

Comparative Analysis of Internet Connection Quality Between Home Wi-Fi and Cellular Networks Based on Download Speed, Upload Speed, and Latency Using M-Lab Speed Test

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ABSTRACT

Internet connection quality is commonly evaluated using download speed, upload speed, and latency; however, many previous measurements focus on individual network performance without systematically comparing home and cellular networks under different usage periods. This study addresses this gap by conducting a comparative evaluation of home and cellular internet connection quality using the M-Lab Speed Test under morning, afternoon, and evening testing scenarios. The novelty of this study lies in its time-based comparative assessment of two different access networks using identical measurement parameters and testing procedures. A quantitative descriptive method was employed, with measurements conducted over seven consecutive days at three different periods each day, resulting in 21 measurements for each network and 42 measurements in total. The collected data were validated and analyzed using average download speed, upload speed, and latency as performance indicators. The results show that the cellular network achieved a higher overall average download speed of 22.98 Mbps compared with 21.84 Mbps on the home network, representing approximately 5.22% higher performance. The home network provided a slightly higher average upload speed of 17.55 Mbps than the cellular network at 17.28 Mbps. In terms of latency, the cellular network performed better, with an average of 28.76 ms compared with 30.14 ms on the home network. Time-based analysis also revealed variations in network performance across morning, afternoon, and evening periods. These findings demonstrate that connection type and measurement period influence internet performance differently and highlight the importance of repeated, time-based measurements rather than relying on a single speed-test result. The study provides an empirical reference for evaluating and selecting internet access networks based on specific performance requirement.

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I. Introduction

The development of information and communication technology has made the internet a primary need in various activities ranging from education, work, communication, business to entertainment [1]. Increasing internet use demands stable connection quality so that digital activities can run well. The number of internet users, especially in Indonesia, has increased from year to year with the number of internet users reaching 221.56 million [2]. This increase in internet usage has also increased since the COVID-19 pandemic which has caused dependence on the internet [2]. This condition shows that the internet is not just an additional facility but is the most important part in supporting productivity and access to information. [3]. The quality of the internet connection is one



of the important factors that determines comfort in accessing digital services [4]. An unstable internet connection can cause various problems, including slow data downloading processes, file delivery can be disrupted, online communications can be interrupted, video conference quality is low, and response times will increase in applications that use the network [5][6]. Therefore, the quality of the internet connection needs to be measured using several parameters objectively [7].

Some parameters used to assess the quality of an internet connection are download speed, upload speed and latency [8] [9]. Download speed indicates the network's speed in receiving data from the server to the end device. Upload speed indicates the opposite: the network's ability to send data from the end device or user device to the server. Meanwhile, latency indicates the delay time required for data to travel from the user's device to the server to receive a response. These three parameters are interrelated in describing internet connection performance. A common problem with using data is assessing internet quality based on subjective perceptions such as "fast internet" or "slow internet" without understanding systematic measurements. Such assessments are inaccurate because conditions do not change based on usage time, number of users, traffic load, connection type, and infrastructure conditions. Therefore, structured measurements are needed so that internet connection quality can be analyzed based on data, not just assumptions.

The tool used to measure the quality of an internet connection is the M-Lab Speed Test [10][11]. This free browser-based tool generates measurement data with download speed, upload speed, and latency parameters. This tool is used as a research tool to evaluate internet connection performance. Measurements are conducted not just once, but repeatedly at different times to obtain more representative data. The measurement results will be analyzed to determine network performance, the time of use with the best quality, and the time of use that indicates a decrease in connection quality. Based on this explanation, this research is important to provide an empirical overview of the quality of the connection used. The results can serve as a basis for evaluation in understanding internet connection performance. Furthermore, this research can serve as a reference for measuring network quality with various subjects using free, website-based tools. The results can serve as a basis for evaluation in understanding internet connection performance. Furthermore, this research can serve as a reference for measuring network quality with various subjects using free, website-based tools

II. Method

This study uses quantitative descriptive analysis as shown in Figure 1 to measure the quality of internet connections using three main parameters: download speed, upload speed, and latency. Measurements were made using the M-La Speed Test tool. Download speed is measured in Mbps, which is the speed of receiving data. Upload speed is measured in Mbps, including the speed of sending data. Latency, measured in ms, includes connection delay time and testing time to see differences in performance. The purpose of this study is to determine the level of internet quality based on test results at several measurement times.

