2011 Third International Conference on Computational Intelligence, Communication Systems and Networks

Traffic Modeling of LTE Mobile Broadband Network Based on NS-2 Simulator

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Abstract— **Recently, Long-Term Evolution (LTE) is the result of ongoing work by the Third Generation Partnership Project (3GPP) toward Fourth Generation (4G) systems. LTE will be used for mobile, fixed and portable wireless broadband access, and will offer several benefits to operators, aimed at increasing capacity, reducing network complexity and thus lowering deployment and operational costs. It will enable operators to meet the growing demand for mobile data solutions, making it possible for richer services to be delivered to consumers more cost effectively. The targets for LTE indicate bandwidth increases as high as 100 Mbps on the downlink, and up to 50 Mbps on the uplink. However, this potential increase in bandwidth is just a small part of the overall improvement LTE aims to provide. This study illustrates the model and representation of LTE links and traffics using NS-2 network simulator and observation of TCP Reno performance investigated. The Evaluation of the network performance with TCP Reno is mainly based on congestion window behavior, throughput, average delay and lost packet.**

Keywords– LTE; EUTRAN; 3GPP,SAE; TCP; NS-2

I. INTRODUCTION

Next-generation and new wireless technologies such as WiMax and LTE, provide very high rates of data of several Mbps to mobile users. Then, the mobile users will come to expect better peak performance from the networks than from current mobile networks. LTE is intended to be a mobile-communication system that can takes the telecom industry into the 2020's. The core network is focused on the packet-switched domain, migrating away from the circuit-switched network.

LTE will provide significantly increased peak data rates, with the potential for 100 Mbps downstream and 50 Mbps upstream, reduced latency, scalable bandwidth capacity, and backwards compatibility with existing GSM and UMTS technology. The System Architecture Evolution (SAE) core network architecture significantly enhances the core network performance while ensuring interoperability with previous networks such as High Speed Packet Access (HSPA). Hence LTE will be very convincing for network operators that already have HSPA networks running [1].

The LTE standard was first published in March of 2009 as part of the 3GPP release-8 specifications. Comparing the performance of 3G and its evolution to LTE, LTE does not offer anything unique to improve spectral efficiency, i.e. bps/Hz. LTE improves system performance by using wider bandwidths if the spectrum is available [2]. Universal Terrestrial Radio Access Network Long-Term Evolution (UTRAN LTE), also known as Evolved UTRAN (EUTRAN) is a new radio access technology proposed by the 3GPP to provide a very smooth migration towards 4G networks [3]. EUTRAN is a system currently under development within 3GPP. LTE systems is under developments now, and the TCP protocol is the most widely used protocol for wired and wireless systems, although TCP was not originally designed for real time applications and not for wireless networks then, we need to develop a new TCP mechanisms, or at least choose a suitable TCP variant for each new network, to be more efficient and more reliability with this network.

In this paper, we presented a model of LTE systems with all links, traffics, nodes, and terminals and test the performance of this model with TCP Reno using one of the better network simulators, NS-2 [4].

The rest of this paper is organized as follow. Section II describes the details of LTE network architecture with main parameters and requirements. TCP over LTE networks will discuss and comment in section III. The modeling of LTE and topology simulation will presents in Section IV. The performance evaluation and analysis will explain in Section V. The Last Section VI concludes the paper.

II. LTE NETWORK ARCHITECTURE

Developed by 3GPP, LTE is the leading Orthogonal Frequency-Division Multiple Access (OFDMA) wireless mobile broadband technology. LTE offers high spectral efficiency, low latency and high peak data rates. LTE leverages the economies of scale of 3G, as well as the ecosystem of infrastructure and devices vendors to provide the highest performance in a cost effective manner [2].

The notion of LTE technology depends on the understood that it improves system performance in terms of data rate, throughput, latency, coverage and cost. LTE offers a pure packets assigned architecture, with viability of the movement management.

The latest step being studied and developed in 3GPP is an evolution of 3G into an evolved radio access referred to as the LTE and an evolved packet access core network in the System Architecture Evolution (SAE) [5]. In this section, architecture for LTE/SAE introduced. So, the architecture which is considered for 3GPP is shown in Fig. 1.

