THE EVOLUTION TO LTE-ADVANCED

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ABSTRACT

This paper provides Associate in nursing in-depth read on the technologies being thought-about for long term Evolution-Advanced (LTE-Advanced). First, the evolution from third generation (3G) to fourth generation (4G) is delineated in terms of performance necessities and main characteristics. The new spec developed by the Third Generation Partnership Project (3GPP), that supports the mixing of current and future radio access technologies, is tinted. Then, the most technologies for LTE-Advanced area unit explained, at the side of impending enhancements, their related challenges, and a few approaches that are thought-about to tackle those challenges.

Keyword – *LTE, LTE-Advanced, 4G,Carrier aggregation, CoMP, Relay, MIMO architectures.*

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1. INTRODUCTION

The fourth generation (4G) of wireless cellular systems has been a topic of interest for quite a long time, probably since the formal definition of third generation (3G) systems was officially completed by the International Telecommunications Union Radio communication Sector (ITU-R) in 1997. A set of requirements was specified by the ITU-R regarding minimum peak user data rates in different environments through what is known as the International Mobile Telecommunications 2000 project (IMT-2000). The requirements included 2048 kbps for an indoor office, 384 kbps for outdoor to indoor pedestrian environments, 144 kbps for vehicular connections, and 9.6 kbps for satellite connections. With the target of creating a collaboration entity among different telecommunications associations, the 3rd Generation Partnership Project (3GPP) was established in 1998.

It started working on the radio, core network, and service architecture of a globally applicable 3G technology specification. Even though 3G data rates were already real in theory, initial systems like Universal Mobile Telecommunications System (UMTS) did not immediately meet the IMT- 2000 requirements in their practical deployments. Hence, the standards needed to be improved to meet or even exceed them. The combination of High Speed Downlink Packet Access (HSDPA) and the subsequent addition of an Enhanced Dedicated Channel, also known as High Speed Uplink Packet Access (HSUPA), led to the development of the technology referred to as High Speed Packet Access (HSPA) or, more informally, 3.5G.

Motivated by the increasing demand for mobile broadband services with higher data rates and Quality of Service (QoS), 3GPP started working on two parallel projects, Long Term Evolution (LTE) and System Architecture Evolution (SAE), which are intended to define both the radio access network (RAN) and the network core of the system, and are included in 3GPP Release 8. LTE/SAE, also known as the Evolved Packet System (EPS), represents a radical step forward for the wireless industry that aims to provide a highly efficient, low-latency, packet-optimized, and more secure service. The main radio access design parameters of this new system include OFDM (Orthogonal Frequency Division Multiplexing) waveforms in order to avoid the inter-symbol interference that typically limits the performance of high-speed systems, and MIMO (Multiple-Input Multiple-Output) techniques to boost the data rates. At the network layer, an all-IP flat architecture supporting QoS has been defined. The world's first publicly available LTE service was opened by Telia Sonera in the two Scandinavian capitals Stockholm and Oslo on December 14, 2009, and the first test measurements are currently being carried out.

However, by the time the standard development started, the ITU-R framework for 4G systems was not in place, and later research and measurements confirmed that the system did not fully comply with ITU 4G requirements. For this reason, the term 3.9G has been widely used with the expectation of their evolving towards official 4G status in due course. Before 3GPP started working in the real 4G wireless technology, minor changes were introduced in LTE through Release 9. In particular, femto-cells and dual-layer beam forming, predecessors of future LTE-Advanced technologies, have been added to the standard. The formal definition of the fourth generation wireless, known as the

International Mobile Telecommunications Advanced (IMTAdvanced) project, was finally published by ITU-R through a Circular Letter in July 2008 with a call for candidate radio interface technologies (RITs) [1]. In October 2009, six technologies were submitted seeking for approval as international 4G communications standard. 3GPP's candidate is LTE-Advanced, the backward-compatible enhancement of LTE Release 8 that will be fully specified in 3GPP Release 10 [2]. By backward compatibility, it is meant that it should be possible to deploy LTE-Advanced in a spectrum already occupied by LTE with no impact on the existing LTE terminals. Other candidate technologies are IEEE 802.16m and China's Ministry of Industry and Information Technology TD-LTE-Advanced (LTE-Advanced TDD specification) [3, 4].

