

TCP PERFORMANCE ON LTE MOBILE NETWORK BY USING NS-3

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Abstract— Our inspiration for this research is to propose additional information to researchers based on our field of study: Networking systems. The world has been entering a new era of Long Term Evolution, LTE. There is different research gap in view based on internet connectivity, security, data privacy, system efficiency, data accuracy and another research gap that can be explored and research. The LTE supported mixed data, voice, video and messaging traffic and can provide new business opportunity based on LTE. In LTE cellular network, one of the most critical issues considered by researchers is to improve QoS (Quality of Service). Performances of protocols depend on network throughput, an end to end delay and packet drop. Performance analysis of improved protocols can be tested using simulation tools. The characteristic of LTE has been researched but it is in generic, makes it hard for any IT company to fulfill the characteristic. Our aim of the study is to provide information regarding the performance of LTE to LTE users, companies IT managers and LTE service providers.

Keywords—LTE, TCP performance, NS-3 simulator

I. INTRODUCTION

Long Term Evolution (LTE) is a fourth generation (4G) wireless network for mobile communication networks. LTE provides higher data rate, lower latency, and a simplified architecture. To greatly improve wireless services, LTE system uses OFDMA-based multicarrier modulation, MIMO techniques, and other advanced features. It is necessary to evaluate its performance with an increasing use of LTE in mobile networks.

In this research, the performance of LTE for mobile networks under TCP traffic for both directions uplink and downlink were evaluated. The performance parameters: average delay and average jitter were focused during the evaluations. The effect of the link bandwidth and packet size on the performance parameters using NS-3 were evaluated, then the data were extracted to do some analysis.

The easiest and effective ways used in the study of communication networks is the simulation method which is used in numerous fields. Using the simulation, the network connections, nodes and the traffics generated in the network can be designed in a way like those in the real world. The circumstances which may be impossible to generate in real life due to financial or other constraints can be easily observed in the network simulators.

A. Problem Statement

The traffic progress after wireless and mobile devices will become a sensation in the future. Hence, the weights for bearing the developing mobile applications and refining network performance become progressively critical for the operators. In this research, we investigate on how LTE performs for applications that run over TCP. The performance of TCP is critical mainly to the end-to-end application performance. The optimization of TCP performance over wireless networks is a critical importance as the wireless traffic volume ascending. Currently, the characteristic of LTE has been researched but it is in generic, makes it hard for any IT company to fulfill the characteristic.

B. Research Objectives

The objectives of this research were to evaluate the Quality of Service (QoS) of average jitter and end-to-end delay.

To achieve these, there were few steps that have been carried out as stated below:

- i. A testbed of mobile LTE was designed and developed by using the NS-3 simulator.
- ii. Data on delay, jitter, and throughput were collected
- iii. Statistical reading was used to see the trending.
- iv. The report was analyzed.

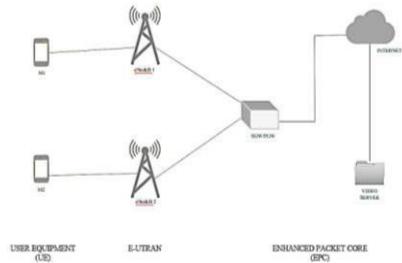


Fig. 1: LTE Diagram

II. RESEARCH METHODOLOGY

A. Test Scenarios Identification

The test scenarios were acknowledged in the first phase. Several parameters have been identified to see the impacts on link bandwidth, the number of users and the number of packets sent on the metrics performance, the average delay, throughputs, average jitter and the real goodput. The performance of LTE network was examined on the following parameters:

- i. Jitter
- ii. End-to-end delay
- iii. LTE delay
- iv. Mean Opinion Score (MOS)

There were three scenarios for analyzing the performance of LTE network as shown in Table 1.