978-0-7695-4482-3/11 $26.00 © 2011 IEEE
DOI 10.1109/CICSyN.2011.36

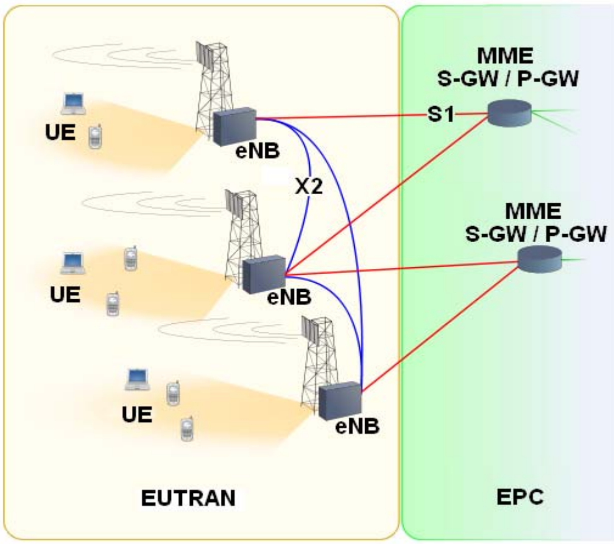

Fig. 1 E-UTRAN and EPC Architecture

E-UTRAN architecture based on, eNB-1, eNB-2, and eNB-3 acts as a base station, and called E-UTRAN Node B. MME represents the Mobility Management Entity. S-GW is a serving gateway, and last, P-GW is a PDN (Packet Data Network) Gateway. Each eNB are connected to the MME/SAE Gateway by the S1 interface where as X2 interface is interconnecting the eNBs. The X2 interface is used also on U-plane for temporary user downlink data. The main functions of the eNB are: (1) radio resource management (radio bearer control, radio admission and connection mobility control, dynamic scheduling) and (2) routing user plane data towards SAE Gateway. The main task of MME/SAE Gateway is to distribute the migration of messages to eNBs; security control; encryption of user data, switching of U-plane to support of UE mobility; idle mode mobility handling [6].

Fig. 2 shows the interface protocol stacks of S1 and X2. We used the same block diagram for two interfaces because it is similar, where the term (S1, X2 - AP) means that (S1-AP) or (X2-AP).

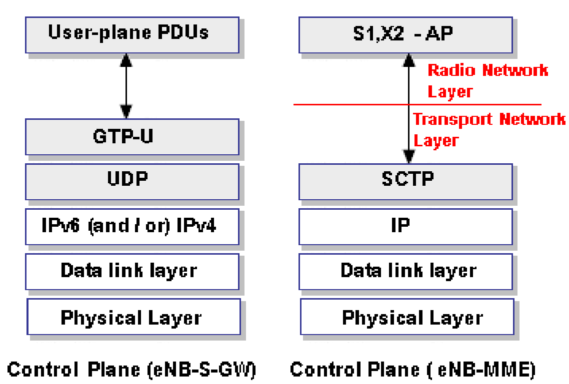

Fig. 2 (S1 and X2) Interface User and Control Planes

The S1 user plane interface (S1-U) is defined between the eNB and the S-GW. The S1-U interface uses GTP-U (GPRS Tunneling Protocol-User Data Tunneling) on UDP/IP transport and provides non- guaranteed delivery of user plane PDUs between the eNB and the S-GW.

The S1 control plane interface (S1-MME) is defined as being between the eNB and the MME. Similar to the user plane, the transport network layer is built on IP transport and for the reliable transport of signaling messages SCTP (Stream Control Transmission Protocol) is used on top of IP. The SCTP protocol operates analogously to TCP ensuring reliable, in-sequence transport of messages with congestion control. The application layer signaling protocols are referred to as S1 application protocol (S1-AP) and X2 application protocol (X2-AP) for S1 and X2 interface control planes respectively [7].

The main other part of LTE/SAE architecture, represented by EPC (Evolved Packet Core). The term LTE encompasses the evolution of the (UMTS) 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. The E-UTRAN and EPC together set up and release bearers as required by applications.

The basic three nodes of the EPC are: PDN Gateway (P-GW), Serving Gateway (S-GW), Mobility Management Entity (MME), and this permit to EPC to be the core of network (called EPC in SAE) and it is responsible for the overall control of the UE.

