Revolutionizing 5G: NBTC QOS Regulations and Cutting-Edge Smartphone Applications for Future Mobile Communication Services

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Abstract

The rapid advancement of mobile communication technology, particularly the deployment of 5G, has significantly enhanced global connectivity by providing faster speeds, lower latency, and increased capacity. These improvements drive innovations across various sectors, including healthcare, autonomous vehicles, and smart cities. However, achieving the full potential of these advancements requires robust tools to monitor and optimize network performance effectively. In Thailand, the National Broadcasting and Telecommunications Commission (NBTC) plays a crucial role in ensuring that network quality meets stringent performance standards. This study aims to address the gap in comprehensive network performance assessment tools by developing an application that evaluates both Radio and End parameters of 5G networks in realworld scenarios. Unlike most commercial applications that typically focus on only one set of parameters, the developed application provides a dual parameter monitoring approach, offering a more complete and accurate assessment of network performance. The application was tested at six locations within Suranaree University of Technology, with five measurements taken at each site. Comparative analysis indicated that the developed application demonstrated consistent performance in 5G Radio Parameters, as reflected by a lower average standard deviation (SD) of 1.71 compared to 2.70 for commercial applications. These findings demonstrate the application's capability to deliver reliable and stable network performance evaluations, positioning it as a valuable tool for advancing 5G network management and optimization.

Keywords: 5G Technology, 4G Technology, Quality of service, Application Performance

1. Introduction

The transition from 4G LTE to 5G represents a significant leap in wireless communication technology, driven by the need for faster data rates, lower latency, and greater network capacity. While 4G LTE revolutionized mobile broadband by enhancing data speeds and supporting a wide range of applications, it has certain limitations in addressing the growing demand for seamless connectivity, particularly with the rise of IoT devices and high definition streaming services [1-3], as well as the integration of artificial intelligence (AI) in network management [4]. 5G technology builds upon the foundation laid by 4G, introducing advanced features such as millimeter wave (mmWave) communication, massive multiple input multiple output (MIMO), and network densification. These innovations are specifically designed to handle the increasing data demands and ensure robust connectivity across various applications, including smart cities, autonomous vehicles, and industrial automation [5]. In the healthcare domain, real-time communication and tracking enabled by 5G have also been applied to support mobile emergency response systems, such as the MSU-SOS® platform for stroke treatment in Thailand [6]. The enhanced capabilities of 5G also allow it to support a more complex Quality of Service (QoS) framework, which is critical for applications requiring high reliability and low latency [7,8]. Additionally, 5G provides the flexibility needed to support the explosive growth in connected devices, which is anticipated to surpass 100 billion IoT devices by 2030 [9].

QoS in both 4G and 5G networks is evaluated using two primary categories of parameters: Radio Parameters and End Parameters. 4G Radio Parameters include metrics such as Received Signal Strength Indicator (RSSI), Reference Signal Received Quality (RSRQ), Reference Signal Received Power (RSRP), and Signal to Interference plus Noise Ratio (SINR). In 5G, Radio parameters include SS-RSRP, SS-SINR and SS-RSRQ. These parameters are essential for assessing the strength and quality of the radio link between the User Equipment (UE) and the eNodeB/gNB, which directly impacts the overall performance of the network [10-12]. End Parameters include metrics such as Download Speed, Upload Speed, Ping, and Jitter. These parameters are critical for evaluating the overall user experience, as they measure the performance of the entire network path from the user device to the service endpoint [13,14]. In Thailand, the NBTC plays a crucial role in regulating and enforcing these QoS standards, ensuring that network performance aligns with the expectations of end users and accommodates the diverse range of services enabled by 5G [15].