This study employed a quantitative comparative approach to evaluate the performance of two types of internet access, namely a home network and a cellular network, using three Quality of Service (QoS) indicators: download speed, upload speed, and latency. The measurements were conducted using the M-Lab Speed Test through the same testing device and browser environment to minimize variations caused by differences in measurement tools. The home network and cellular network were selected as the two testing objects and were evaluated under the same measurement procedure. All measurements were performed using the same device and browser configuration under comparable testing conditions. During testing, unnecessary background applications and downloads were minimized to reduce additional traffic generated by the testing device

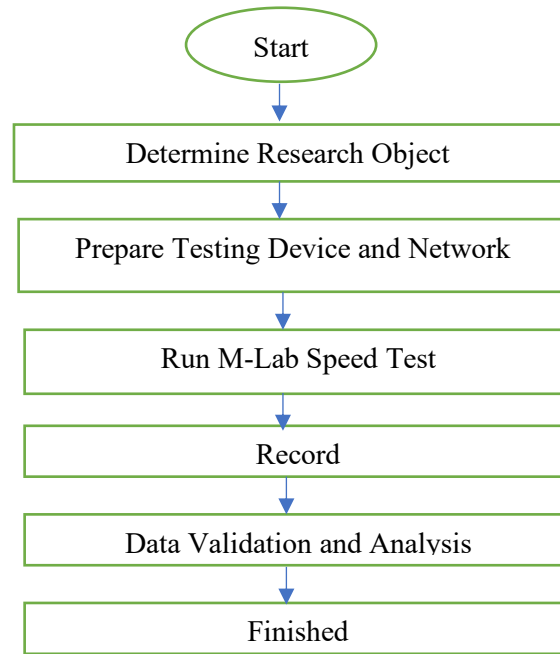


Fig 1. Research diagram

This research stage is preceded by determining the research object. Where the object of this research determines the targeted internet network, or the internet network being tested. The research object used can be a home network, school, public or cellular network. In this research, the objects chosen were home networks and cellular networks with several experiments. After determining the research object, the condition of the network and testing equipment is checked so that the measurement process runs consistently. The data collection stage is carried out by running the M-Lab Speed Test through a testing browser which produces data in the form of download speed, upload speed and latency. Testing was carried out several times at different times of the week in the morning, afternoon and evening categories to obtain more representative results for analysis. After the data is collected, data validation is carried out by checking the test results. Invalid data is not used in the analysis process. Valid data will be analyzed by calculating the average download speed, upload speed and latency, this needs to be done to determine the quality and stability of the internet connection. The final stage is to analyze the results. An internet connection is considered better if it has high download speed and upload speed values and low latency.

III. Results and Discussion

Tables 1 and 2 demonstrate internet connection quality measurements using M-Lab Speed, using three parameters: download speed, upload speed, and latency. Testing was conducted over a one-week period, using morning, afternoon, and evening indicators. The testing times were chosen to determine differences in internet connection performance when using different networks.

Table 1. Measuring the quality of connections on a home network

Day	Time	Download Speed (Mbps)	Upload Speed (Mbps)	Latency (ms)
Monday	morning	25.79	19.57	31
Monday	Afternoon	20.65	21.23	29
Monday	evening	24.57	18.30	31
Tuesday	morning	16.26	16.68	31