LTE, 3GPP is also defining IP-based, flat network architecture. This architecture is defined as part of the (SAE) effort. The LTE/SAE architecture and concepts have been designed for efficient support of mass-market usage of any IP-based service.

III. TCP OVER LTE SYSTEMS

TCP is designed in early days of ARPANET specifically for wired networks, shows poor performance over wireless channels, mainly due to high error rates [8]. In order to compensate wireless errors, LTE employs error recovery techniques at the link layer, which partially overlap with error recovery performed at the transport layer of TCP/IP. LTE assumes that the end-to-end TCP governs the congestion control and adapts to the varying network conditions and handle packet loss [9].

In addition, LTE systems are support a good concept of QoS (Quality of Service) on radio and transport network, in other hand, no flow control mechanisms are supported, and this will cause some dropping in packet while congestion period at any terminal or node. So, we know that each variant of TCP, have a private behavior in congestion period, then we need to monitor each variant and analysis the performance through LTE system to choose – develop or modify- the best TCP that will be more efficient over LTE system. However, development of TCP over LTE, or any other network with large bandwidth, and delay variation, with high rate of packets lost, will remain the main challenge.

TCP over LTE is expected to improve substantially end-user throughput, cell capacity, and transmission latency. Given the popularity of the Transmission Control Protocol TCP, and Internet Protocol (IP) for carrying all types of traffic, LTE supports TCP and IP-based traffic with end-to-end quality of service [10]. There are many parameters to evaluate TCP performance in any network topology, such as, effective throughput, throughput variation, file transfer time, round trip time (RTT), delay variation, fairness, buffer space, and transmission power, so, in our evaluation we will choose three metrics, one of them is the effective bandwidth. This metric of performance evaluation depends on the rate of data transmission over the application in bps, which is more significant than the communication channel throughput, since it takes into account the effective amount of data delivered at the TCP layer.

IV. MODELING AND SIMULATION

The traffic model designed for an LTE system is generally more complex in nature than the traffic model used for a GSM or 3G system. In an LTE system, the mobility management entity (MME) and the system architecture evolution (SAE) gateway communicate with the eNB by way of an S1 interface. For traffic transport, the S1 interface employs the hub-and-spoke model, which is similar to the traffic model of Iub interface in a 3G system. An X2 interface is used between eNBs in the LTE system to ease the SAE gateway traffic load caused by frequent handover. However, using this type of interface greatly increases the complexity of the traffic model for backhaul networks, as shown in Fig. 1.

Theoretically, each eNB must have a direct physical or logical link with its neighboring eNBs in order to support X2 interfaces, if connection-oriented technology is used. However, physical or logical links tend to multiply exponentially, thereby making this type of solution unaffordable in terms of cost and management. Since X2 interface capability is an outgrowth of connectionless technology, this necessitates the use of L3 routing in the backhaul network.

Before describing the model requirements and configuration, and because we used the network simulator, NS-2, we must explain, NS-2 is a discrete event simulator targeted at networking research. NS-2 provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks [4].

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. In our research, we used NS-2 version 2.32 , and this version, can installed over Windows Xp with using Cygwin, where Cygwin provides a Linux-like environment under Windows, because NS-2 already supported a Linux operating system only, then we need to get a virtual environment.

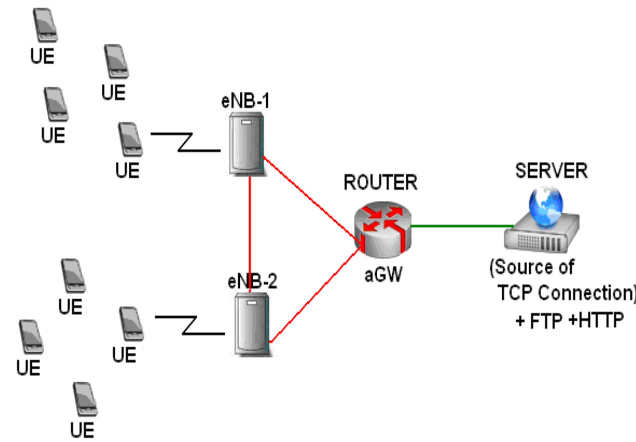

Fig. 3 Proposed Topology

Fig. 3 shows the proposed model for this research. It consists from one server for serving FTP and HTTP, and to provide a source connection for the TCP link over the topology. The router aGW, connected to the server with duplex link (two ways) and DropTail, with bandwidth of 100 Mbps, and propagation delay of 2 msec. The main job of aGW router is to control the flow rate of the streaming data from server to eNB-1, and eNB-2, so these two nodes, responsible for buffering the data packets for User Equipments UEs. Each eNB, connected to the corresponding aGW through wired simplex link (one way) of 10 Mbps bandwidth and 2 msec delay.