Table 1: Scenario

	CASE 1	CASE 2	CASE 3
BANDWIDTH (gb/s)	100	100	100
DELAY (ms)	5	10	15
JITTER	RESULT		
END-TO-END DELAY	RESULT		
QUALITY OF EXPERIENCE (QOE)	RESULT		

B. Monitoring Tools

NS-3 network simulation script was used to create LTE network topology and then the topology was evaluated using the trace functions of the LTE-EPC module. Fig. 1 gives an overview of the LTE network topology used in this study. LTE network consists of three subsystems: user equipment (UE), the radio access network (RAN), and the Enhanced Packet Core (EPC). UEs are basically mobile handsets carried by end users. The RAN allows connectivity between a UE and the EPC. It consists of multiple base stations called Evolved Node B (eNB). The centralized EPC is the backbone of the cellular network. It was connected to the Internet. Within the EPC, “Monitor” was our data collection point. “SGW” and “PGW” referred to the serving gateway and the packet data network gateway, respectively. “PEP” corresponds to the performance enhancing proxy.

C. Service Performance Monitoring

The performance metrics carried out in this study were average jitter, average delay, average throughput and real goodput. UE established a TCP connection to the server when TCP throughput and RTT were measured, which transferred random data without any interruption. For throughput measurement, the first 10 seconds of the TCP connection was ignored and the slow start phase was

skipped, and throughput was calculated every 500 ms from the continuously transferred data [1]. The RTT was measured by computing the gap between timestamps of transmitting a data packet and receiving the corresponding ACK from the sender-side trace collected by the tcpdump tool. TCP handshakes were examined to calculate promotion delays with the following property: the user does not send or receive a packet within the time window.

D. Data Analysis

Various information on the metrics such as average delay, throughputs, and jitter performances was extracted from the TCP packet traces by using the Network Simulator, which is NS-3 that has been visualized into charts to make it a readable data. Then, the data on the impact of link bandwidth, the number of users and the number of packets sent on these metrics were analyzed.

E. Result Verification

This is where the result of the fourth phase was verified to identify whether the data and the design implemented to meet the requirements of the project. The conclusions have been made after the data were analyzed.

III. RELATED WORK

A. Characterizing Mobile Network Usage and Performance

Prior efforts [2, 3, 4] deployed smartphone user studies and collected data from tens to hundreds of participating users. Those studies examined numerous aspects including the variety of smartphone users, the popularity of mobile applications, and the effectiveness of compression techniques on cellular traffic etc. The 3G Test study [5] implements another method by publishing an app

that measures various network performance metrics on users' handsets. Sommers et al. compared cellular and WiFi performance using crowd-sourced data from speedtest.net covering 15 metro areas, focusing on throughput and latency [6]. Xu et al. profiled diverse usage behaviours of smartphone applications [7]. Qian et al. studies the measurement of cellular periodic transfers [8]. Earlier studies [9, 10] also studied mobile handsets using WiFi networks.

B. Cellular Resource management and Cross-layer Interaction

A radio resource control (RRC) manages the handset radio interface which is the key coupling factor bridging the application traffic patterns and the lower-layer protocol behaviours. Previous studies [15] and [16] examine the RRC state machine and its interaction with cellular traffic, for 3G UMTS and 4G LTE networks. Earlier studies also observed the interaction between TCP and cellular networks. For example, Liu et al. studied the physical and MAC layers in 3G EvDO networks and their impact on TCP performance [17]. Jiang et al. examined how large buffers in cellular networks contribute to significant TCP queuing delay [18].

C. Cellular Network Infrastructure

Xu et al. characterized 3G data network infrastructures, leading to an observation that the routing of cellular data traffic is quite restricted as traffic must traverse through a small number of gateway nodes [15]. Wang et al. unveiled cellular carriers' NAT and firewall policies [16]. Balakrishnan et al. investigated IP address dynamics in 3G networks. They found that cellular IPs embed much less geographical information than wired IPs do [17]. In this work, characterizing LTE infrastructures is not our immediate focus, but we do have novel findings that they highly affect our measurement methodology.

