Supporting LTE Networks in Heterogeneous Environment Using the Y-Comm Framework

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Abstract There are two trends in the research to develop future networks. While the first aims to introduce new technologies such as the Long Term Evolution (LTE) and WiMAX with high-speed data. The second aimed at providing clients with a ubiquitous connectivity via proposing new communication architectures to integrate different networking technologies and enabling mobile devices to switch seamlessly between them. Examples of such architectures are Y-Comm, Mobile Ethernet and IEEE 802.21. In this paper we will show how these research trends could be integrated. This is achieved by discussing how future communication frameworks like Y-Comm could fulfil the requirements and provide the functionalities of newly introduced technologies such as UMTS and LTE networks.

1 Introduction

In order to enhance user experience in future and Next Generation Networks (NGNs), a large number of research groups have been working on developing new communication mechanisms. The research effort in this field was divided into two directions. In the first, the research was concerned with enhancing the capabilities of current

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technologies and developing new ones with a high speed and low latency. This led to the evolution track of 2G, 3G and finally 4G networks such as the LTE [1]. While the second followed rather a different approach. Thus, in stead of developing a new brad technology or addressing the shortages of current ones, the research effort concentrated on introducing novel communication frameworks to integrate different wireless technologies and enabling future mobile terminals, which will be multi-homed by nature [2], to seamlessly switch between these technologies using vertical handover mechanisms. As a result of this research effort, novel communication architectures for Next Generation Networks (NGNs) have been proposed such as Y-Comm [13], the Ambient Networks [3]; the Mobile Ethernet [4] and IEEE802.21 [5].

In order to support the integration of a wide variety of wireless networks and enable the communication in such heterogeneous networks, each of the newly proposed communication frameworks has introduced a generic network architecture which provides the required functionalities to accommodate different wireless technologies and to support the mobility between them. However, as stated in [6], Y-Comm is the most completed one with a well-structured architecture that supports the provision of security, QoS, mobility and communication in an integrated manner. Therefore, this paper will consider Y-Comm as a representative of communication frameworks in heterogeneous networks. To the best of our knowledge, this is the first research work to bring the two research trends together and discuss how future communication architectures, the Y-Comm in this paper, could support newly introduced technologies such as the LTE.

The rest of this paper is organized as follows: Sect. 2 describes the LTE network infrastructure and its networking entities. Section 3 gives an overview of the Y-Comm framework and describes the Y-Comm's network structure along with its operational network entities. In order to show how Y-Comm could accommodate the LTE, Sect. 4 maps the Y-Comm framework onto the LTE Infrastructure and highlights the correspondence between the operational network entities in the LTE and Y-Comm network infrastructures. The paper concludes in Sect. 5.

2 The Long Term Evolution

2.1 An Overview

LTE is the preferred development path of GSM, Wideband Code Division Multiple Access (W-CDMA) and the High Speed Packet Access (HSPA) [7] networks currently deployed. This essential evolution will enable networks to offer the higher data throughput to mobile terminals needed in order to deliver new and advanced mobile broadband services.

LTE only supports packet-switched services and 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. The LTE networks resulted from the evolution of the Universal Mobile Telecommunications System (UMTS) radio access through the Evolved UTRAN (E-UTRAN) as well as the 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) [8].

2.2 Network Architecture

For both UMTS and LTE, the basic network architectures are very similar. In comparison to UMTS, the network elements used for LTE are upgraded and mostly renamed. However, they fulfil the analogous tasks in both cases [9]. The LTE network comprises three parts. Firstly, The EPC or the Core Network (CN) which contains several network elements such as the Home Subscriber Server (HSS), the PDN Gateway (P-GW), the Serving Gateways (S-GWs) and the Mobility Management Entity (MME). Each of these elements has different role which will be described later in this paper. Secondly, the Radio Access Network (RAN) or the E-UTRAN contains a number of base stations called eNodeBs (eNBs) and their controlling units which are directly connected to the Core network. Each eNB is connected to one or more MMEs/S-GWs with the S1 interface as shown in Fig. 1. Thirdly, the User's Equipment (UE) (also called the Mobile Terminal (MT)) includes the mobile device and a tamper-resistant card and the Universal Subscriber Identity Module (USIM) [10, 11]. Similar to the SIM card in 2G technology, the USIM is issued by the mobile operator and used to store security-related information that will be used to identify the subscriber.