2. NETWORK ARCHITECTURE

3GPP specified in its Release 8 the elements and requirements of the EPS architecture that will serve as a basis for the next-generation networks [7]. The specifications contain two major work items, namely LTE and SAE, that led to the specification of the Evolved Packet Core (EPC), Evolved Universal Terrestrial Radio Access Network (E UTRAN), and Evolved Universal Terrestrial Radio Access (E-UTRA), each of which corresponds to the core network, radio access network, and air interface of the whole system, respectively. The EPS provides IP connectivity between a User Equipment (UE) and an external packet data network using E-UTRAN. In Fig. 1, we provide an overview of the EPS, other legacy Packet and Circuit Switched elements and 3GPP RANs, along with the most important interfaces.

In the services network, only the Policy and Charging Rules Function (PCRF) and the Home Subscriber Server (HSS) are included, for simplicity. In the context of 4G systems, both the air interface and the radio access network are being enhanced or redefined, but so far the core network architecture, i.e. the EPC, is not undergoing major changes from the already standardized SAE architecture. Therefore, in this section we give an overview of the E-UTRAN architecture and functionalities defined for the LTE-Advanced systems and the main EPC node functionalities, shared by Releases 8, 9, and 10.

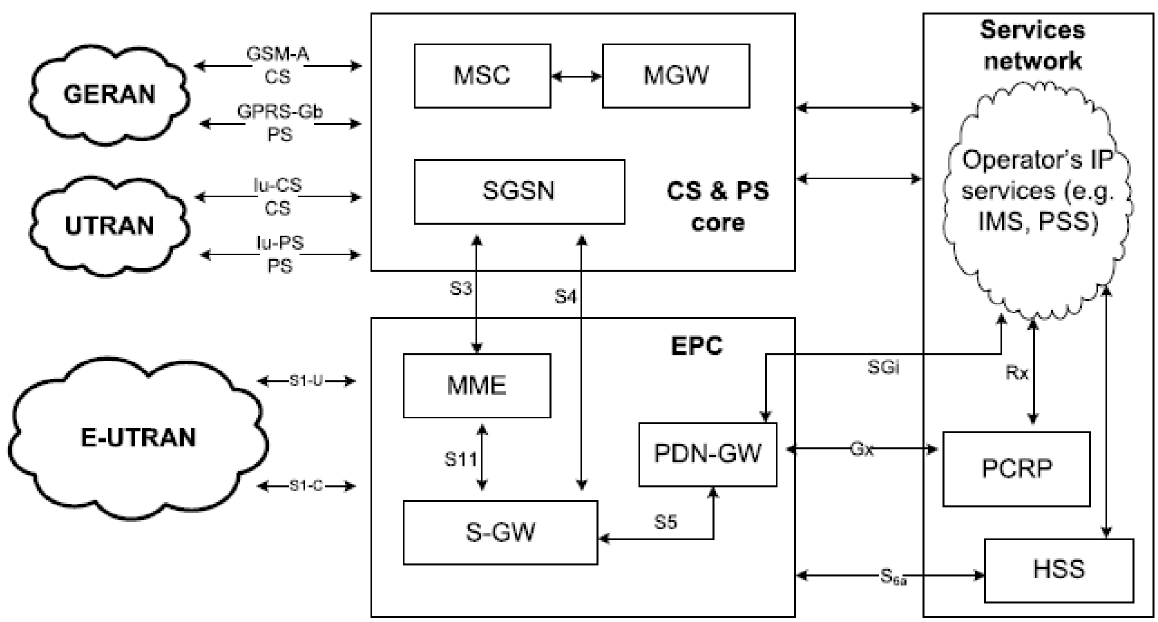

Fig. 1. Overview of EPS for 3GPP accesses (non-roaming architecture).