The other main parameters of proposed LTE topology illustrated in Table 1, and we can note that all link kept for one propagation delay of 2msec, and the maximum packet size of TCP was set to 1500 Byte, with minimum window size of 48 Kbytes. The simulation and the requirements of performance evaluation divided in to two parts, one deals with the system modeling animator (represented in nam file) as shown in Fig. 4, and the other parts deals with using the graph ability of NS-2 to analysis and monitoring the behavior of throughput, queue size and packet loses of the proposed topology, and all these results, represented by NS-2 scripts using trace files.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
TCP protocol	Reno
Propagation Delay of all links	2 msec
Bandwidth eNB-eNB	10 Mbps
Bandwidth eNB-aGW	10 Mbps
Bandwidth aGW-Server	100 Mbps
Packet Size	1500 Byte
Window size	128 Kbytes
Simulation Time	30 sec

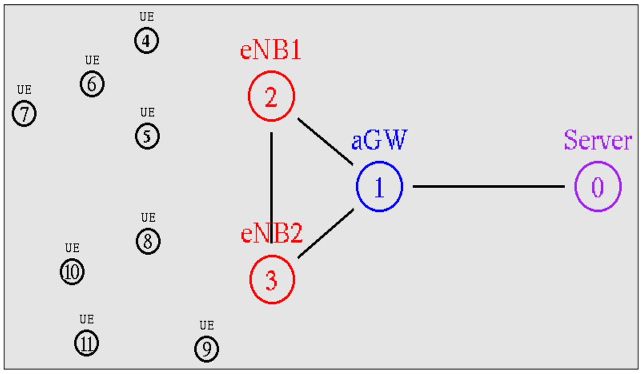

Fig. 4 NS-2 Network Animator

As explained in Fig. 4, the wireless nodes UEs linked to the corresponding eNB, through wireless link as a mobile node, where the nodes 4, 5, 6, and 7 connected to eNB-1, and the nodes 8,9,10, and 11 connected to eNB-2. Really, the UE nodes not have full mobility features, because they not move yet, and if we support the movement of these nodes we must add a Handover scenario to the topology, and this is not our goal in this research. The two base stations, eNB-1 and eNB-2 connected directly with 10 Mbps bandwidth link and delay of 2 msec, and each eNB connected to aGW with 10 Mbps bandwidth too. In other hand the main network link that connect aGW and Server linked with 100 Mbps bandwidth and the delay kept to 2 msec. The evaluation of TCP throughput performance on wireless cellular networks, it is necessary to consider the effect of packet losses and transmission errors on the radio link on the TCP performance, which is the main subject of this paper. We evaluated the TCP performance by explicitly modeling the performance characteristics of the underlying data link layer protocol.

V. ERFORMANCE EVALUATION OF LTE MODEL

The evaluation of the network performance is mainly based on the three main criteria, throughput, queue size, and packet losses. The throughput can represents as:
Throughput (bits/s) = (Number of delivered packets * size of packets * 8) / Total duration of simulation.

The throughput is a function of various parameters such as queue size, window size, amount of error on the link, maximum segment size and round trip delay. So we can add the behavior of Congestion Window *cwnd*, as a main metric for network performance. Throughput is the total amount of data exchanged per second between a source and destination in the network. The packet losses defined as the probability of a new packet arrives when the queue is full versus time, and it's a main measure of the amount of effective performance of data streaming from sender to receiver in any topology. Here, in this paper as we mentioned, throughput, queue size, number of packet losses per time unite, measured for TCP Reno.

