Speed test Analysis of LTE mobile networks in Malaysia

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Abstract— Despite the huge growths in the mobile network with the LTE technology usage, the network operators are facing challenges to provide the best mobile network for the users. LTE technology is the key elements for mobile operators to provide the best mobile network to their users. Different mobile operators provide a difference network performance to the mobile users. Based on the speed test, this study investigates on what factors that can impact the network performance of LTE technology. Mobile users are facing different experience in mobile network coverage. Users received varying LTE signal in their devices at different locations. This paper focuses on which mobile operators provide the best network performances to their mobile users. Besides drive test, LTE performance can also be measured by a speed test. This paper represented the LTE network performance from the speed test analysis of two different types of smartphones. This speed test of LTE mobile network is based on the three major mobile operators in Malaysia which are Celcom, Maxis and Digi. Speed test is performed by `Speed test by Ookla` and `OpenSignal` mobile applications. The parameters of speed test are calculated based on latency, download and upload speed. This speed test is performed anywhere and anytime in Malaysia. This is to prove the users` behavior of using LTE mobile network. The results presented the average speed of the LTE network in Malaysia based on the top three mobile operators in Malaysia such as Celcom, Digi and Maxis. In this paper, we analyzed the factors that impact the LTE network performance based on the results collected.

Index Terms— LTE, Network Performance, Speed test analysis, mobile networks, LTE technology, LTE mobile network, LTE speed test

I. INTRODUCTION

LTE (Long Term Evolution) is the latest mobile network technology and deliver high-speed data services to the mobile network. It is wide uses in the mobile network, as the exponential increasing of mobile users, the network technology growth with it. LTE network topology consists of three sub-systems which are user equipment (UE), the Radio access network (RAN) and the core network (CN). UE are consists of end user`s devices such as smartphones, tablets and etc. The connectivity between UE and CN are connected by RAN which is consists of Envolved Node B (eNode B). The core network is the backbone of LTE network and it's connected to the internet.

LTE network started on air in Malaysia since 2013, and in few years four major mobile operators in Malaysia have been deployed the LTE infrastructure in most of the countries [8]. At this new era, mobile users are wide uses the data network and voice call. In this environment, the difficult challenge is to capture the view of network performance representative of conditions at end user devices.

LTE provides higher throughput with DL (download) up to 300Mbps and UL(upload) up to 150 Mbps [10].LTE have four to five times download speed compare with 3G networks. Malaysia`s LTE coverage is not the fasters in the world but its close enough to the global average speed of 17.4 Mbps [8]. As of today, based on report [8] South Korea leading the LTE network coverage with 95.71% availability, while Singapore leading the globally best speed of LTE network with 45.86 Mbps.

People are excited about this LTE technology because of the fastest data speed. At this new era, users are demanding for the fastest data speed with reasonable price. This created the big challenging for mobile operators in order to provide the best data speed to users. Currently, there are 6 mobile operators in Malaysia, such as Celcom, Digi, Maxis, Umobile, Tune Talk, and Webe. Users experience different coverage and network quality for the LTE technology in a different location. To maintain the quality of LTE networks, there are a few test to measure the LTE network performance, such as drive test and speed test. This study demonstrates the LTE network performance based on the speed test application from the top 3 mobile operators in Malaysia. In this paper, the data is collected from the speed test application by 2 types of smartphones, iPhone iOS and Samsung Android. This paper answered the question of `which mobile operator works best in LTE performance at Malaysia' and 'how LTE network been the measure for the best LTE coverage?' A depth study in this paper analyze the factors impact of LTE network performance based on the results of the speed test. It is important to understand the LTE performance. The finding in this study will benefits users to understand the factors impacted on LTE mobile network performance and it helps users consider the best mobile

operators in their areas in Malaysia.

The rest of the paper demonstrates in sections as follows: Section 2 describe the background of LTE networks and literature review, Section 3 explains the methodology of the speed test, while section 4 presents the results and analysis of the data collected based on the results of speed test by the mobile application. The last section, which the most important parts discuss the conclusion of the project conducted.

II. Background and Literature Review

Long Term Evolution (LTE) is a field of interest throughout the world due to the demand of using data in the mobile devices in terms of streaming of media such for internet TV, video conference, emails, and online gaming. It is a network system that supports higher data rate and improved overall performance compared with 3G. Mobile users required the best mobile network with a high download and upload speed and lower latency.