2.1. LTE-Advanced E-UTRAN overview

In Fig. 2, we show the architecture of E-UTRAN for LTE-Advanced. The core part in the E-UTRAN architecture is the enhanced Node B (eNodeB or eNB), which provides the air interface with user plane and control plane protocol terminations towards the UE. Each of the eNBs is a logical component that serves one or several E-UTRAN cells, and the interface interconnecting the eNBs is called the X2 interface. Additionally, Home eNBs (HeNBs, also called femtocells), which are eNBs of lower cost for indoor coverage improvement, can be connected to the EPC directly or via a gateway that provides additional support for a large number of HeNBs.1 Further, 3GPP is considering relay nodes and sophisticated relaying strategies for network performance enhancement. The targets of this new technology are increased coverage, higher data rates, and better QoS performance and fairness for different users.

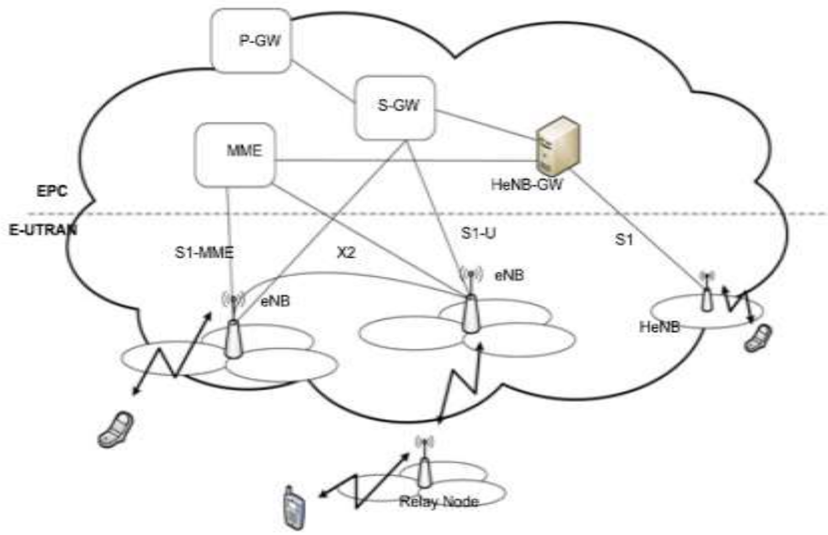

Fig. 2. LTE-Advanced E-UTRAN architecture.

As mentioned earlier, eNBs provide the E-UTRAN with the necessary user and control plane termination protocols. Fig. 3 gives a graphical overview of both protocol stacks. In the user plane, the protocols that are included are the Packet Data Convergence Protocol (PDCP), the Radio Link Control (RLC), Medium Access Control (MAC), and Physical Layer (PHY) protocols. The control plane stack additionally includes the Radio Resource Control (RRC) protocols.

