

Verification and Validation of Long-Term Evolution Advanced Model using Network Simulator

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Abstract—LTE-Advanced was accomplished in late of 2010 and it enhanced the LTE spectrum flexibility over carrier aggregation, further its extended multi antenna broadcast, where that introduced a supporting for the relaying and provided an enhancement in the part of inter-cell interference coordination in heterogeneous network utilizations. Recently, LTE-Advanced network is the promised candidate for 4G cellular systems to run into top rates of data reaches to 100 Mbps with high mobility and 1Gbps with low mobility, where that are wanted in 4G system. Furthermore, LTE-Advanced must be capable to upkeep broader bandwidth than it provided by LTE. This article offered the prediction model with the characterization and the main components of LTE-Advanced further to the key features with the full configurations and the simulation tools to modeling the traffic links using network simulator 2 (NS-2).

Index Terms— NS-2, LTE, LTE-Advanced.

I. INTRODUCTION

The Private requirements and targets for LTE Release-10 and these requirements/targets are extended to the requirements and targets of the International Telecommunication Union (ITU) to be more aggressive. In addition, Release-10 includes supplementary requirements. One of the main requirements was backwards compatibility.

Fundamentally, that's mean an earlier release of LTE terminal must always be capable to access a carrier supporting of Release-10 functionality, though clearly not be able to employ all the features of Release-10 of this carrier [1]. LTE specified by 3GPP as very high flexible for radio interfacing. LTE deployment started in the last of 2009.

The first LTE release is providing greatest rate reaches to 300 Mbps, delay of radio network not as much of than 5 msec, a spectrum significant increasing in efficiency of spectrum if comparing with any other cellular systems, and a different regular architecture in radio network that is designed to shorten the operations and to decreasing the cost [2]. LTE systems are supporting Frequency Division Duplex (FDD) with Time Division Duplex (TDD) technique as a varied array of bandwidths to operating in a wide amount of dissimilar spectrum allocations. The standardization of LTE in 3GPP is gotten an established state, and the modifications in the design are narrow. Form the end of 2009, the LTE system has been installed as a normal growth of Global System for Mobile communications (GSM) and Universal Mobile Telecommunication System (UMTS).

The ITU has devised the IMT-Advanced term to recognize the new mobile systems that capable to going beyond IMT 2000 (International Mobile Telecommunications). Exactly, the requirements of data rate have been amplified. To providing applications and other advanced facilities, then, 1 Gbps for low and 100 Mbps for high mobility scenarios should be comprehended. Since 2009, 3GPP has operated on a research with objective to identify the required enhancements for LTE systems to achieve the requirements of IMT-Advanced. In September 2009, the partners of 3GPP have prepared the official suggestion to the proposed new ITU systems, represented by LTE with Release 10 and beyond to be the appraised and the candidate toward IMT-Advanced.

II. LTE-A FEATURES

After attaining the requirements, the main object to bring LTE to the line call of IMT-Advanced is that IMT systems must be candidates for coming novel spectrum bands that are still to be acknowledged [3]. LTE-Advanced is applying various bands of spectrum, which are already valid in LTE along with the future of bands of IMT-Advanced. More developments of the spectral efficacy in downlink and uplink are embattled,

specifically if users serve at edge of cell. In addition, LTE-Advanced aims quicker exchanging between the resource of radio states and between additional enhancements of the figures of latency. All at once, the bit cost must be decreased [4].

IMT-Advanced represents the next generation in systems of wireless communications, which aim to accomplish other main advance of the current third generation systems, by reaching to uplink (UL) rate of 500 Mbps and to 1Gbps in downlink (DL). To achieve this goal, the society of 3GPP is presently evolving LTE-Advanced as a development of the standard of LTE [5]. With LTE-Advanced starting, there are many key of requests and features that are up come to the light. It not considered in system specifications yet, there are various high level purposes for the new specifications of LTE-Advanced. Its need to verifying and much effort rests to be accepted before going fixed it in the specifications. Presently, several of the core significant intentions for LTE-Advanced can be illustrated below [6]:

- The data rate with peak uplink of 500 Mbps and peak downlink of 1 Gbps.
- Provide spectrum efficiency with more than three times that provided by LTE.
- Offer spectrum efficiency in uplink 15 bps and in downlink 30 bps.
- The spectrum using the capability to backing the scalable bandwidth and the aggregation of spectrum where non-contiguous spectrum is need to using.
- The link latency in case from idle status to connected status are a smaller than 50 msec and less than 5 msec for one-way in single packet transferring.
- The throughput of edge of user cell to be doubles that in LTE.
- The average throughput of any user is to be triple that in LTE.
- The mobility environments are the similar that used in LTE.
- It can provide compatibility by interworking with 3GPP and LTE.