IV. RESULT AND ANALYSIS

To evaluate the performance of TCP in LTE mobile network by using NS-3, the effects of delay, packet loss rate, throughput and jitter on the video qualities have been analyzed.

```

>> EvalVidServer: Video streaming successfully completed!
>> EvalVidClient: Received packet at 76.568s  Ld: 2101  udp  242
>> EvalVidClient: Received packet at 76.568s  Ld: 2102  udp  285
>> EvalVidClient: Received packet at 76.568s  Ld: 2103  udp  254
>> EvalVidClient: Received packet at 76.568s  Ld: 2104  udp  292
>> EvalVidClient: Received packet at 76.568s  Ld: 2105  udp  256
>> EvalVidClient: Received packet at 76.568s  Ld: 2106  udp  382
ant@antara-VirtualBox:~/ns3/ns-allinone-3.27/ns-3.27$
    
```

Fig. 2: Request from client

A. Trace Function

Table 2 shows the simulation parameters of the topology that have been applied in the trace functions, enabled in the script. The simulation time has been set for 10 seconds based on NS-3 LENA module [1].

Table 2: Simulation parameters

SimTime (s)	10
NBlocks	5
NMacroEnbSites	1
NMacroEnbSitesX	1
EPC	1
epcDI	1
epcUI	1
useUdp	1
outdoorUeMinSpeed (kmph)	2
outdoorUeMaxSpeed (kmph)	60

```

[2415/2436] Linking build/bindings/python/ns/energy.so
[2416/2436] Linking build/bindings/python/ns/cnna_layout.so
[2417/2436] Linking build/bindings/python/ns/cnna.so
[2418/2436] Linking build/bindings/python/ns/config_store.so
[2419/2436] Linking build/bindings/python/ns/cap_brIDGE.so
[2420/2436] Linking build/bindings/python/ns/ds-ss.so
[2421/2436] Linking build/bindings/python/ns/nix_vector_routing.so
[2422/2436] Linking build/bindings/python/ns/rtt_max.so
[2423/2436] Linking build/bindings/python/ns/paint_to_point.so
INFO: Leaving directory /home/antara/ns3/ns-allinone-3.27/ns-3.27/build
build commands will be stored in build/compile-commands.json
build: finished successfully (33m42.096s)
>> EvalVidClient: Sending request for video streaming to EvalVidServer at 1.0.0.2:8000
>> EvalVidServer: Client at 7.0.0.2 is requesting a video streaming.
>> EvalVidServer: Starting video streaming...
>> EvalVidServer: Send packet at 10.1219s  Ld: 1  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 2  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 3  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 4  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 5  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 6  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 7  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 8  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 9  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 10  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 11  udp  1460 to 7.0.0.2
>> EvalVidServer: Send packet at 10.1219s  Ld: 12  udp  358 to 7.0.0.2
>> EvalVidClient: Received packet at 10.1354  Ld: 1  udp  1460
>> EvalVidClient: Received packet at 10.1364  Ld: 2  udp  1460
>> EvalVidClient: Received packet at 10.1374  Ld: 3  udp  1460
>> EvalVidClient: Received packet at 10.1374  Ld: 4  udp  1460
    
```

Fig. 3: Reply from server

B. Client-Server Communication

A list of data has been received showing that a client sent a request to a server for streaming a video as shown in Fig. 2 after the configuration was run. Then, the server has replied to a client request. It showed a message as shown in Fig. 3.

C. Jitter Result

Figure 4 shows the jitter result of the LTE performance for all eleven videos. Since each video has different duration and frame movement, the network latency decreases for two consecutive packets. In summary, Mobile video was affected the most by delays more than Bridge-far, Bus, Football, and Foreman video as it has the biggest size which is 53,1968 bits among the others. Thus, For Akiyo, Bridge-Close, Coastguard, Flower, Hall and Highway videos, they shared similar result as the size of the videos has slight differences between them.

