A COMPARATIVE STUDY OF MOBILE NETWORK OPERATORS (MNOs) FOR EVALUATING NETWORK PERFORMANCE AT KOLEJ TUN GEMALA

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Article Info	Abstract
	The increasing use of mobile networks for internet connectivity shows the importance of evaluating network performance, especially in locations with high user density such as Kolej Tun Gemala. This project focused on addressing connectivity issues faced by students, caused by network congestion and WiFi limitations, by assessing and comparing the performance of three main MNOs: Maxis, U Mobile, and CelcomDigi. Through Android smartphones and network monitoring tools such as Speedtest by Ookla, nPerf, WiFiMan, and Cellular-Z, data on throughput (download and upload), latency, and signal strength were collected during measurements conducted at Levels 1 and 5 of Blocks A and C between 9 pm to 11 pm. Based on network performance results revealed Maxis as the top performer overall, excelling in throughput and signal strength. In contrast, U Mobile shows strong download speeds but experiences latency issues while CelcomDigi demonstrated moderate and balanced performance. This comparative analysis provides actionable insights for students to select suitable MNOs and offers valuable performance to network providers for service improvement. Enhancing mobile network quality in college improves students' learning experiences and personal development and facilitates better connectivity solutions for enhanced educational networks.

INTRODUCTION

The Internet era began in 1983, and its usage has increased dramatically. This surge was driven by the widespread use of smart and mobile gadgets that could connect to the Internet

from any place at any time, enhancing access to digital connectivity (Umoh et al., 2022). The growing demand for data has resulted in many consumers relying on various cellular technologies and services. Consequently, mobile communication networks require continuous improvements in spectrum efficiency, infrastructure, and service quality to meet increasing demands (El-Saleh et al., 2022).

For mobile network companies, college campuses present both opportunities and challenges. Locations with high student populations and dense infrastructure often experience network interference, congestion, and weak signals in certain areas. This study evaluates the performance of three major MNOs: Maxis, U Mobile, and CelcomDigi within Kolej Tun Gemala to determine the best-performing network. The research aims to provide insights into signal strength, latency, and data transfer rates, helping students choose the most reliable service provider while offering recommendations for network enhancements (Shokohyar et al., 2021).

LITERATURE REVIEW

Overview of Mobile Network Operators

The Malaysian telecommunications industry has experienced substantial growth, driven by key players such as Maxis, CelcomDigi, and U Mobile. These MNOs provide extensive coverage and cater to diverse customer segments. The competitive landscape encourages continuous technological advancements, including 4G LTE and emerging 5G networks, aimed at enhancing data speeds and service reliability.

Network Performance Metrics

To evaluate mobile network performance, this study focuses on three primary metrics. Throughput (Mbps) measures download and upload speeds, which affect user experience during browsing and streaming. Latency (ms) represents the time taken for data packets to travel between source and destination, impacting real-time communication. Signal Strength (dBm) indicates network coverage and connectivity stability, with stronger signals ensuring better performance.

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Network Performance Tools

To measure network performance effectively, this study utilized four primary tools. Speedtest by Ookla provided reliable assessments of internet performance by measuring download and upload speeds, latency, and jitter. nPerf offered a comprehensive evaluation through detailed network quality analysis, including browsing and streaming tests. WiFiMan analyzed signal strength and network performance, helping to identify weak coverage areas. Cellular-Z delivered real-time insights into signal quality and mobile network parameters, aiding in comparative analysis. Table 1 below presents a comparison of the features of network monitoring tools used in this study.

Table 1: Comparison Features of Network Monitoring Tools.

Tools	Cost	User-Friendliness	Platform Compatibility	Signal Strength (dBm)	Throughput	Latency
Speedtest by Ookla	Free (with ads) Paid: Ad-free version	Very user-friendly, simple interface	Android, iOS	No	Yes	Yes
nPerf	Free (with ads) Paid: Premium version (ad-free)	User-friendly, detailed reports	Android, iOS	No	Yes	Yes
WiFiMan	Free	Very user-friendly, clean interface	Android, iOS	Yes	Yes	Yes
Cellular-Z	Free	User-friendly, comprehensive data	Android only	Yes	Yes	Yes

Related Works

Three related works used a similar approach by evaluating mobile network performance through real-world measurements and analysis.

a) *Measurement analysis and performance evaluation of mobile broadband cellular networks in a populated city*

El-Saleh et al. (2023) analyzed the performance of five mobile network operators (MNOs) in Malaysia, both indoors and outdoors, using key metrics like signal quality, throughput, ping, and handover. The study, conducted in a smart city, found that outdoor areas suffer from lower signal-to-noise ratio (SNR) due to noise interference.