2.2.1 The Elements of the Core Network

It is responsible for controlling the UE, establishing different bearers for different sessions while maintaining the desired QoS as well as authenticating subscribers to access the network resources. The CN includes the following logical elements [8]:

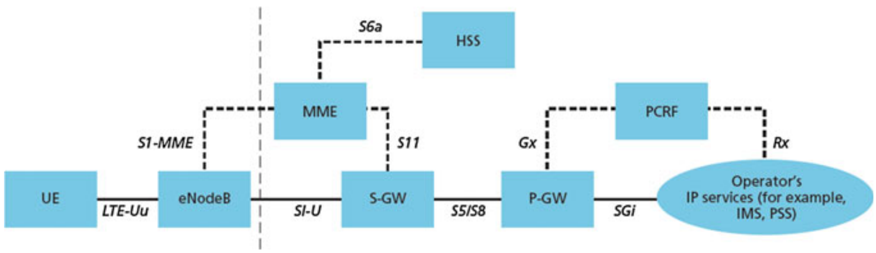

Fig. 1 LTE network architecture [8]

- **The Mobility Management Entity (MME)** manages session states, authentication, paging, mobility with 3GPP, 2G and 3G networks.
- **The Home Subscriber Server (HSS)** stores and manages all users' subscriber information such as QoS of different bearers, any roaming restriction. The HSS also contains dynamic information such as the identity of the MME to which the user is currently connected to.
- **The PDN Gateway (P-GW)** performs a per-user packets filtering and QoS enforcement for guaranteed bit rate (GBR) bearers, assigns IP address to UEs and serves as the mobility anchor for interworking with non-3GPP technologies. This implies that P-GWs are responsible for managing the so-called Vertical Handover which happens when a mobile device moves between different networking technologies such as LTE and WIMAX.
- **The Policy Control and Charging Rules Function (PCRF)** is a software component that operates at the P-GWs. It is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities.
- **The Serving Gateway (S-GW)** acts as a local Mobility Anchor point for inter-eNB handover and performs some administrative functions in the visited network such as collecting information for charging (for example, the volume of data sent to or received from the user) and lawful interception. The S-GW also acts as a mobility anchor for mobility within 3GPP technologies such as LTE and UMTS.

These elements are interconnected over a well-defined interfaces as shown in Fig. 1.

3 The Y-Comm Framework

The Y-Comm Framework is a communication architecture to support vertical handover for multi-homed nodes in heterogeneous environment. The architecture has two frameworks:

- The Peripheral framework deals with operations on the mobile terminal.
- The Core framework deals with functions in the core network to support different peripheral networks.

A brief explanation of Y-Comm is now attempted starting with the lowest layer. A more detailed explanation can be found in [12].

3.1 The Peripheral Framework

As shown in Fig. 2, this framework comprises the following layers [12]:

1. **The Hardware Platform Layer (HPL)** is used to classify all relevant wireless technologies.

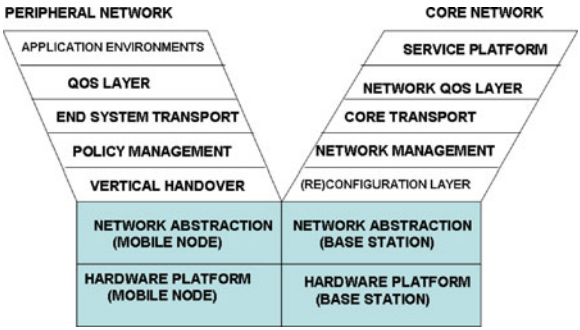

Fig. 2 The Y-Comm framework

2. **The Network Abstraction Layer (NAL)** provides a common interface to manage and control all the wireless networks. These first two layers for both frameworks are similar in functionality.
3. **The Vertical Handover Layer (VHL)** acquires the resources for handover.
4. **The Policy Management Layer (PML)** decides whether and when handover should occur.
5. **The End Transport Layer (ETL)** allows the mobile node to make end-to-end connections across the core network.
6. **The QoS Layer (QL)** monitors the QoS used by the wireless network as a whole to ensure stable operation.
7. **The Applications Environments Layer (AEL)** specifies a set of objects, functions and routines to build applications which make use of the framework.

3.2 The Core Framework

As previously mentioned, the first two layers of the Core Framework are engaged in controlling base-station operations. The third layer is called the **Reconguration Layer (REL)**. It is a control plane to manage key infrastructure using programmable networking techniques. **The Network Management Layer (NML)** is a management plane that is used to control networking operations in the core. **The Core Transport System (CTS)**, is concerned with moving data through the core network. **The Network QoS Layer (NQL)** is concerned with QoS issues within the core network. **The Service Platform Layer (SPL)** allows services to be installed on various networks at the same time.