The transition to 5G has spurred extensive research on QoS and network performance. Takale and Lokhande [16] conducted a comparative analysis of QoS, highlighting the importance of assessing both End Parameters (such as network reliability and delay) and Radio Parameters (such as RSRP and SINR) for a comprehensive evaluation of network performance. Similarly, Daengsi et al. [17] introduced a real time methodology for 5G performance measurement, emphasizing the connection between Radio and End Parameters. Rischke et al. [18] further emphasized the need for robust QoS measurements across various operational settings, particularly in 5G campus environments. Additionally, Narayanan et al. [19] investigated commercial 5G performance on smartphones, revealing discrepancies in user experiences due to inadequate measurement of both parameter types. Al Jahdhami et al. [20] emphasized the significance of assessing both parameters in indoor environments for a more accurate reflection of real world user experiences. Isaeva et al. [21] and Lazar et al. [22] provided valuable insights into mobile technology performance, stressing the need for robust measurement techniques to enhance QoS in 5G networks.

Despite these advancements, significant limitations persist in existing tools and methodologies for QoS measurement. Most commercial applications primarily focus on measuring End Parameters, neglecting critical Radio Parameters, which can result in incomplete assessments of network performance [16]. Moreover, synchronization challenges in simultaneous measurement of both parameter types further complicate accurate QoS evaluations. As a result, existing tools often fail to capture the full scope of data, limiting their effectiveness and hindering optimization efforts in 5G networks. In conclusion, while considerable progress has been made in the field of 5G performance measurement, current tools and methodologies remain inadequate for providing a complete and accurate picture of network quality. Addressing these gaps are vital for the successful deployment and utilization of 5G networks worldwide. In response to these challenges, this study presents the development of a novel application designed to provide a comprehensive assessment of 5G networks by integrating the measurement of both Radio and End Parameters. The application offers a more holistic view of network performance, overcoming the limitations of existing tools.

To address these gaps, an Android application was developed to support integrated measurement of both 4G and 5G Radio and End Parameters. Developed using Android Studio, the tool enables real-time data retrieval, signal strength assessment, and performance visualization within a single interface. This unified platform simplifies the testing process, offering greater convenience and efficiency compared to using multiple commercial applications.The proposed application was tested in real-world academic environments, with full details of the setup and locations provided in the methodology section.

2. Research Method

2.1 Application Development

2.1.1 Technology Stack

The application was developed using Android Studio, with Kotlin and Java as the primary programming languages for managing the application's functionalities. To retrieve cellular network data and SIM card status, the application utilizes the Telephony Manager API and Subscription Manager API, enabling access to critical information such as CellInfoLte and CellInfoNr from active cellular networks and SIM cards [23,24].

The Permissions API is employed to manage user consent for accessing necessary data, such as location information and phone status, ensuring that the application operates in compliance with best practices for data privacy and security [25].

Additionally, Kotlin Coroutines were implemented to handle asynchronous data retrieval from the network, ensuring that the process is continuous and highly efficient. This approach enhances the application’s performance in real time data processing, making it more responsive and capable of handling dynamic network conditions effectively [26].

2.1.2 User Interface Design

The user interface (UI) of the developed application was designed with a focus on simplicity, functionality, and user experience. The main screen of the application in Fig.1 provides users with direct access to critical network performance metrics, including Download Speed, Upload Speed, Ping, and Jitter. The interface is cleanly organized to facilitate quick interpretation of data, employing color coded indicators to enhance the user's ability to assess network quality in real time.

Navigation Tools:

The application includes five primary tools, each conveniently accessible through clearly labeled icons positioned at the bottom of the screen. These tools are strategically positioned to allow seamless transitions between different network testing functions, thereby enhancing the user experience by minimizing interruptions and facilitating efficient workflow.se a consistent spelling style throughout the paper (US English only).

The tools include options for testing End Parameters, Video Streaming, Mapping Function, Radio Parameters and Web Testing. Each tool is crafted to deliver comprehensive insights into various aspects of network performance, ensuring that users can evaluate their network conditions from multiple perspectives.

End Parameters Tool:

The application features a set of five primary tools, each tool prominently displays key metrics such as Download Speed, Upload Speed, Ping and Jitter. The results are presented in both numerical format and through graphical charts, providing users with clear and immediate insights into network performance. The use of color coded indicators further enhances data interpretation, allowing users to quickly assess network quality.