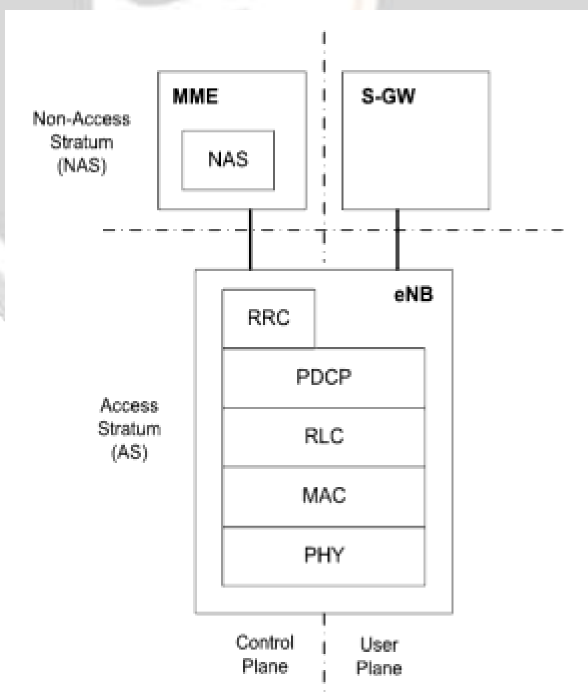

Fig. 3. Protocol stack.

2.2. Evolved Packet Core overview

The EPC is a flat all-IP-based core network that can be accessed through 3GPP radio access (UMTS, HSPA, HSPA+, LTE) and non-3GPP radio access (e.g. WiMAX, WLAN), allowing handover procedures within and between both access types. The access flexibility to the EPC is attractive for operators since it enables them to have a single core through which different services are supported. The main components of the EPC and their functionalities are as follows.

- Mobility Management Entity (MME)
  This is a key control plane element. Among other functions, it is in charge of managing security functions (authentication, authorization, NAS signalling), handling idle state mobility, roaming, and handovers. Also selecting the Serving Gateway (S-GW) and Packet Data Network Gateway (PDN-GW) nodes is part of its tasks. The S1-MME interface connects the EPC with the eNBs.
- Serving Gateway (S-GW)
  The EPC terminates at this node, and it is connected to the E-UTRAN via the S1-U interface. Each UE is associated to a unique S-GW, which will be hosting several functions. It is the mobility anchor point for both local inter-eNB handover and inter-3GPP mobility, and it performs inter-operator charging as well as packet routing and forwarding.
- Packet Data Network Gateway (PDN-GW)
  This node provides the UE with access to a Packet Data Network (PDN) by assigning an IP address from the PDN to the UE, among other functions. Additionally, the evolved Packet Data Gateway (ePDG) provides security connection between UEs connected from an untrusted non-3GPP access network with the EPC by using IPSec tunnels. From a user-plane perspective there are only the eNBs and the gateways, which is why the system is considered ‘‘flat’’. This results in a reduced complexity compared to previous architectures.

3. SPECTRUM AND BANDWIDTH MANAGEMENT

In order to meet the requirements of IMT-Advanced as well as those of 3GPP operators, LTE-Advanced considers the use of bandwidths of up to 100 MHz in the following spectrum bands (in addition to those already allocated for LTE) [12].

- 450–470 MHz band (identified in WRC-07 to be used globally for IMT systems).
- 698–862 MHz band (identified in WRC-07 to be used in Region 22 and nine countries of Region 3).
- 790–862 MHz band (identified in WRC-07 to be used in Regions 1 and 3).
- 2.3–2.4 GHz band (identified in WRC-07 to be used globally for IMT systems).
- 3.4–4.2 GHz band (3.4–3.6 GHz identified in WRC-07 to be used in a large number of countries).
- 4.4–4.99 GHz band.

3.1. Carrier aggregation

In order for LTE-Advanced to fully utilize the wider bandwidths of up to 100 MHz, while keeping backward compatibility with LTE, a carrier aggregation scheme has been proposed. Carrier aggregation consists of grouping several LTE ‘‘component carriers’’ (CCs) (e.g. of up to 20 MHz), so that the LTE-Advanced devices are able to use a greater amount of bandwidth (e.g. up to 100 MHz), while at the same time allowing LTE devices to continue viewing the spectrum as separate component carriers .It may not be always possible for an operator to obtain 100 MHz of contiguous spectrum. For this reason, the use of noncontiguous carrier aggregation is also proposed. In this case, the component carriers that are going to be aggregated can be noncontiguous in the same spectrum band or noncontiguous in different spectrum bands. In either case, several challenges need to be addressed before carrier aggregation can be successfully introduced, as discussed later.