3.3 A Generic Network Architecture for Heterogeneous Networks

Due to the fact that various networking technologies will coexist in NGNs, its network infrastructure will be owned by different operators. Additionally, new operators could install their network hardware and join the core network. However, interoperability between different operators is a key challenge in this open, heterogeneous environment. To address this issue, the study of the Y-Comm group [13] and Daidalos II [14] proposed the concept of Core End-Points (CEPs) as administrative entity to control the different wireless networks in a regional area, as shown in Fig. 3.

A detailed view of the CEP's structure along with the attached networks is shown in Fig. 4. The figure shows a hierarchical architecture, where the bottom level is represented by several access points (APs) and access routers (ARs) that communicate with the wireless interfaces in the mobile terminals. The middle level comprises a number of technology-specific domains, where each domain represents a certain network operator and technology such as 2G, 3G, and Wi-Fi. For these domains to interoperate, the CEP, which is residing at the top level acts as a central administrative domain to control the inter-domain functions and provide overall management.

In order to deal with the QoS and security tasks in this architecture, a number of operational entities have been proposed as follows:

1. **The central A3C server (CA3C):** This is the central authentication, authorization; accounting and cost (A3C) server in the CEP. The CA3C holds the service level of agreements (SLAs) along with the network level of agreements (NLAs), which describe the clients' terms for using the service and accessing networks, respectively

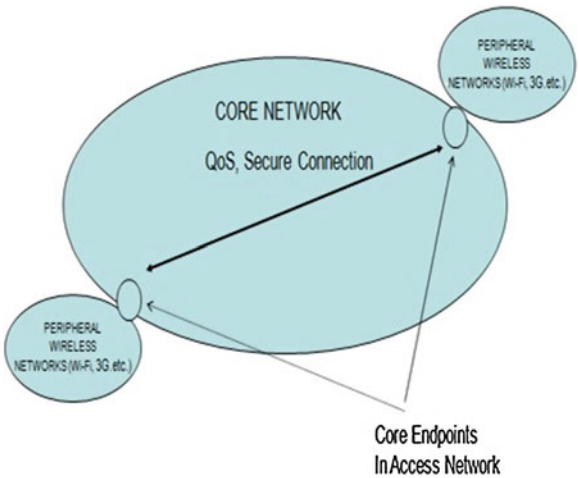

Fig. 3 The future internet

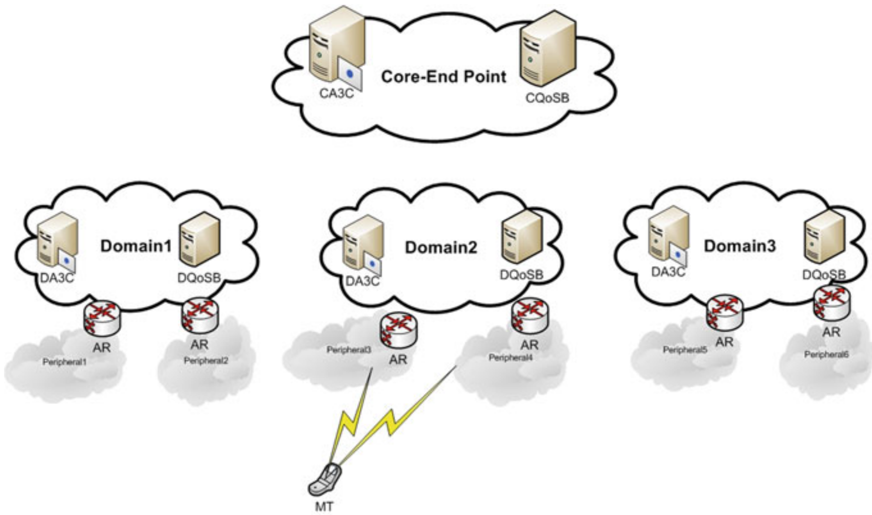

Fig. 4 The future network architecture

2. **The central QoS broker (CQoSB):** It is responsible for negotiating QoS in case of cross-CEP handover. It comprises three modules: the QoS Engine manages inter-domain connection and provides end-to-end QoS across CEPs, the A3C interface is used for the interaction with the CA3C server.
3. **The domain A3C server (DA3C):** The DA3C is responsible for handling users' service aspects.
4. **The domain QoS broker (DQoSB):** It manages the resources of the attached peripheral networks with respect user preferences and network availability, it also makes a per-flow admission control decision. The DQoSB has five modules as shown in 5, detailed description of these modules is found in [15].
5. **The access router (AR):** This is the link between the domain and the peripheral networks; it enforces the admission control decision, taken by the DQoSB. The AR comprises five modules as shown in 5, these are explained in [15].
6. **The Mobile Terminal (MT):** A multi-homed mobile device used by the subscribers to switch between different access networks to get various services. As shown in [15], the MT has four interfaces.