The highest average download and upload speeds were 14.3 Mbps and 7.1 Mbps, respectively, with a low ping of 36.5 ms. Indoor coverage was generally strong, ranging from -76 to -85 dBm. The study emphasized the need for MNOs to enhance network performance, reduce interference, and improve data rates for a better user experience

b) *Performance Analysis of Mobile Broadband Networks With 5G Trends and Beyond: Urban Areas Scope in Malaysia*

Shayea et al. (2021) evaluated the performance of 3G and 4G networks in Malaysia across Klang Valley, Johor, Sarawak, and Sabah, using metrics like coverage, latency, user satisfaction, and speed. The study found that 4G consistently outperformed 3G in all locations, making it the preferred choice for users. The research highlighted the importance of improving mobile broadband (MBB) services in urban areas to meet rising traffic demands and enhance user experience.

c) *A Comparative Study of User-Experienced Mobile Broadband Performance*

Umoh et al. (2022) investigated mobile broadband performance in Nigeria by measuring download/upload speeds and delay for four MNOs. The study found that Airtel had the best performance on 3G, while MTN excelled on 4G. 9Mobile had the highest and most inconsistent latency, affecting user experience. Additionally, network performance fluctuated based on the time of day, impacting end-user experience across both 3G and 4G networks.

METHODOLOGY

This study follows a methodology framework illustrated in Figure 1 consisting of five key phases: planning and preparation, data collection, data analysis, interpretation of findings, and documentation. Each phase plays an important role in guiding the project to completion.
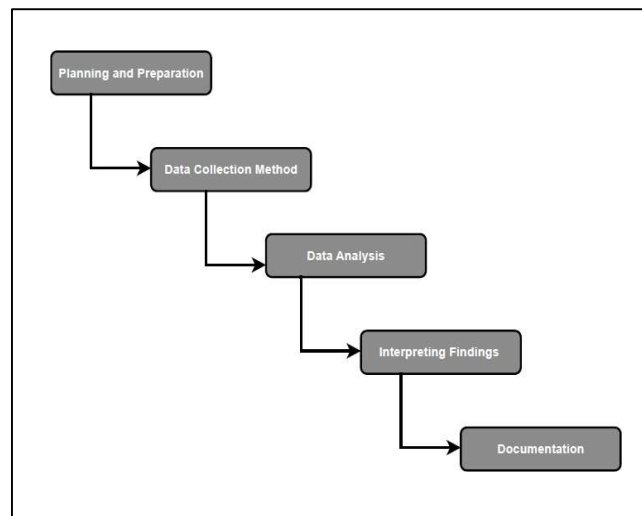

Figure 1 Methodology Framework

Data Collection

Network performance data were gathered using four applications: Speedtest by Ookla, nPerf, WiFiMan, and Cellular-Z. Tests were conducted on Android devices at specific locations within Kolej Tun Gemala, focusing on Level 1 and Level 5 of Blocks A and C.

Testing Parameters:

a) *Timeframe*: 9 PM - 11 PM (peak usage hours)
b) *Testing Locations*: Kolej Tun Gemala, UiTM Jasin
c) *Devices*: Standardized Android smartphones with MNO-specific SIM cards