3.1.1. Control channels

In order to utilize the available spectrum, devices must be able to access the control channels in the downlink and uplink frames (in addition to other reference signals). Hence, to keep backward compatibility with LTE devices, each component carrier must maintain its own control channels. On the other hand, if a service provider wants to support only LTE-Advanced devices, the control channels could be reduced from one set per component carrier (of up to 20 MHz) to one set per group of aggregated component carriers (of up to 100 MHz). The option of enabling/disabling the control channels and reference signals could allow a service provider to do a progressive

migration from LTE to LTE-Advanced, by controlling which spectrum bands are accessible to LTE and which to LTEAdvanced devices. For example, in [15], a layered control signaling structure is proposed where the signaling structure depends on the assigned component carriers.
In terms of scheduling, the resource assignment information (for DL and UL) can refer to resources within the same CC in which it was sent, or to resources in another CC. The first case is suitable for scenarios where the UE is configured to receive resource assignment information at each CC, and it can reliably receive it in each CC. On the other hand, the second case is suitable for scenarios where the UE is not configured to receive resource assignment information at each CC, e.g. when the bandwidth of the extra CCs is small or is only available to LTE-Advanced devices. The second case is also suitable for cases when it is not reliable to send resource assignment information in some CCs.

3.2. Research challenges

The use of wider bandwidths, multiple spectrum bands, and spectrum sharing introduces new challenges in terms of transceiver, signal processing, resource management, and error control mechanism design, among others.

3.2.1. Transceiver design

- The design of wideband transceivers will be affected by several factors, such as the following.
- Frequency-dependent path loss: As higher frequencies are used, the path loss increases nonlinearly.
- Doppler frequency and spectrum: At higher frequencies, the Doppler effects affect the signals more severely, which would require faster adaptation algorithms, increasing the overhead.
- Effective noise power: As the bandwidth increases, the effective noise increases as well.
- Receiver input signal: Using a wider bandwidth translates into receiving more undesired signals from other services (e.g. broadcast and radar signals). So, issues such as image rejection, reciprocal mixing have to be considered.
- Nonlinearities in analogue receiver components: Distortion and intermodulation create additional signals under overload conditions, which can affect the demodulation process.
- Reciprocal mixing: When undesired signals mix with the oscillator noise, additional noise is introduced into the receiver, resulting in an additional noise figure.
- Receiver performance: The performance of the receiver will be limited by all the previous listed elements.

3.2.2. Other aspects

Radio parameters, such as the number of carriers that are needed as guard bands between contiguous component carriers, must be optimized to achieve high utilization of the spectrum without degrading the performance. an initial investigation of the minimum spectrum distance (carrier guard band) between component carriers in contiguous spectrum bands was done. Even though 3GPP's initial deployment scenarios consider the use of up to five component carriers and up to three spectrum bands, it is reasonable to expect that more scenarios will be required and investigated.

4. COOPERATIVE MULTIPOINT TRANSMISSION AND RECEPTION FOR LTE-ADVANCED

Future cellular networks will have to simultaneously provide a large number of different users with very high data rates, and the capacity of the new radio access systems needs to be increased. Traditionally, in cellular systems each user is assigned to a base station on the basis of criteria such as signal strength. At the terminal side, all the signals coming from the rest of base stations in the form of interference dramatically limit the performance.
The user also communicates with a single serving base station while causing interference to the rest of them. Due to the interference limitation of cellular systems, the task of high data delivery cannot be accomplished by simply increasing the signal power of the transmission. Each base station processes in-cell users independently, and the rest of the users are seen as inter-cell interference whose transmission power would also be increased.
One strategy to reduce the performance-limiting interference is to reduce the inter-cell interference with the help of cooperative transmission. Cooperative Multipoint (CoMP) transmission and reception is a framework that refers to a system where several geographically distributed antenna nodes cooperate with the aim of improving the performance of the users served in the common cooperation area. It encompasses all required system designs to achieve tight coordination for transmission and reception. Cooperation among eNBs is characterized by the need of