III. LTE-A ARCHITECTURE

3GPP identified in Release 8 the requirements and features, and requirements of the architecture of Evolved Packet Core (EPC) which that serving as a base for the next generation systems. This identification specified two main work objects, called LTE and System Architecture Evolution (SAE) that leading to the description of EPC, Evolved Universal Terrestrial Radio Access Network (E-UTRAN), and Evolved Universal Terrestrial Radio Access (E-UTRA). Each of them is

correspond respectively to the network core, system air interface, and the radio access network. EPC is responsible to provide IP connection between an external packet data network by using E-UTRAN and the User Equipment (UE).

In the environment of 4G systems, the radio access network and the air interface are actuality improved, while the architecture of core network (i.e., EPC) is not suffering large modifications from the previously systematized architecture of SAE. In Fig. 1, E-UTRAN architecture of LTE-Advanced is shown.

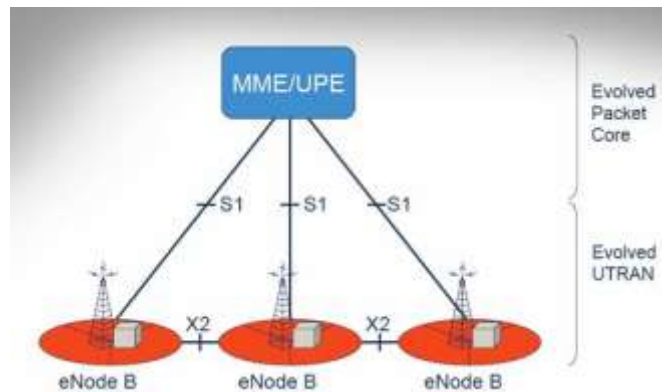


Fig. 1 LTE-Advanced with E-UTRAN and EPC architecture

The main part in the architecture of E-UTRAN is the improved Node B (eNB or eNodeB), that is provide the air interface between the control plane protocol terminations and the user plane towards user equipment. Each one of the eNodeBs is a logical element that serving one or more E-UTRAN cells and the interfacing between the eNodeBs is termed the X2 interface. Completely, the interfaces of network are built on IP protocols. The eNodeBs are connected by an X2 interface and to the MME/GW (Mobility Management Entity/Gateway) object by an S1 interface as illustrated in Fig.

The interface S1 is support a many relationship between eNodeBs and MME/GW. The functions splitting between MME/GW and eNodeB and is shown in Fig. 2 [7].