Project Methodology Flowchart

Figure 2 below illustrates the process of collecting network performance data. The test begins by connecting Android devices to one of the three MNOs CelcomDigi, Maxis and U Mobile then installing selected tools: Speedtest, nPerf, WiFiman, and Cellular-Z. Tests are carried out at Level 5 and Level 1 of Tun Gemala Blocks A and C between 9 pm and 11 pm. Each tool was used to measure metrics like download and upload throughput, latency and signal strength. The process was repeated five times for consistency, and all data was recorded systematically for analysis, ensuring a thorough evaluation of network performance.
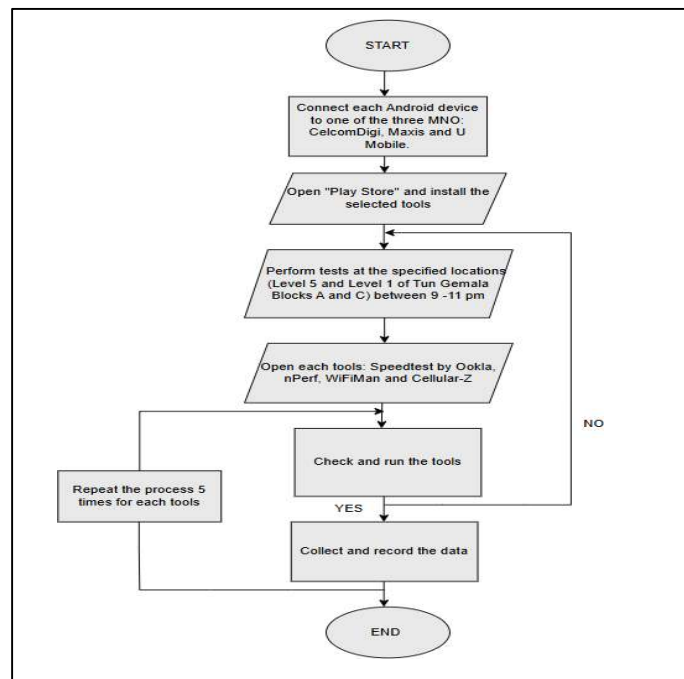

Figure 2 Flowchart of Measurement Methodology

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Evaluation Testbed

The evaluation testbed was designed to create a controlled environment for testing network performance. Figure 3 below illustrates the experimental setup and data collection process. The testbed collects detailed data about mobile network access quality and technology at Kolej Tun Gemala. This data was evaluated to determine the exact setting where each experiment was conducted, focusing on access network metrics like latency, throughput, and signal strength.
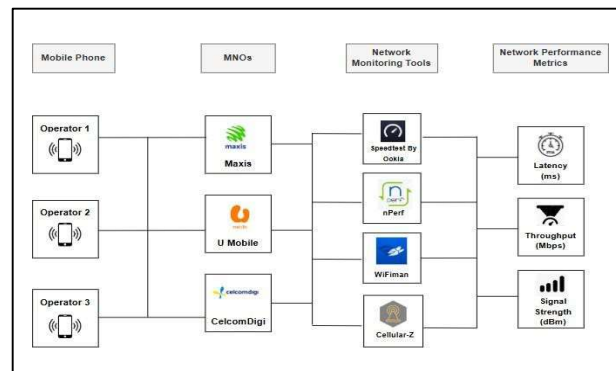

Figure 3 Evaluation Testbed

RESULT AND DISCUSSION

The results gathered from the research approach mentioned in the previous chapter. It further discussed and analyzed the findings of the experiment in detail. The first step before proceeding to the testing was to ensure that each of the three Android handphones had a connection with the selected MNOs. The next step was network performance testing, where each of the four selected tools was run to analyze the metrics and collect the data at different locations. These tests were performed to achieve the project objectives.

Performance Comparison between Selected MNOs and Network Monitoring Tools

This section will delve into the location results to better understand the level of network performance and MNOs provided to users at each relevant level and block of Tun Gemala. The measurement focused on areas where the distance difference between far and near from the BTS which Tun Gemala C is located near BTS than Tun Gemala A. The results of each metric are discussed in the table and graph below.
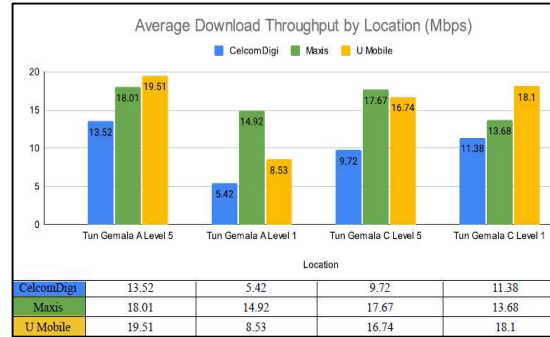
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Figure 4 Average Download Throughput for each location in Kolej Tun Gemala