an interconnection among the different nodes in the form of very-high-speed dedicated links. Optical fiber, wired backbone connection or even highly directional wireless microwave links could be some feasible examples. These low-latency links are essential for the success of the cooperative communication, although its design is a very challenging issue due to the large amount of data that may need to be exchanged among the nodes. LTE-Advanced will use the standardized interface X2 for these purposes. CoMP in the context of LTE-Advanced involves several possible coordinating schemes among the access points. Coordinated beam forming/scheduling is a simpler approach where user data are transmitted only from a single cell. Joint processing techniques, however, requires multiple nodes to transmit user data to the UE. Two approaches are being considered: joint transmission, which requires multi-user linear precoding, and dynamic cell selection, where data are transmitted from only one cell that is dynamically selected.
This section of the paper presents a broad overview of the architectures, approaches, and main challenges regarding CoMP in the context of LTE-Advanced. It is necessary to mention that most of these ideas are currently being studied and therefore may change throughout the standardization process.

5. The CoMP architecture

Coordination among eNBs is a very promising technique to reduce inter-cell interference in the network in both the downlink and the uplink. CoMP is applied in the downlink by performing a coordinated transmission from the base station, whereas interference in the uplink can be reduced by means of a coordinated reception in eNBs. Most of the CoMP approaches share the requirement of needing some scheduling information regarding the users at the different base stations that must be shared among them.
This means that very-low-latency links are required so that information can be exchanged between coordinated nodes in the order of milliseconds.
Two kinds of architecture can be distinguished with respect to the way this information is made available at the different transmission points as described: centralized and distributed CoMP. Both types of architecture can be combined with any of the different CoMP transmission schemes that will be presented, although the degree of complexity to implement them may vary from one scheme to the other.

5.1. Centralized architecture

In a centralized approach, a central entity is needed in order to gather the channel information from all the UEs in the area covered by the coordinating eNBs. This entity is also in charge of performing user scheduling and signal processing operations such as precoding. Furthermore, tight time synchronization among eNBs is needed and user data need to be available at all collaborating nodes. On the downlink of FDD systems the UE needs to estimate the channel and derive channel coherent or non-coherent indicators (CSI/CQI) to feed back to the eNB. In TDD systems, the channel information can be obtained by using channel reciprocity. depicts the centralized framework for coordination among different base stations. In the case of FDD operation, terminals must first estimate the channel related to the set of cooperating eNBs. The information is fed back to a single cell, known as the anchor cell, which acts as the serving cell of the UE when coordination is being employed.
Once the information is gathered, each eNB forwards it to the central entity that is in charge of deciding the scheduling and the transmission parameters, and this new information is sent back to the eNBs.
The main challenges of this architecture are related to the new associated communication links between the central entity and the eNBs. They must support very-low latency data transmissions and in addition communication protocols for this information exchange must be designed.

6. CONCLUSIONS

LTE-Advanced, the backward-compatible enhancement of LTE Release 8, will be fully specified in 3GPP Release 10. It has already been submitted as 3GPP's 4G candidate radio interface technology to ITU-R. We have described its main technologies: carrier aggregation, enhanced MIMO, cooperative multipoint transmission and reception, and relays. For each one, we have examined their benefits, challenges, and some existing approaches to tackle these challenges. However, several issues in each of them are still open and require further research.
It is the combination of these technologies, and not just a single one, that will enable achieving the target performance requirements established by IMT-Advanced. The development and integration of this elements will not end with 3GPP Release 10, but will provide the starting point for their implementation.

In addition to the elements that we have examined in this paper, it is also expected that the use of femto-cells, self-organizing networks, and energy management systems will drive the evolution of current and future mobile wireless networks.

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BIOGRAPHIES

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