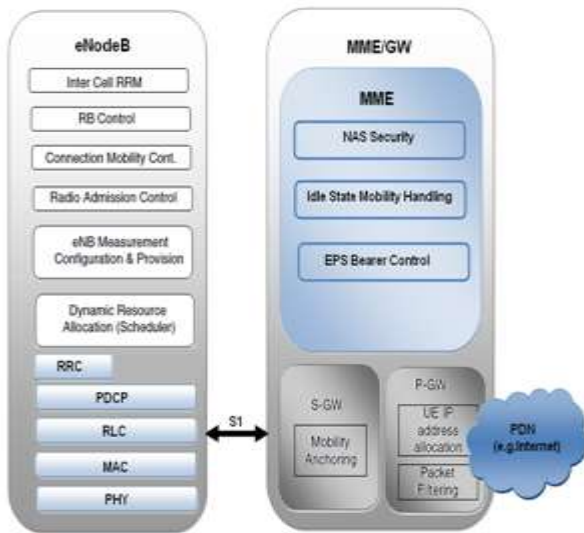


Fig. 2 Functions splitting between MME/GW and eNodeB

The two entities of the logical gateway are termed Serving Gateway (S-GW) and the other is Packet Data Network Gateway (P-GW). The Serving Gateway (S-GW) is act as limited anchor for the mobility service to receiving and forwarding packet rates from and to the eNodeB to serve the UE, while the P-GW is interface with the exterior Packet Data Networks (PDNs) for example the Internet Multimedia Server (IMS) and the Internet. P-GW provides other IP functions such as packet filtering, routing, policy statement, and address allocation. The MME is an entity to provide signaling only and later the user packets of the IP do not pass over the MME. The main benefit of separating the network entities is for indicating if the capacity of network for traffic and signaling can independently grow. Actually, the core tasks of MME are to idle mode the reachability of UE together with controlling the retransmission of paging, roaming, authorization, P-GW/S-GW selection, tracking area list management, bearer management including dedicated bearer establishment, authentication, security negotiations and signaling of NAS [7].

The eNodeB is implementing the functions of eNodeB along with protocols usually applied in Radio Network Controller (RNC). The eNodeB functions are ciphering, packet reliable delivery, and header compression.

But in controlling side, eNodeB is incorporating functions such as:

- Radio resource management (radio bearer control, radio admission and connection mobility control, dynamic scheduling).

- Routing user plane data towards SAE Gateway.

Several benefits by using one node in the network accessing are to reducing the latency and the RNC processing distribution load in to many eNodeBs. The stack of user plane protocol is shown in Fig. 2. From the Fig. 2, the Radio Link Control (RLC) and the Packet Data Convergence Protocol (PDCP) layers usually concluded in RNC on the network side are now concluded in eNodeB. The control plane protocol stack demonstrates in Fig. 2, where the Radio Resource Control (RRC) functional conventionally applied in RNC is integrated in to eNodeB. The layers of Medium Access Control (MAC) and RLC are implementing similar roles to user plane. The RRC functions are include paging, system information broadcast, radio bearer control, connection management for RRC, measurement reporting to UE, and mobility functions. In the MME network side, the Non-Access Stratum (NAS) protocol is terminated while on the terminal side, the UE executes functions such as Evolved Packet System (EPS), authentication, security control, and bearer management.

In details, S1 interfacing is separating the EPC and the E-UTRAN. It is splitting in to two interfaces; the first is S1-U that is transfers traffic data between S-GW and the eNodeB, and the second is S1-MME that is a signaling the interface between the MME and eNodeB. In other hand, the X2 is the interfacing between the eNodeBs and involving two interfaces; the first is X2-C, which is the control plane interface between eNodeBs, and X2-U, is the user plane interface between eNodeBs. It is supposed that always there is an X2 interface between eNodeBs, which is to provide communicating between each other [8]. S1-MME represents the S1 control plane interfacing between MME and eNodeB. Similarly, the transport network layer and user plane is based on IP transport and in case of reliable transport to the signaling messages; the Stream Control Transmission Protocol (SCTP) is applied over IP top. These protocol functions analogously to Transmission Control Protocol (TCP) confirming reliable, in sequence transmission of all messages with congestion control.

The signaling protocol of application layer are mentioned to as X2 application protocol (X2-AP) and S1 application protocol (S1-AP) for X2 and S1 interface control planes correspondingly.

In S1 interface (and the same applies to the X2 interface described below), SCTP/TCP is used over the usual IP network layer. There is only one association per instance of S1 interface (or eNodeB to MME relation). Over this association, one SCTP (or TCP) stream is used for all common procedures – such as the paging procedure – between two pieces of equipment. Regarding all dedicated procedures – which include all procedures, which apply to a specific communication context – they all are supported over a limited number of SCTP streams [9].

IV. PREDICTION MODEL OF LTE-ADVANCED

The requirements and expectation of forthcoming wireless communication networks remain to develop and grow. Thus, the test of the behavior of protocols or any other components of these networks requires providing an experiment model for the candidate networks to ensure its performance over different scenarios. The modeling and simulation is an operative method to exploration the difficulties and resolve the problems because the modeling is easy to create an experiment scenarios and low-cost in varying experiment arrangements and executing many test scenarios. This section introduces how to figure a precise enough traffic model of LTE-Advanced.