Based on Figure 4, higher average download throughput indicated that the MNOs can provide consistently higher throughput for most tested locations. Based on the data collected, U Mobile consistently produces the highest average throughput in each level and block, especially at Tun Gemala C Level 1 with 18.1 Mbps. While Maxis also maintained their speeds with 17.67 Mbps at Tun Gemala C Level 5. On the other hand, CelcomDigi demonstrated lower throughput values across all tested locations, with Tun Gemala A Level 1 showing the lowest performance at 5.42 Mbps. These findings reveal that at the tested locations both U Mobile and Maxis offer good value for users in terms of network performance.
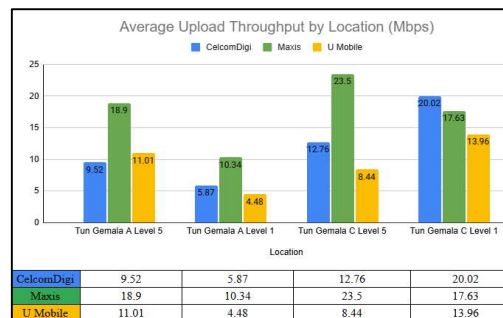

Figure 5 Average Upload Throughput for each location in Kolej Tun Gemala

Chart 5 shows that higher average upload throughput indicated that the MNOs can provide consistently higher throughput for most tested locations. Based on the data collected, Maxis consistently produces the highest average throughput in each level and block, especially at Tun Gemala C Level 5 with 23.5 Mbps. CelcomDigi with a competitive uploading speed of 20.02 Mbps at Tun Grmala C Level 1. U Mobile's results were lower than all other locations except at Tun Gemala C at 13.96 Mbps. Thus, these results indicate Maxis and CelcomDigi as key players offering the best network quality in the observed area.

Average Latency by Location (ms)

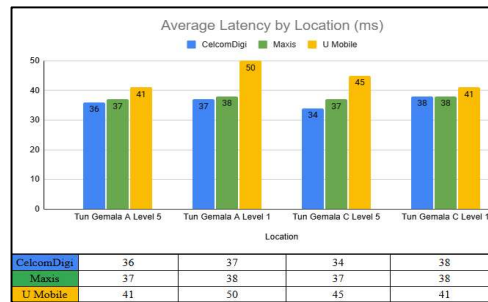|	Tun Gemala A Level 5	Tun Gemala A Level 1	Tun Gemala C Level 5	Tun Gemala C Level 1
CelcomDigi	36	37	34	38
Maxis	37	38	37	38
U Mobile	41	50	45	41

Figure 6 Average Latency for each location in Kolej Tun Gemala.

From Graph 6 and the data table illustrating the latency results, it was found that CelcomDigi's latency rate was the lowest constantly across all tested locations which were 34 ms to 38 ms only. Maxis with a second higher latency of between 37 ms to 38 ms. However, latency by U Mobile was comparatively higher, especially at Tun Gemala A Level 1 which has a maximum value of about 50 ms. The findings indicate that CelcomDigi is likely to offer a more reliable and faster network performance than U Mobile, particularly for users that have real-time activities like online gaming, video calls and use of real-time applications. Furthermore, lower latency values have been observed in Tun Gemala C than in Tun Gemala A suggesting that being closer to the BTS had a positive effect on latency for all MNOs.

Average Signal Strength (RSRP) by Location (dBm)

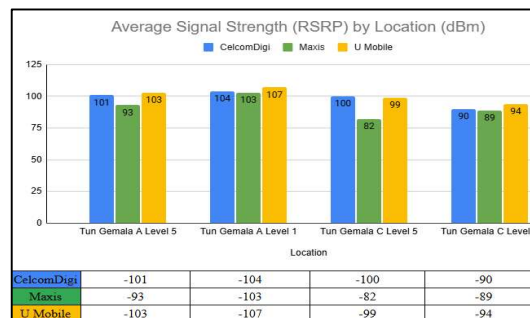|	Tun Gemala A Level 5	Tun Gemala A Level 1	Tun Gemala C Level 5	Tun Gemala C Level 1
CelcomDigi	-101	-104	-100	-90
Maxis	-93	-103	-82	-89
U Mobile	-103	-107	-99	-94