LTE is specified to provide downlink data rates over 150Mbps, round trip time less than 30ms and three times higher spectral efficiency than 3G. Table 1 below shows the LTE performance requirements [6]

TABLE I: LTE performance requirements

Measured	Requirements
Packet data rates	Downlink: 100 Mbps, Uplink: 50 Mbps For 20MHz spectrum
Mobility Supports	Up to 500 km/h but performed for low speeds from 0 to 15 km/h
Control plane latency (Transition time to active state)	Less than 100ms both in idle and active
User plane latency	Less than 5ms
Control plane capability	More than 200 users per cell for 5MHz spectrum
Cell size (Coverage)	5-100km with minor degradation following 30km
Range flexibility	1.4, 3, 5, 10, 15 and 20MHz

Average speeds of LTE network in Malaysia is 13 Mbps which nearly the speed of the US. The main parameters to analyze the LTE performance are by analyzing the jitter, end to end delay, LTE delay, and the throughput. These parameters are used to analyze the Voice calls [3]. Based on the thesis [3], there are two ways to analyze the LTE performance, which are simulating the Voice calls and web browsing in different distance and number of mobile users. The results from [3] proved that the increment in end to end delays when the distance between users and base stations is increased. It is concluded that in the same network the fewer users or the closer to user beside the base stations, the better internet browsing performance.

In thesis [8], the writer examined the network performance in Malaysia`s Klang Valley and it shows that Maxis providing an LTE signal 77% of the time in the Klang Valley, while Celcom and DiGi with time coverage around 66% only. The study in [8] shows the metric of LTE network coverage in Malaysia are 70% by Maxis based on February 2016 analysis. The data measured by the speed test reflect the eNode B location and mobile user behavior.

LTE network performance is reflected the environment factors including the location of the mobile user (indoor or outdoor), device model, mobility and also the geographical environment. The study in the paper [15] show that the lower average throughput in the indoor environment compares to the outdoor environment. In every speed test, most of the mobile users are interested in download speeds, which is important for browsing, streaming and downloading.

III. Methodology

The speed test is performed by using mobile applications. For this study, the data are collected from two different type of smartphones, iPhone iOS, and Samsung Android. In order to determine the measurement of LTE performance, there are lots of mobile applications can be used to collect the measurement data. Only two mobile applications are chosen to perform the speed test, which is the most popular application for this test, ` Speed test by Ookla and Open signal`. The main factors that influence LTE network performance are the data speeds, latency, packet loss in LTE and others that related to LTE performance. For this study, the data are collected from two different type of smartphones which are iPhone iOS and Samsung Android.

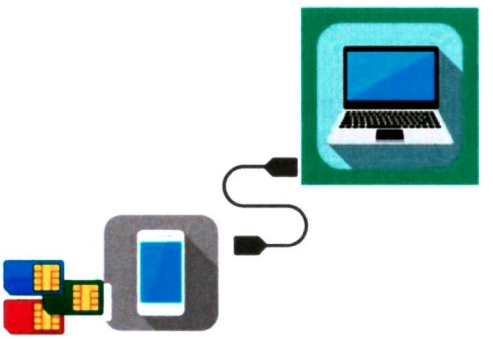

Fig. 1. Speed test tools

The tools that are used to measure the LTE network are the software applications, laptop (to generate the results into Excel file), three different mobile operators sim cards (Celcom, Digi and Maxis), and smartphones (iPhone 6 and Samsung Edge 7). Speed test is performed at any locations with 4G LTE connection, no test are performed in 3G connections. This test is tested at random location around Malaysia, whether indoor or outdoor, in a city or in a countryside, even in vehicles, this is to represent performance as the way user experience it. Instead of measuring the speed test at random locations and times, these data are collected at the urban and rural places where the user are using the mobile phones. These measurement results are based on the full range of consumer behavior [8]. The signal is measured on how much signal from user`s smartphones are getting and it is displayed on the signal bars. Full signal bars mean the user get full coverage to make a voice/video calls and the data speed are fasters compared to low bars signal. The speed test results are based on the download speed, upload