The proposed model of LTE-Advanced based on the structure of LTE/SAE where the architecture of it represents a challenge in the future of wireless broadband. The LTE/SAE presents an advanced radio interfacing with main improvement upcoming from using of Orthogonal Frequency Division Multiplexing (OFDM) with compound antenna technique [10]. These technologies previously exist and in employment in WiMAX as itemized in IEEE 802.16. Sideways with the advanced radio interfacing, LTE/SAE states the development in the architecture of network.

E-UTRAN is the authorized 3GPP name for the radio access network of LTE/LTE-Advanced. In Fig. 1, X2 interface between eNodeBs carries the traffic of user plane (X2-U) and control plane (X2-C). The core network contains control plane elements MME with S1 control plane (S1-C) traffic and user plane gateways S-GW with S1 user plane (S1-U) traffic. The X2 interfaces are a straight communication among eNodeBs. These interfaces will be used for control plane and bursts of user plane traffic through handover event. Presently, the estimations specify that the mutual X2-C and X2-U traffics could be between %4 and %10 of the core facing bandwidth (S1-U) and the propagation delay must be less than 30 msec. These traffics are of the highest significance, and it is clear for LTE-Advanced that additional user plane traffic will negotiate these interfaces. Furthermore, in LTE-Advanced specifications, there will be strict latency necessities required to apply the features for

example, cooperative Multiple Input Multiple Output (MIMO). The requirements in the area of 10 msec latency are presently being considered. That means, the time compassion will increment and maybe there are other value to route these requirements locally specifically in areas of upper network latency.

In LTE-Advanced systems, may a different base stations are cooperated together using the X2 interface, where this interface is simply a logical one and so it's not guaranteed that there is continuously a straight link among cooperating sites [4]. Therefore, structure of the network possibly will have to be adjusting by the operator to allow the effective application of the schemes for Coordinated Multipoint (CoMP) in practice. The Coordinated Multipoint (CoMP) techniques used in reception and transmission are built on the cooperation among different base stations via fast backhaul network to meaningfully enhance the interference condition and consequently the whole system performance. In the downlink, this attitude can be used for comprehending cooperative transmission, such as, where an UE is instantaneously served by many base stations. In this way, not only the strength of the signal proposed for the corresponding UE can extensively improve, but also the interference creating from transmission to other UEs can be decreased. Nevertheless, in common multiple UEs must be mutually served by a set of cooperative cells. In other side, in the uplink, the supporting of CoMP procedures is generally considered as employment detailed issue and for several schemes, it is essentially satisfactory to systematize the data switched by the X2 interface only.

V. LTE-ADVANCED TRAFFIC TYPES

Many traffic types are held from the eNodeB and each one might have different transmissions, security requirements, and connectivity will be gave direction en route for different network elements. The traffic types include:

- S1-u traffic intended to SGW.
- S1-c traffic intended to MME.
- X2-c and X2-u traffics intended to other eNodeBs.
- Operations Support System (OSS) traffic intended to the core applications that deliver fault, performance management, and configurations.
- Traffic of the network synchronization.

VI. MODEL CONFIGURATION

When using (NS-2) [11], the resources of data in the network is accessible, therefore the performance of the network session can be simply investigated. In addition, NS-2 is permitted and

the source code is opened, also it's appropriate to figure the simulation in any level of the network, thus it is installed to simulating LTE-Advanced. In network modeling, many of configuration parameters of the proposed network can simply be altered using TCL such as change the number of UE used and the bandwidth among network components. In other hand, some of other parameters cannot be easily to change it within simulation scenario because of the limitations in the model implementation, such as the number of eNodeB and aGW [10]. In LTE-Advanced, E-UTRAN part be made up of eNodeBs, providing the EUTRAN control plane (RRC) and user plane (PDCP/RLC/MAC/PHY) protocol terminations on the way to the UE. The eNodeBs are connected to each other via X2 interface, and these eNodeBs are too interconnected to the EPC via S1 interface. The S1 connection interface is support the relationship among MMEs/S-GWs and the eNodeBs. The E-UTRAN architecture is illustrated in Fig. 1. The core of the

architecture of SAE is the EPC, where the EPC will serve as correspondent of GPRS networks using the S-GW, MME and P-GW.