Fig. 5 shows the congestion window and other phases, where the slow-start time was about 0.5 sec, and congestion point of network set on 55 Kbytes because the maximum expected window size is 110 Kbytes. That mean, Reno *cwnd* kept to the classical and standard behavior in our proposed topology, so we got a regular and ideal *cwnd*, especially in congestion avoidance phase.

```
/* Slow-Start Phase (Exponential Increment) */
if (cwnd_ < ssthresh_)
cwnd_ = cwnd_ +1;
/* Congestion Avoidance Phase */

else {
cwmd_ = cwnd_ + (1 / cwnd_);
}
```

That mean, in slow-start phase, *cwnd* will increase until congestion happen or until *cwnd* less than slow start threshold (*ssthresh*). But if congestion happened, *cwnd* will decrease by (1/*cwnd*).

Fig. 6 indicates the queue size of data streaming, and as illustrated, we can see that when window size decreases, the performance of TCP' Reno will be better and almost same when window size in default. In general, in high speed networks the queue size increase with time, because of the expected congestion through network bottleneck and that will cause increasing in packets delay transferred through network.

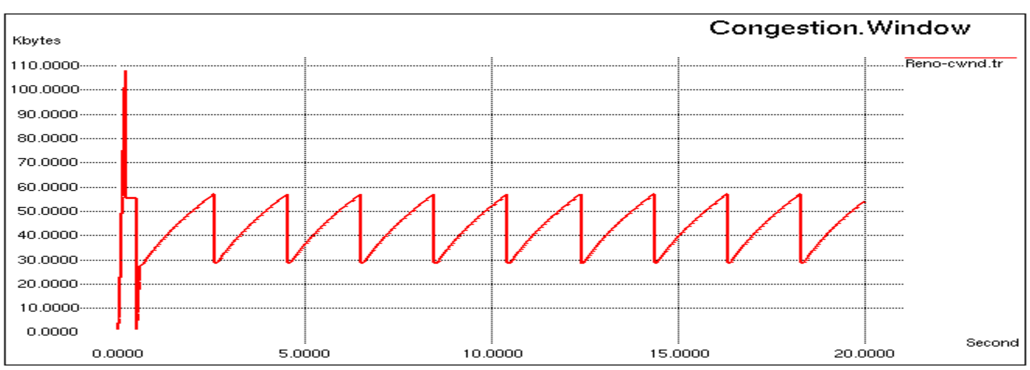

Fig.5 Congestion window (*cwnd*) of TCP Reno over LTE model

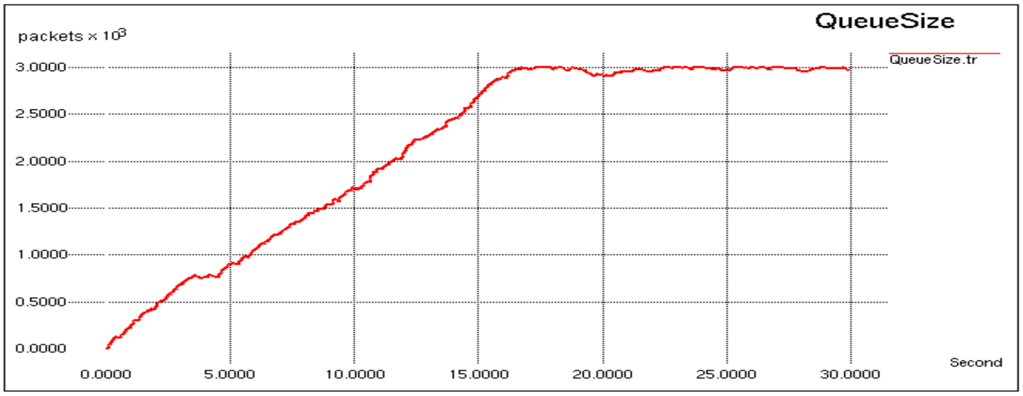

Fig.6 Queue Size versus time of TCP Reno over LTE model

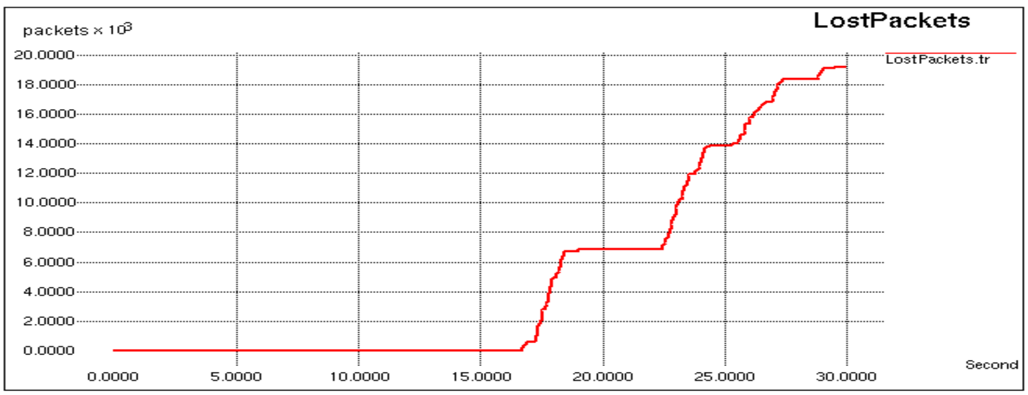

Fig.7 Lost Packets versus time of TCP Reno over LTE model

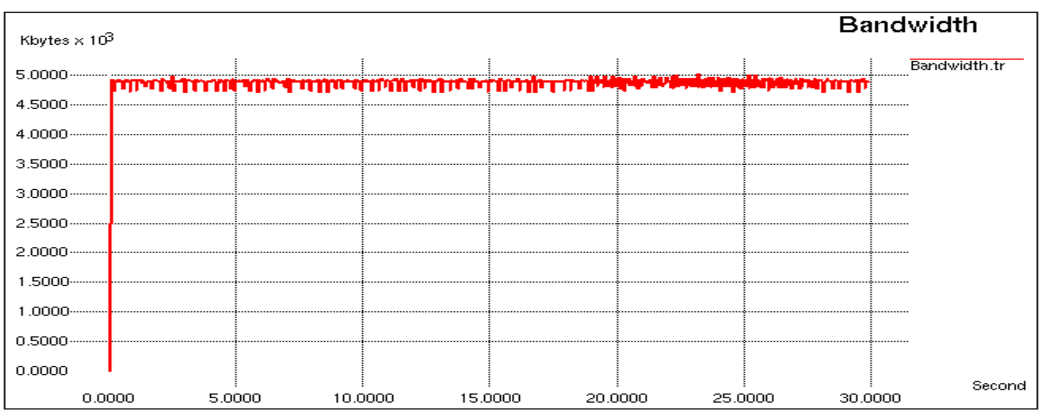

Fig. 8 Bandwidths versus time of TCP Reno over LTE model

In lost packets graph, which shown in Fig. 7 , it is apparent from the results that TCP Reno reach to 20000 packets, and that represents a high value compared with standard values. Fig. 8 represents the results of throughput of TCP Reno performance under LTE model. It is easy to notes that we cannot get stable throughput over wired-wireless heterogeneous network and over high speed, high data rate networks, because we must expect a high bit error rate (BER) under this model. However it can be observed that TCP Reno perform