experiment

At first, we should activate the Core Network. Thus, we run the following executables in different terminals on node_3:

- HSS

[1]The term node is used to describe a PC

[2]Universal Software Radio Peripheral (USRP) is a range of software-defined radios designed and sold by Ettus Research

[3]openairinterface5G is a gitlab repository of open-air-interface project. Link here.

[4]MySQL is an open-source relational database management system (RDBMS). Link here.

[5]A dongle is a small piece of computer hardware that connects to a port on another device to provide it with additional functionality, or enable a pass-through to such a device that adds functionality.

[6]Minicom is a serial communication program that connects to devices through a GNU/Linux PC's serial ports.

- SP-GW
- MME

It is necessary that we always run HSS's script first. Then, we can continue by activating eNB by running its executable. In this moment if there is no error, we achieved LTE-transmission from our node. Now, we subscribe the UE-node to our network and finally achieve *pinging* to a destination (e.g. EPC's IP: 172.16.0.1)

V. D2D-COMMUNICATION

Using D2D communication, a large amount of data can be transferred quickly between mobile devices in short range. Some of the scenarios that show the importance of D2D communication are:

- *Local data services*: D2D communication could assist local data services by sharing information (e.g. files, audios and videos) through D2D-links using higher data rates and by providing data and computation offloading. The last means that devices with good internet connection could provide hotspot[7], offloading in this way, the Base Station. Moreover, UE's could cooperate with each other to deal with computation-heavy tasks.
- *Coverage extension*: D2D communication could assist boosting poor signal quality by using D2D-links with one or multiple UEs that have better signal quality.
- *Machine-to-machine (M2M) communication*: D2D connections can be used to establish M2M communication in Internet of Things since they afford ultra low latency and hence, real-time responses. A particular application is vehicle-to-vehicle (V2V) communication where D2D links can be utilized to share information between neighboring vehicles quickly and offload traffic efficiently.

[7] A hotspot is a physical location where people may obtain Internet access, typically using Wi-Fi technology, via a wireless local-area network (WLAN) using a router connected to an Internet service provider.A private hotspot, often called tethering, may be configured on a smartphone or tablet that has a network data plan, to allow Internet access to other devices.