Day	Time	Download Speed (Mbps)	Upload Speed (Mbps)	Latency (ms)
Tuesday	Afternoon	23.29	10.39	29
Tuesday	Evening	22.66	17.91	30
Wednesday	Morning	16.84	18.77	30
Wednesday	Afternoon	9.62	14.67	30
Wednesday	Evening	20.56	17.93	30
Thursday	Morning	24.84	18.67	30
Thursday	Afternoon	23.87	15.61	29
Thursday	Evening	23.17	18.92	32
Friday	Morning	24.73	19.7	31
Friday	Afternoon	23.59	12.10	31
Friday	Evening	24.82	18.49	30
Saturday	Morning	27.55	20.42	28
Saturday	Afternoon	21.35	20.70	30
Saturday	Evening	21.80	16.94	30
Sunday	Morning	19.78	19.46	31
Sunday	Afternoon	18.33	14.81	30
Sunday	Evening	24.62	17.34	30

Tables 1 and 2 show activity on the home network and cellular network. The highest download speed, with a value of 25.79 Mbps, is in the morning in Table 1. This indicates better download performance in the morning compared to the evening. This situation also occurs because internet usage in the morning is relatively lower compared to the evening when internet users tend to experience an increase for zoom, communication, or accessing social media. Low upload speeds affect data transmission activities. With an average upload speed of 17.55 Mbps as shown in Table 3 on the home network, this connection is still usable for basic activities, but is less optimal for use in large data upload activities. The latency parameter shows results that are inversely proportional to upload speed and download speed. The lowest latency with a value of 29 on the three afternoon sessions shown in Table 1 with the home network. Meanwhile, in Table 2 with the same value is found at various times: twice in the morning, twice in the evening, and once in the afternoon with an average of 28.76 ms. This shows that the lower the latency value, the faster the network responds to data requests. Figure 2 is the output of monitoring results for home networks on Monday in the morning with the highest download speed in Mbpsa and a upload value of 19.57 Mbps and a latency of 31 ms.

Table 2. Measurement of connection quality on cellular networks

Day	Time	Download Speed (Mbps)	Upload Speed (Mbps)	Latency (ms)
Monday	Morning	25.05	23.16	29

Day	Time	Download Speed (Mbps)	Upload Speed (Mbps)	Latency (ms)
Monday	Afternoon	24.64	21.50	30
Monday	Evening	23.60	18.60	32
Tuesday	Morning	24.96	18.76	21
Tuesday	Afternoon	22.16	12.36	30
Tuesday	Evening	22.25	15.56	30
Wednesday	Morning	22.80	18.14	30
Wednesday	Afternoon	24.47	0.38	11
Wednesday	Evening	24.56	17.76	32
Thursday	Morning	22.39	12.72	30
Thursday	Afternoon	21.46	12.19	30
Thursday	Evening	22.52	10.12	29
Friday	Morning	23.66	20.86	29
Friday	Afternoon	11.47	21.83	31
Friday	Evening	22.21	14.17	31
Saturday	Morning	21.40	19.60	30
Saturday	Afternoon	21.04	19.85	30
Saturday	Evening	25.66	22.36	29
Sunday	Morning	24.99	22.82	31
Sunday	Afternoon	25.64	22.24	29
Sunday	Evening	25.66	17.94	30

For cellular network connections in Table 2, the highest value is in the morning with a download speed of 25.05 Mbps, the highest upload speed is in the morning with a value of 23.16 Mbps. The lowest latency is in the morning with a value of 21. The average download speed in Table 3 with the highest home network is in the evening with a value of 23.17 Mbps. The highest average upload speed is in the morning with a value of 19.04 Mbps. The lowest latency is in the afternoon with a value of 29.17 ms. Table 4 is an average of connection quality measurements on cellular networks with the highest download speed at night with a value of 23.78 Mbps. The highest average upload speed is in the morning with a value of 19.45 Mbps. and the lowest latency is in the afternoon with a value of 27.29 ms.