The the structure of these entities along with their interactions are shown in Fig. 5. Also more detailed information about these entities could be found in [15, 16].

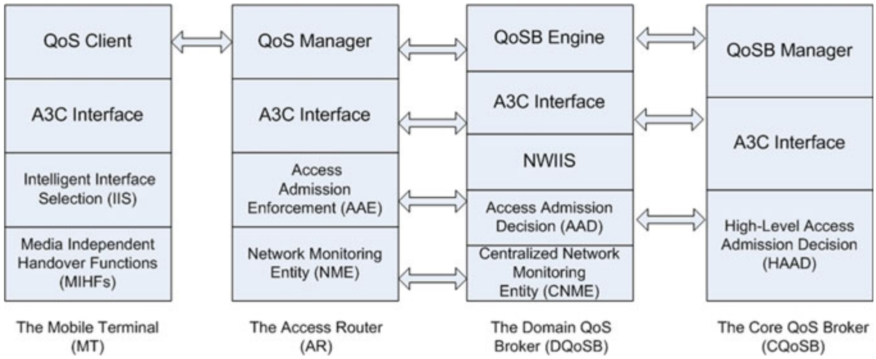

Fig. 5 The network entities interactions

4 Mapping Y-Comm and LTE

4.1 Mapping Y-Comm onto LTE Infrastructure

In this section we show the relationship between Y-Comm and LTE infrastructure. We believe that Y-Comm can easily be mapped onto well-established networks such as the UMTS or LTE architecture. The mobile node runs the LTE protocol stack while the required network functionality is distributed using several core entities. The eNBs interact directly with the mobile node using specified radio channels defined by the MME. Therefore, the functionality of eNBs/MMEs is mapped to the first two layers (HPL and NAL) of the Core Framework in Y-Comm. Each eNB/MMR pair is connected to the S-GW using S1 interfaces as shown in Fig. 1. The S-GW is responsible for managing mobility with other 3GPP networks such UMTS. However, the connection with packet switching networks such the Internet or supporting the mobility with non-3GPP networks such as WiMAX and Wi-Fi is achieved by the P-GWs which are connected to the S-GWs using S5/S8 interfaces. This implies that S-GWs and P-GWs are responsible for managing different types of handover as described in Sect. 2.2.1. Therefore, the functionalities of S-GWs and P-GWs correspond to the Reconfiguration Layer (REL)and the Network Management Layer (NML), respectively in the Core Framework of Y-Comm. We can now show how the functions of Y-Comm can be mapped onto the LTE infrastructure making possible the transition from LTE to Y-Comm. This is shown in Fig. 6. The Mobile Node (MN) runs the entire Peripheral Framework as shown. The Core Framework is distributed throughout the core network in a similar way to the LTE infrastructure. The Hardware Platform and Network Abstraction Layers run in the eNBs and MME. Y-Comm however, supports different wireless technologies including 3G base stations, Wi-Fi and WiMax APs, etc. The Reconfiguration Layer of Y-Comm runs in the S-GW for LTE. This layer uses programmable techniques on the Network Abstraction Layer to control