well with our model and this decision come from notes that in spite of the lost packets and the latency through network, but also we got a reasonable and stable bandwidth throughput. The results of modeling and simulation of proposed LTE system shows the value and the performance level of the TCP Reno, and it is no doubt it looks close to a large extent the level of performance and efficiency in our proposed model, and this is likely since all the species that have been addressed in this research was not designed to support high-speed networking or to deal with the a high rate of data transferring, in addition, it did not take into consideration the prospects for work in wireless networks and can pass its conditions of interruption, interference, or the BER. So we not found any distinctive to a species from one to the others, and that leads to find a new technique and mechanisms added to those species to make it working in more efficiency rate than what they are now.

VI. CONCLUSION

In this paper the traffic model of LTE/SAE presented using NS-2 as a network simulator and this model underwent the examination and evaluation supporting by TCP Reno. LTE system representation is complex but we tried to adding and including the most configuration parameters and the interfaces between UEs, aGW, eNBs, and Server, and taking in consideration the real values and requirements of all links and the limitation of the real LTE system to try to get into a model that simulates the reality of LTE networks. The performance of the final model evaluated by analyzing the behavior of congestion window, lost packets, latency, and the model throughput and compare the results obtained from graphs with standard results supported by real LTE model, and these results and comparisons leaded that the model provided has a lot of realism and credibility as a simulator model for LTE networks.

ACKNOWLEDGMENT

This study is sponsored by Universiti Kebangsaan Malaysia (UKM) through the university research grant UKM-OUP-ICT-36-185/2011.

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