Table 3. Average of Connection Quality Measurements on Home Networks

Time	Average Download Speed (Mbps)	Average Upload Speed (Mbps)	Average Latency (ms)
Morning	22.26	19.04	30.19

Time	Average Download Speed (Mbps)	Average Upload Speed (Mbps)	Average Latency (ms)
Afternoon	20.10	15.64	29.71
Evening	23.17	17.98	30.42
Overall Average	21.84	17.55	30.14

Table 4. Average of Connection Quality Measurements on Cellular Networks

Time	Average Download Speed (Mbps)	Average Upload Speed (Mbps)	Average Latency (ms)
Morning	23.61	19.45	28.57
Afternoon	21.55	15.76	27.29
Evening	23.78	16.64	30.43
Overall Average	22.98	17.28	28.76

Based on Tables 3 and 4, the home network achieved an overall average download speed of 21.84 Mbps, an upload speed of 17.55 Mbps, and a latency of 30.14 ms. In comparison, the cellular network achieved an average download speed of 22.98 Mbps, an upload speed of 17.28 Mbps, and a latency of 28.76 ms. Accordingly, the cellular network provided approximately 5.21% higher average download performance and 4.58% lower latency than the home network, whereas the home network provided approximately 1.54% higher average upload speed. These findings indicate that neither network consistently outperformed the other across all performance indicators. The cellular network showed an advantage in download speed and latency, while the home network showed a slight advantage in upload performance.

Table 5. Comparison of Home and Mobile Network Performance Statistics

Parameter	Home Network Mean $\pm$ SD	Cellular Network Mean $\pm$ SD	CV Home	CV Cellular	Statistical Test	p-value
Download Speed (Mbps)	21.84 $\pm$ 4.04	22.98 $\pm$ 3.05	18.50 %	13.25 %	Paired t-test	0.368
Upload Speed (Mbps)	17.55 $\pm$ 2.76	17.28 $\pm$ 5.50	15.71 %	31.82 %	Paired t-test	0.818
Latency (ms)	30.14 $\pm$ 0.91	28.76 $\pm$ 4.61	3.02%	16.04 %	Wilcoxon signed-rank	0.389

Note: SD = standard deviation; CV = coefficient of variation. Download and upload differences satisfied the normality assumption and were evaluated using paired-samples t-tests. Latency differences were non-normal and were evaluated using the Wilcoxon signed-rank test. Statistical significance was assessed at $p < 0.05$ ($n = 21$ paired observations per parameter).

Table 5 shows that the numerical differences between the home and cellular networks were not statistically significant at the 5% significance level. The paired comparison produced a p-value of 0.368 for download speed and 0.818 for upload speed, while the Wilcoxon signed-

rank test for latency produced a p-value of 0.389. Since all p-values were greater than 0.05, the observed differences cannot be interpreted as statistically significant differences between the two network types during the observation period. Nevertheless, the descriptive results indicate different performance characteristics between the networks.

The coefficient of variation provides additional information regarding network stability. Cellular network download performance showed lower variability (13.25%) than the home network (18.50%), indicating relatively more consistent download performance. In contrast, the home network showed considerably lower variability in upload speed and latency. The coefficient of variation for home-network latency was only 3.02%, compared with 16.04% for the cellular network. This indicates that although cellular access achieved a slightly lower average latency, home-network latency was substantially more stable during the measurement period.

Table 6. Classification of Measured Network QoS

Network	Average Download Speed (Mbps)	Average Upload Speed (Mbps)	Average Latency (ms)	Latency-based QoS Class	Interpretation
Home Network	21.84	17.55	30.14	High (2H)	Very responsive; latency < 100 ms
Cellular Network	22.98	17.28	28.76	High (2H)	Very responsive; latency < 100 ms

The findings of this study can be compared with previous network-performance research. Meilaningrum and Hamidah [8] evaluated QoS using download speed, upload speed, latency, and Base Transceiver Station characteristics, while Hulu et al. [9] focused on latency characteristics in a 5G network. In contrast, the present study compares home and cellular networks using the same three performance indicators and corresponding measurement periods. Therefore, its contribution lies in providing a direct comparative evaluation of two commonly used internet access types under a consistent measurement procedure.