The proposed LTE-Advanced model based on LTE/SAE network model, with the traffic flow control model. The proposed model consists of the following main elements:

- A server to offer FTP and HTTP to signaling services.
- Two routers point represents an aGW to offer flow control to the data stream.
- Three eNodeBs as base stations to provide flow control information to UEs.
- Thirty UEs are connected to the eNodeBs which distributed by 10 UEs for each eNodeB.
- Fig. 3 shows the simulated LTE-Advanced model with main elements and links.

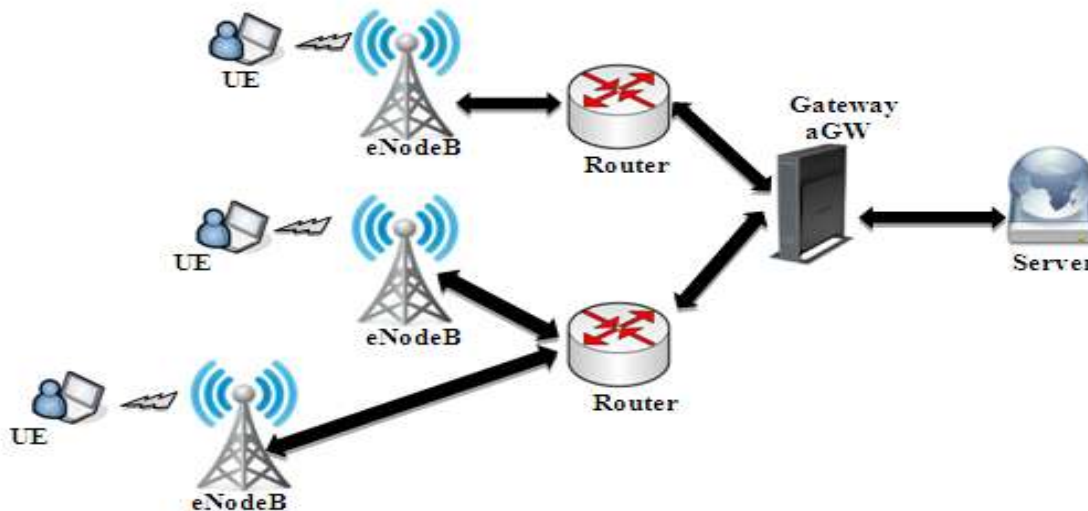


Fig. 3 Proposed simulation topology

VII. MODEL PARAMETERS

The proposed topology consists of three eNodeBs, which are connected to the access routers, Router 1 and Router 2 with 20 Mbps bandwidth link. The Gateway (aGW) represents the network core includes the MME/SAE where it connected to the access routers with large bandwidth link of 1Gbps and with the server with 100 Mbps. Each eNodeB interconnected with 10 UEs with 2 Mbps bandwidth, so the total UEs used in this scenario become 35 and all used wired link instead of wireless due to the proposed UE not have full mobility features to avoid the handover scenario that may happen if the one or more UE move from one eNodeB to another. In fact, the assumption of use wired UEs to achieve high data streaming between each UE and the server or to other UE, while the wireless assumption of UEs cannot provide high congestion network where that represents a major goal to test the developed congestion control mechanism. However, the using of full mobility feature of UE will be a continued project to this research to develop a new congestion control technique taking into account the probability of handover over LTE-Advanced. For each link in proposed model, it's necessary to assign the bandwidth and the propagation delay (latency). Actually, in LTE-Advanced (and LTE) networks we should expected low latency connection because it one of the main requirement of IMT-Advanced where the latency has come to be a significant performance pointer in wireless communication systems. Practically, in first release of LTE, it provides a radio-link delay of less than 5 msec [2]. One of the proposed techniques to enhance the latency in LTE-Advanced are by immediate processing of RRC and NAS requirements at the eNodeB, decreasing the delay in message processing at different nodes, and decreasing the Random Access Channel (RACH) and Physical Uplink Control Channel (PUCCH) duration. There are two categories of latency are defined. The first is the control plane latency where that related with the connection setup latency. The second is the user plane latency, which related with the transferring delay in RAN [12]. Idyllically, for best circumstance scenario, the latency of all links in proposed LTE-Advanced model set to 3msec where this value represents the best latency expected for any developed LTE network and to achieve high-speed link over the simulated model to experiment the all expected risks and degradation may cause by the new congestion control mechanism. But in applied scenarios, it is sensible to adopt an extra delay of 10 msec for S1-C transfer delay plus MME processing of NAS application.