speed and latency of the network. Download speed is the speed information from the internet being transferred to user's devices, which is the time to download files, load websites or videos from the internet. Upload speed is the speed of transferred data from user's devices to the internet, such as upload the video in social media or attachment in emails. If the upload speed is high, the data speed is fast for the photo, video sharing to social media. Normally download speed are faster compared to uploads, but somehow it depends on the network connections or the web pages setting. Latency or it's also referred as Ping, which measures the time takes from the user devices to send data to other smartphones and to receive the response when the data packet was received. The lower the latency value, the better network performance. Latency is the measurement on how far the data travel to send data to other smartphones. The latency is increased when the communication routes are longer, where the data pass through many switches and routers. Latency is measured in milliseconds while download and upload speed is measured in kb/s.

This paper investigates the LTE network performance based on the collected results from the speed test by using mobile applications.

A. Results measurement

LTE network is measured by speed test or drive test. The results measurement is based on the network latency, download speed, and upload speed. The lower the latency, the better network performance while download and upload speed, the higher speed the better network performance. Lower latency means the response to a request are sending faster which are important to use in online gaming, voice calls, remote desktop and etc. For best results, the latency shouldn't exceed 200ms.

B. Latency analysis

The applications that reliable for low latency are games, voice call, email and file sync, applications sharing and video/voice conference over IP. Latency in numbers based on the applications are shown in the table below [12].

Medium	Application	Degree of symmetry	Data rate	e2e one-way delay	Delay variation within a call	Information loss
Audio	Conversational voice	Two-way	4-25 kb/s	< 150 msec preferred < 400 msec limit	< 1 msec	< 3% FER
Video	Videophone	Two-way	32-384 kb/s	< 150 msec preferred < 400 msec limit Lip-synch < 100 msec		< 1% FER
Data	Telemetry	Two-way	<28.8 kb/s	< 250 msec	N.A	Zero
Data	Realtime games	Two-way	< 60 kb/s	< 75 msec preferred	N.A	< 3% FER preferred < 5% FER limit
Data	Telnet	Two-way (asymmetric)	< 1 KB	< 250 msec	N.A	Zero

Fig. 2. LTE latency requirement

LTE latency is based on the requirement metric by ITU (International Telecommunication Union), shown in table below. [19]

Plane	Max Latency (ms)
Control Plan	100
User Plan	10

Fig 3. LTE latency metric by ITU

There is two type of latency in LTE such as control panel latency and user plane latency. The User Equipment or its also called as UE, transit time required from idle state to the active state is clarify by control plane latency. There is no connection between UE and RRC (Radio Resource Control) in the idle state. RRC is established when UE turns into connected state. At dedicated mode, UE turns into the active state. User plane latency is clarified as one way transmit time between available packets at IP layer in the UE/E-UTRAN node. This latency is calculated for TDD (Time Division Duplex) and FDD (Frequency Division Duplex) cases. There are four components that involved in latency calculation, such as UE processing time, transmission time interval (TTI), Hybrid Automatic Repeat Request (HARQ) retransmission and base stations processing time.

Description	Duration
LTE_IDLE→LTE_ACTIVE delay (C-plane establishment)	47.5ms + 2 * Ts1c
TTI for UL DATA PACKET	1ms
HARQ Retransmission (@ 30%)	0.3 * 5ms
eNB Processing Delay (Uu -> S1-U)	1ms
U-plane establishment delay (RAN edge node)	51ms + 2 * Ts1c
S1-U Transfer delay	Ts1u (1ms – 15ms)
UPE Processing delay (including context retrieval)	10ms
U-plane establishment delay (Serving GW)	61ms + 2 * Ts1c + Ts1u

Ts1c = 2ms – 15 ms
Ts1u = 1ms – 15 ms

Fig 4. User plane latency

As per shown in table above, the user plane latency is calculated based on the components above. The average round trip can be below 15ms without any scheduling delay. The best user plane latency can reached as low as 10-20ms.

C. Bandwidth analysis

Similar as latency, downlink transmissions from the base stations is also consists of user plane and control plane. In the protocol stack, these data are from the higher layers that multiplexing together with physical layer signaling in order to support the data transmission [19]. Dimensions of time, frequency and space are transmission resources for both downlink and uplink.