Figure 7 Average Signal Strength for each location in Kolej Tun Gemala

The findings from Figure 7 show that the signal strength of RSRP differs from level to level and block to block within Tun Gemala depending on distance with the BTS. Tun Gemala C has a better RSRP value than Tun Gemala A as it is closer to BTS. As can be observed from the results Maxis has the highest overall signal strength at Level 5 Tun Gemala C at -82 dBm while U Mobile and CelcomDigi have moderate to weak signals. On the other hand, Tun Gemala A received lower RSRP values and the worst signal on Level 1 with only -107 dBm

for U Mobile. These findings show the important role of distance from the BTS in determining signal quality and the variations in the network performances of the different MNOs in both locations and levels tested.
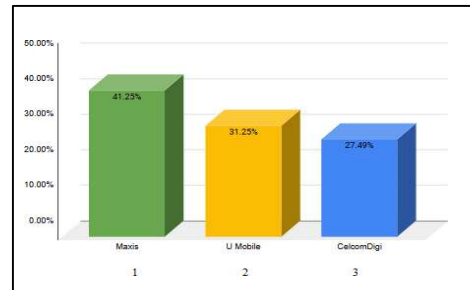

Figure 8 Percentage of MNO's Performance

Based on chart 8 above shows the result of this overall performance evaluation of MNOs at Kolej Tun Gemala indicating that Maxis had better performance than other MNOs and had the highest percentage performance of 41.25%. U Mobile came second with a performance score of 31.25% while CelcomDigi was the third rank at 27.49%. All these results were obtained by analyzing download and upload throughput, latency, and signal strength over three weeks of collected data using selected network monitoring tools. Maxis has scored higher than the other MNOs because of its high throughput and strong signal quality in every testing area, Tun Gemala A and C at Levels 1 and 5, making it the most reliable choice for students facing WiFi congestion issues.

Table 2: Prepaid Plan for each MNO

MNOs	maxis	mobile	celcomdigi
Prepaid Plan	Unlimited data, hotspot and calls. Uncapped 5G speed.	Unlimited Calls + Data @ 12Mbps (FUP: 200 GB) Unlimited Hotspot	Unlimited + 10GB High Speed + Calls
Price (RM)	40 per month	40 per month	40 per month

Surprisingly, all three MNOs have a prepaid package that costs RM40 per month with unlimited data as presented in Table 2. However, the network quality that Maxis has over its competitors creates the advantage of value-added for customers willing to pay for quality

services. As for the outcome, it could also be noted that U Mobile faced reasonably high performance which makes it a reliable alternative for being considered as another choice at least for the areas with limited Maxis's signal coverage. CelcomDigi performing slightly worse than the other MNOs, still offers services for users with moderate data usage and less connectivity demanding connectivity needs.
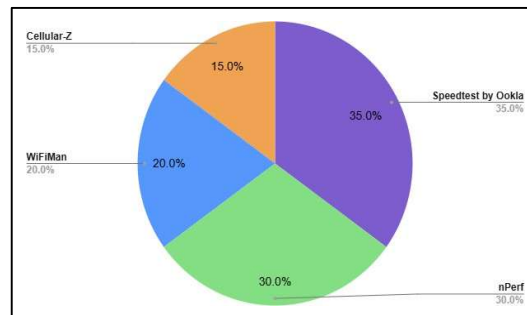

Figure 9 Percentage of Tools Performance

Figure 9 shows that Speedtest by Ookla (35%) and nPerf (30%) were the most reliable tools for assessing network performance, making up 65% of the evaluation. WiFiMan (20%) focused on latency and signal strength but had inconsistent throughput results under congestion. Cellular-Z (15%) excelled in signal strength metrics like RSRP and SINR but was less accurate in overall network performance. This suggests that Speedtest and nPerf are best for performance testing, while WiFiMan and Cellular-Z are better for signal analysis. Using all four tools together provides a complete network assessment.

CONCLUSION

In conclusion, the LTE network performance of three major mobile network operators (MNOs) in Malaysia—CelcomDigi, U Mobile, and Maxis was analyzed using network monitoring tools in selected locations. The results showed that LTE networks provide full coverage in most tested areas, with similar speed test results across MNOs. Factors such as the distance between mobile devices and base stations, physical obstructions, and environmental conditions impact network performance. Higher building levels tend to have better signal strength due to fewer obstructions and a clearer line of sight to base stations. Among the MNOs, Maxis performed the best in Kolej Tun Gemala, particularly in Tun Gemala C, with the highest average download speed and lowest latency. Device specifications

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also influence network performance. Future tests could be expanded to different building levels and weather conditions to provide a more comprehensive understanding of LTE network performance.

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