Radio Parameters Tool:

The Radio Parameters tool presents 4G and 5G essential metrics including RSSI, RSRQ, RSRP, SINR, SS-RSRQ, SS-RSRP and SS-SINR. Data is displayed in a straightforward list format, accompanied by color coded indicators that convey signal quality at a glance. This tool is designed to offer a detailed yet uncluttered view of radio signal parameters, aiding users in identifying potential network issues related to signal strength and quality.

Mapping Function:

The Mapping Function integrates GPS data to provide a visual representation of the locations where network tests are conducted. The interactive map allows users to zoom in and out, offering a detailed view of network performance across different geographic locations. This feature is particularly valuable for identifying areas with varying signal strengths and for understanding the spatial distribution of network quality.

Real time Feedback and Results:

The application emphasizes real time data presentation, offering users immediate feedback on network performance during testing. This feature ensures that users can monitor changes in network conditions as they occur, with results being promptly displayed in an accessible and user friendly manner. The real time aspect of the UI is crucial for professionals requiring accurate and timely data for decision making.

(a)

(b)

Fig. 1 Main screen of the application, illustrating key network data and navigation tools. : (a) network parameter selection and test modes.; (b) Speed test interface displaying initial test parameters.

2.2 Test Environment Setup

The test environment was meticulously configured to accurately assess the performance of the developed application under various real world conditions. The setup included the following key considerations.

2.2.1 Technology Stack and Test Locations

The experiments were conducted at six distinct locations within Suranaree University of Technology, strategically selected to represent diverse environmental conditions. These included both indoor and outdoor settings with varying levels of network usage density. This diversity ensured that the testing environments encompassed a wide range of realistic scenarios.

To obtain comprehensive and reliable data, five measurements were taken at each location between 09:00 a.m. and 06:00 p.m., which corresponds to peak activity hours for students, lecturers, and staff. The high user density during this time likely influenced network measurements, particularly in terms of congestion and signal fluctuation. This time frame was intentionally chosen to reflect typical usage patterns within an academic environment.

While the selected environments offer practical and realistic insight into university-based usage, it is acknowledged that they may not fully represent broader network conditions. Future studies will expand the testing scope to include a wider variety of environments such as urban centers, rural areas, and complex indoor structures like malls and transportation systems. Additionally, more refined methods will be applied to identify specific factors that affect signal performance, such as user density and building interference.

2.2.2 Hardware and Devices

The primary device used for testing was a Samsung A53, running OneUI V.6.1 on Android V.14. The device was connected to the commercialize 4G and 5G network, a major network provider, to ensure consistent testing conditions. By utilizing a single device model, any variations in the results could be attributed to network performance rather than hardware differences.

2.2.3 Network Configuration

Tests were conducted using both 4G LTE and 5G connections provided by the AIS network. This dual network approach allowed for a comprehensive evaluation of the application's performance across different generations of mobile technology, ensuring that the application's capabilities were thoroughly tested under varying network conditions.

2.3 Data Collection

The data collection process was meticulously designed to capture a comprehensive range of network performance metrics, including advanced parameters specific to 5G networks. Data were also collected using four commercial network testing applications: nPerf [27], OpenSignal [28], Speedtest by Ookla [29], and NetMonster [30].

To ensure global relevance a nd methodological consistency, the QoS evaluation framework adopted in this study follows the NBTC regulations, which are aligned with the international standard ETSI TS 102 250-2 v2.7.1 (2019-11) [31]. This standard defines key performance indicators (KPIs) for end user quality in mobile networks, and its adoption reinforces the credibility and international applicability of the proposed evaluation approach.

2.3.1 Collection from the Developed Application

The developed application was used to systematically record both Radio Parameters and End Parameters under various real world conditions. The Radio Parameters included key metrics such as RSSI, RSRQ, RSRP, and SINR. Additionally, for advanced 5G network evaluation, metrics such as SSRSRQ (Secondary Synchronization Signal Reference Signal Received Quality) and SSRSRP (Secondary Synchronization Signal Reference Signal Received Power) were also measured. These advanced metrics are essential for assessing the quality and strength of the 5G radio link, particularly in standalone (SA) network configurations.