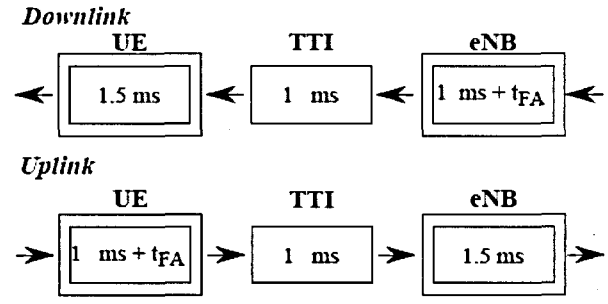

Fig 5. User plane latency components

Component	Process	Downlink HARQ		Uplink HA	
		0%	10%	0%	1(
		(ms)	(ms)	(ms)	(r
1	UE Processing Time	1.5	1.5	1	
2	Frame Alignment	0.6~1.4	0.6~1.4	1.1~5	1.
3	TTI Duration(Fixed)	1	1	1	
4	HARQ Retransmission	0	0.98~1.22	0	1~
5	eNodeB Processing Time	1	1	1.5	1
Total one-way delay		4.1~5.2	5.18~6.2	4.6~8.5	5.7(

Fig 6. User plane latency in uplink

IV. Results and Analysis

As described in the methodology section, the speed test data results are obtained from the Speed Test mobile application, These tests are performed with two smartphones, iPhone iOS and Samsung Android. In this study, we investigate the network performance based on the mobile operators, mobile devices, and the geographical location. There is 144-speed test performed at random places in Malaysia.

Phonr/Operator	Min of Latency(ms)	Max of Download(kbps)	Max of Upload
Iphone iOS	3	50.24	101.36
Celcom	3	50.24	101.36
DiGi	7	50.07	31.88
Maxis	6	48.95	22.02
Samsung Android	7	77.43	50.70
Celcom	23	40.08	8.32
DiGi	7	72.21	50.70
Maxis	7	43.29	23.00
Grand Total	3	77.43	101.36

Fig 8.Best speed test results based on latency, download and upload speed

Based on the table above, we can classify that the best results for latency are 3ms, the download speed is 77.43Mbps, and upload is 101.36 Mbps. While the worst network performance for latency is 23ms, the download speed is 40.08 Mbps, and upload is 8.32 Mbps which belong to Celcom network. Low network performance can be due to the environment and user's behavior during the speed test. The environment and user's behavior pattern is a changes in the weathers and different location. These may impact the factor of LTE network performance. Mobile users can travel to various locations and invoke the services through the base station. The network performance can be congested due to the more mobile users in one base stations. This may results on the low network performance to the users.

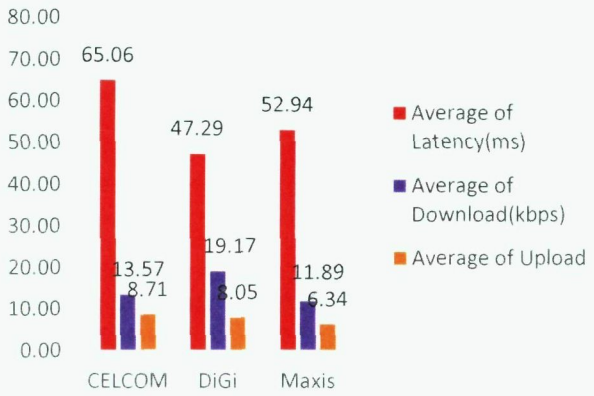

Fig 9.Average speed test results

The graph shows the average of speed test parameters, including latency, download and upload speed based on three mobile operators. Based on this graph, based on the 138-speed test performed, the lower latency average is 47.29ms, Digi network. The higher number of latency means that the operators have a delay time to contact web pages or servers. This higher latency average belongs to Celcom with 65.06ms value. As for download speed average, the higher speed is the Digi speed to 19.17 Mbps, Celcom with 13.57 Mbps and Maxis with 11.89 Mbps. The speed test analysis on paper [8] shows that Maxis won the best download speed with 15Mbps, follow by Digi and Celcom. Paper [8] analysis is based on February 2016. Upload speed is the speed for the user to upload the video or photo on the website. The higher average upload speed is Celcom with 8.71Mbps, Digi with 8.05 Mbps.