The schemes of queue management can generally distribute into two sets. The first scheme uses the immediate queue size such as Drop-Tail. The second scheme advocates elements of averaging the queue size such as Random Error Detection (RED) queue. Actually, Drop-Tail queuing is the simplest queue management strategy where its drop totally the inward packets when the buffer is filled.

For this reason, it is suitable to choose Drop-Tail queue to support the model access links. The proposed LTE-Advanced model can uses several TCP source variants such as Tahoe, Reno, Newreno, Vegas, Sack, and Fack, plus STCP but only one variant can be used in each scenario. The maximum advertised window size sets 48 Kbytes and the maximum TCP/IP packet size sets to 1500 Bytes [13] while the maximum TCP's window size set to different values to monitor the behavior in slow-start phase. Table 1 shows the links parameters of the proposed model including the bandwidth and propagation delay for each link while Table 2 illustrates the other simulation parameters.

VIII. TOPOLOGY ANIMATION

It's important to demonstrate the traffic session after the links and nodes of the topology establish. In NS-2 simulation, all the data in the network is available, thus the performance of the network can be easily analyzed. NS-2 is free and open source code and suitable to build system level simulation, so it is deployed to simulate LTE/SAE, or any other network [14]. Additionally, NS-2 is the most popular one in academia because of its open source and plenty of component's libraries. Many non-benefit organizations contribute a lot in the component's library, and it has been proven that the development mode of NS2 is very successful [15][16]. Fig. 4 shows the screenshot of the real animation of the proposed model using NS-2 where the green node represents the server, which connected to the gateway directly. The two routers connected to aGW with 1 Gbps and 3 msec link parameter where these two links represents the bottleneck of the model. The first router is linked with base station and the second is linked with two base stations, eNB2 and eNB3[17][18]. Each base station is connected with ten UEs to obtain 35 UEs, which connected to these three eNBs. The black nodes represent a UE nodes and all has similar link parameter of 2 Mbps as a bandwidth and 3 msec as latency.

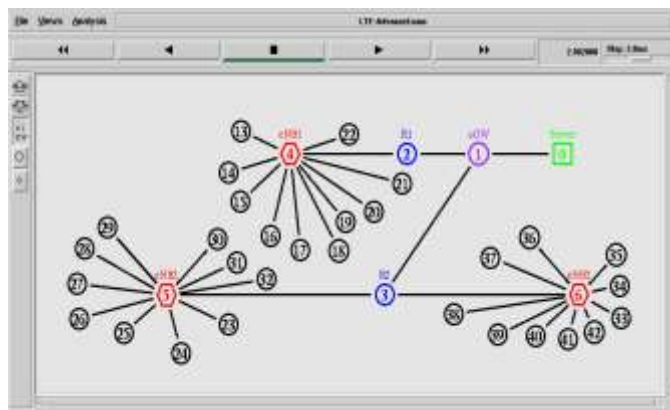


Fig. 4 Screenshot of LTE-Advanced model animation in NS-2

IX.

X. CONCLUSION

This paper provides the full details of the layering, architecture, and the configurations of the traffic model for LTE-Advanced networks. After explaining the development from LTE to LTE-Advanced, the paper focused on the benefits and the key features of it and illustrated how LTE-Advanced will become the major cellular system for the users in next decade. The architecture of E-UTRAN and EPC are specified in details with the links interfacing between the different elements of the network. The main contribution of this article is to present and configure the traffic model of LTE-Advanced using NS-2 simulator. Then, the simulation parameters also identified with all links parameters in sides of bandwidth and propagation delay. In fact, this paper tried to provide an efficient model of LTE-Advanced to assist the researchers to experiment the developed items of this network over different conditions and situation such as improve the congestion control algorithm for the protocol used or to derive new technique to minimize the handover among base stations.

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