This study incorporates variables for network access type and measurement period. The results indicate that a single, isolated speed test cannot adequately represent overall network performance, as both average performance and variability differ depending on the network type and the observation period.

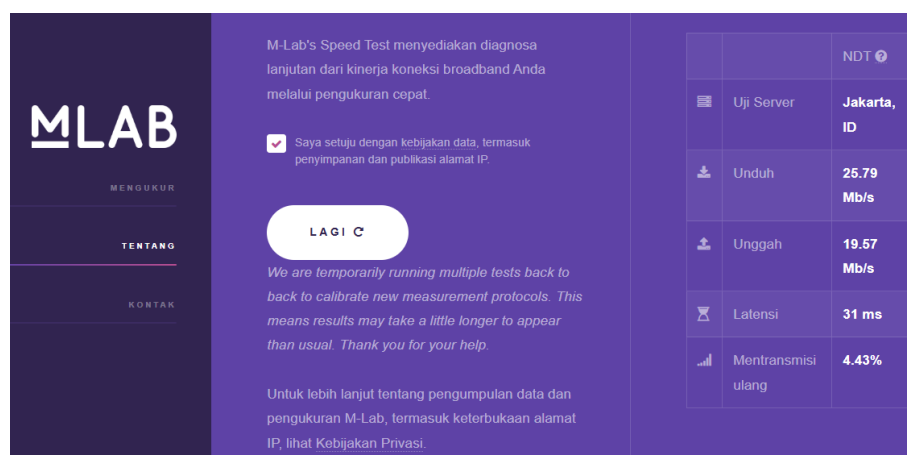


Fig 2. Output Monitoring using M-LAB

IV. Conclusion

This study demonstrates that neither home networks nor cellular networks consistently outperform the other across all Quality of Service (QoS) indicators. Based on aggregate measurements from 21 paired observations, cellular networks achieved superior quantitative performance in terms of download speed and latency; the average download speed was 22.98 Mbps (5.21% higher than the 21.84 Mbps observed on home networks), and the average latency was 28.76 ms (4.58% lower than the 30.14 ms on home networks). Conversely, home networks recorded a slightly higher average upload speed 17.55 Mbps compared to 17.28 Mbps for cellular networks representing a 1.54% advantage.

However, statistical analysis reveals that these differences are not statistically significant at the 5% significance level. A paired t-test yielded p-values of 0.368 for download speed and 0.818 for upload speed, while a Wilcoxon signed-rank test produced a p-value of 0.389 for latency. Therefore, although cellular networks demonstrated better descriptive performance in two of the three indicators, the results do not provide sufficient statistical evidence to conclude that cellular connectivity is fundamentally superior to home connectivity under the observed conditions.

Stability analysis offers further points of distinction between the two networks. Cellular connectivity exhibited lower variability in download speeds, with a coefficient of variation (CV) of 13.25% compared to 18.50% for home networks. In contrast, home networks demonstrated significantly more stable upload speeds and latency—particularly regarding latency—with a CV of only 3.02%, compared to 16.04% for cellular networks. Thus, selecting a superior network should not rely solely on average speed; the choice must also consider the characteristics of the required services and network stability.

The scientific contribution of this study lies in demonstrating that network performance assessment based on a single speed test measurement may be insufficient to represent actual connection quality. Through repeated measurements across two different access networks—conducted in the morning, afternoon, and evening using identical procedures—the study reveals that network type and measurement time can produce distinct performance patterns. Both networks were categorized as having high QoS based on latency criteria, with values consistently remaining below 100 ms.

In practical terms, these findings indicate that cellular networks may be the better choice when the primary priorities are higher download performance and lower average latency, particularly for activities requiring responsive access and data retrieval. Conversely, home networks may be preferable when upload stability and consistent latency are prioritized, such as in activities involving continuous data transmission or applications sensitive to fluctuations. Therefore, users and network administrators should evaluate internet access based on the specific requirements of the applications being used, rather than assuming that a particular access technology is universally superior. Periodic measurements conducted at various times are recommended to obtain a more representative assessment of network quality.

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