Fig 10.Speed test parameters vs smartphones

Three parameters from the speed test are shown in the graph figure 10, compared between two different smartphones devices. The speed test is performed in the same locations at the same time with the same mobile operators but this can analyze from this graph, the varying result appears from these two devices. This varying result is due to the different type of antenna specifications in the smartphones. Most of the

smartphones have a different specification of antenna and this may occur the different received signal of LTE mobile network. As per shown in the table below, the specification of antenna in iPhone 6 and Samsung 8 Edge. These show that both smartphones support different LTE bands.

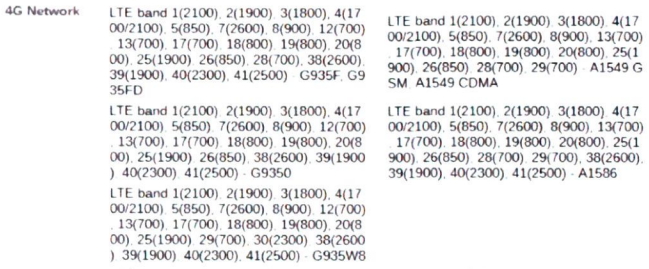

Fig 11. IPhone and Samsung antenna specification

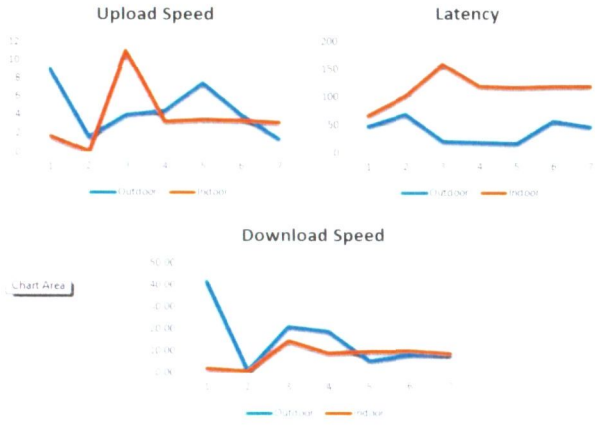

Fig 12. Speed test parameters vs environment

Most of the mobile operators in Malaysia deployed the network elements for LTE network at both indoor and outdoor. For indoor network signal, mobile users device are served by indoor or outdoor base stations. Graph in figure 12 compares the indoor and outdoor performance. Based on the speed test performed, in outdoor environment, the lower latency and high download and upload speed is observed. Outdoor network performance is strongly related to the line of sight (LOS) condition. In previous paper [15], the author compared the basic performance for indoor and outdoor LTE network. They concluded that indoor and outdoor performance signal is similar.

V. Conclusion

In this paper, we examined the LTE network by using the speed test applications in random location by three mobile operators which are Celcom, Digi and Maxis. In terms of speed test between three major mobile operators in Malaysia, whereby we can conclude that most location in Malaysia, especially in urban area, most of the area are fully covered by LTE mobile networks. Most of the speed test results are closely matched compared to the mobile operators. During the speed test, we observed that there are few factors that can impact the network performance in LTE network. The geographical between the mobile user and the base stations (the antenna of the mobile operator) is one of the factors that can impact the network performance. The distance between mobile devices and base stations is impacted in speed test results. The best signal users can get is when the mobile devices are located directly under the base station`s cluster. If the test is performed in the same location with the same mobile operators, the results can slightly different if the test is tested in the outdoor and indoor area. This is due to the blockage or different type of antenna from indoor/outdoor base stations. Network performance is also impacted by the environment-behavior. Based on this study, the best mobile operators in Malaysia is Digi with the best average of latency and download speed compared to Celcom and Maxis. Based on the speed test result, Digi mobile network have a good coverage even in rural area. Further, type of mobile devices is found not to affect the performance of the LTE. This might be due to the similar technical specification of the mobile devices used. It can be therefore concluded that there are some future work to be done for the speed test mobile network. More information can be added in the results for a better view to the users. This might help users to understand the factors effect to the network performance. In addition, the speed test can be more reliable if the test are perform by the drive test and compare both results with the speed test result for all the mobile operators in Malaysia.

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