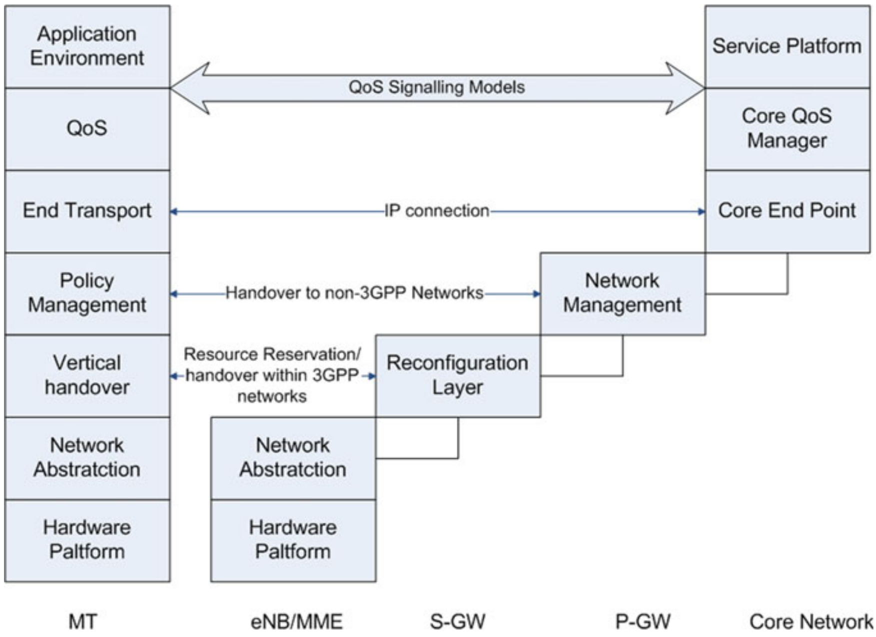

Fig. 6 Mapping the LTE to Y-Comm

the resources on individual eNBs. The Reconfiguration Layer on the S-GWs level and allocates resources to do a handover to a particular eNB.

The Network Management Layer (NML) manages different wireless networks and runs at the level of the P-GW level in current LTE infrastructure. In Y-Comm, a local NML manages all the S-GWs in a local area and knows the status of each wireless network and its topology. This information can be shared with the Policy Management Layer on the mobile node. The core endpoint is used by the mobile node to connect to the wider Internet. For a given connection, IP packets to and from the mobile node are tunnelled through the core network using core endpoints. Finally when an application on the mobile node wishes to make a connection through the core network, the QoS layer running on the mobile node interacts with the QoS manager in the core network with regard to QoS requirements for the new connection. The QoS manager will return two core endpoints which can be used for the new connection.

4.2 Mapping the LTE Infrastructure to the Generic Network Structure

Both Y-Comm and LTE have defined their own network architecture along with a number of operational network entities as explained in Sects. 2.2.1 and 3.3. This

Table 1 The Y-Comm and LTE mapping

The LTE network element	The Y-Comm network entity
The Home Subscriber Server (HSS)	The Central A3C Server (CA3C) and the Central QoS Broker (CQoSB)
The Policy Control and Charging Rules Function (PCRF)	The High-level Access Admission Decision module (HAAD) of the CQoSB
The Policy Control Enforcement Function (PCEF)	The Access Admission Decision (AAD) and the Centralized Network Monitoring Entity (CNME) modules of the DQoSB
The PDN Gateway (P-GW)	The Domain QoS Broker (DQoSB) and the Domain A3C (DA3C) server
The Serving Gateway (S-GW)	The Access Admission Enforcement (AAE) and Network Monitor Entity (NME) modules of the Access Router
The eNB and the MME	The access router

section will show how the LTE networking entities are mapped to those in the generic network architecture of the Y-Comm framework.

The Home Subscriber Server (HSS) in LTE holds the subscription information of all clients, which includes QoS, security and roaming restrictions. In Y-Comm, such information is kept by the Central A3C Server (CA3C) and the Central QoS Broker (CQoSB) which reside in the Core-End Points (CEPs) as seen in Fig. 4.

The Policy Control and Charging Rules Function (PCRF) in the core network and the Policy Control Enforcement Function (PCEF),which resides in the P-GW are responsible for policy control decision-making and controlling the flow based on the derived policy. In Y-Comm, these functions are achieved using the High-level Access Admission Decision module (HAAD)in the CQoSB, the Access Admission Decision (AAD) and the Centralized Network Monitoring Entity (CNME) modules in the DQoSB, respectively.

The PDN Gateway (P-GW) manages mobility with non-3GPP networks as well as QoS control and flow-based charging according to the rules from the PCRF. In Y-Comm, these functionalities are the responsibilities of the Domain QoS Broker (DQoSB) and the Domain A3C (DA3C) server.

The Serving Gateway (S-GW) performs administrative duties such as collecting information for charging and monitoring the volume of data sent/received from users. These duties are accomplished via the Access Admission Enforcement (AAE) and Network Monitor Entity (NME) modules of the Access Router in the generic network architecture of Y-Comm.

The functionalities of the eNBs and their controlling unit, the MME, is delivered by the Access Router (AR) in the generic network architecture. This mapping is shown in Table 1.

5 Conclusion

This work describes two current research trends to enhance communication in future networks. While one trend is keen on enhancing current communication technologies and developing new ones, the other introduces novel communication architectures within which, various wireless technologies will be supported. The paper is the first to discuss how the two trends could be mapped and complement each other in order to enhance the research efforts towards advanced technologies in future networks.

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