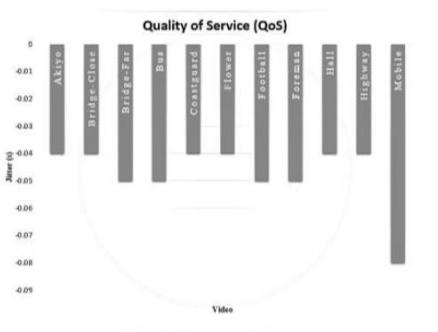


Fig. 4: Jitter result

D. End-to-end Delay Result

Fig. 5 shows the end-to-end delay result of the LTE performance for all eleven videos. NS-3 introduce required delays to help us simulate a real network. However, the delay does not really affect the end-to-end delay of the videos except for Bridge-Far video.

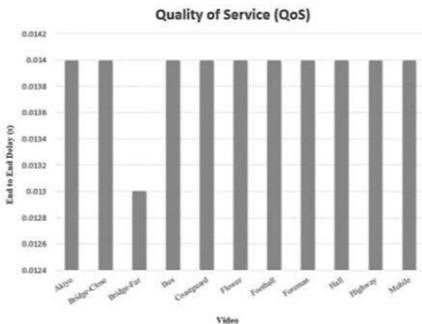


Fig. 5: End-to-end delay

E. MOS Result

Fig. 6 shows the MOS result of the LTE performance for all eleven videos. From the charts,

we can conclude that users were totally not satisfied with the Flower and Mobile video based on PSNR estimations and ITU standard MOS as shown in Table 3. Each coloured bars represent user experience. When the users were extremely dissatisfied with experience, they had the orange coloured bar. The yellow coloured bar represents poor user experience while the green coloured bar represents a fair user experience. When the user had an enjoyable experience while streaming the videos, they had the dark orange coloured bar but when the users were extremely satisfied with the streaming, they had the brownish gold coloured bar. The duration of both, Flower and Mobile videos were longer than others which affected the result. While Bridge-Close and Highway video had about the same result as both had the same duration and frames. To improve the QoE result, we can add enhancement to the current topology.

Table 3: ITU standard for MOS

MOS	QUALITY	IMPAIRMENT
5	Excellent	Imperceptible
4	Good	Perceptible but Annoying
3	Fair	Slightly Annoying
2	Poor	Annoying
1	Bad	Very Annoying

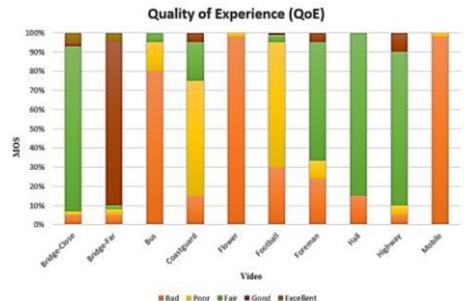


Fig. 6: MOS result

V. CONCLUSION

In conclusion, the technique used in this research could also be used for other performance measurement researchers especially those related to network systems that provide best-effort services like a wireless network, mobile network and an ad-hoc network. NS-3 was set up based on topology diagram. Then, the quality of videos was compared by calculating the average MOS of every PSNR file and the percentage of frames with a video's MOS worse than their original. The objectives set for this research which were to evaluate the quality of Service (QoS) based on the average jitter and the end-to-end delay of videos are met.

The limitation of NS-3 was that it did not provide the option for traffic type selection. Therefore, to evaluate the QoS and QoE of an LTE network topology for a specific traffic type (i.e. video), the Evalvid framework was used. NS-3 has no limitation regarding on the number of UEs created in it. However, with the enormous number of UEs, the performance was very slow, and it only lasts a couple of hours. Furthermore, the limited of execution time and memory consumption to practice on a different number of nodes made it harder to execute the project.

For future recommendations, there are few aspects that can be further enhanced. For example, testing current network topology with a large-scale LTE data set to study the impact of different or newer protocol, codecs and application behaviours on the network performance. In addition, an improvement on the network topology to include latest LTE infrastructure.

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