The End Parameters measured included Download Speed, Upload Speed, Ping, and Jitter, providing a comprehensive overview of the network's performance from an end user perspective. Data collection was conducted at six distinct locations within Suranaree University of Technology, each chosen for its unique environmental characteristics. At each location, five measurements were taken between 09:00 and 18:00 to capture variations in network performance throughout the day, resulting in a total of 30 measurement sets. Although the developed application displayed results in real time, all data were manually recorded to ensure accuracy and consistency. In addition, any clearly abnormal or inconsistent values were reviewed and excluded, and repeated measurements were taken when necessary to improve data reliability.

The developed application stores the collected measurement data locally on the mobile device in JSON format, enabling real time access and simple manual verification. While the current version relies on local storage, a future enhancement is planned to implement a cloud based measurement and storage system. This upgrade will reduce manual effort, enhance data reliability, and support more scalable and automated performance evaluations.

The proposed system selects the best server using a routing based method that considers latency and server proximity. All End Parameters were measured using this selected server. However, discrepancies in results may still occur due to server availability, network congestion, or routing behavior. These factors will be further analyzed in future work to improve consistency and accuracy.

2.3.2 Data Collection from Commercial Applications

To establish a reliable benchmark for comparison, data were also collected using four commercial network testing applications: nPerf, OpenSignal, Speedtest by Ookla, and NetMonster. These applications were selected for their industry relevance and their ability to measure both basic and advanced network parameters, comparable to those captured by the developed application.

For each commercial application, the same set of parameters was measured at the same locations and during the same time intervals as the developed application. The data were manually recorded to ensure that all relevant information was accurately captured. The recorded data from these applications were then averaged to create a comprehensive baseline for comparison.

2.4 Comparison with Commercial Application

To thoroughly evaluate the performance of the developed application, a comparative analysis was conducted against four well established commercial applications: nPerf, OpenSignal, Speedtest by Ookla, and NetMonster. This comparison was categorized into two primary areas: Radio Parameters and End Parameters.

The developed application's capability to measure Radio Parameters such as RSSI, RSRQ, RSRP, and SINR was directly compared to NetMonster, a widely utilized application for monitoring cellular network metrics. This comparison was crucial for validating the developed application's accuracy and reliability in capturing signal strength and quality under varying network conditions.

For End Parameters specifically Download Speed, Upload Speed, Ping, and Jitter the results from the developed application were compared against the averaged results from nPerf, OpenSignal, and Speedtest by Ookla. The method of averaging, supported by existing studies, mitigates the potential biases specific to individual applications, providing a more precise assessment of network performance [11]. By averaging the results from multiple commercial applications, this study ensured that the comparison was fair and robust, offering a comprehensive evaluation of the developed application's effectiveness in measuring end user network experience.

3. Results and Discussion

3.1 Comparison with Commercial Application

The performance of the developed application in measuring both 4G and 5G Radio Parameters was evaluated against the average results from commercial applications. The key metrics assessed included RSSI, RSRQ, RSRP, and SINR for 4G, and SS-RSRQ, SS-RSRP, and SS-SINR for 5G. Below is a detailed comparison across six test points.

3.1.1 4G Radio Parameters

Across the six test locations, the developed application and commercial applications showed generally consistent results in measuring RSSI, RSRQ, RSRP, and SINR, with some variations reflecting the dynamic nature of network conditions. The values presented in Table 1 represent the average measurements taken at each test point.

Table 1 Average 4G Radio Parameters

Test Point	Parameter	Developed application	Commercial application
Point 1	RSSI (dBm)	-83.8	-98.6
	RSRP (dBm)	-83.8	-99.0
	RSRQ (dB)	-9.8	-10.2
	SINR (dB)	8.2	1.4
Point 2	RSSI (dBm)	-95.6	-97.4
	RSRP (dBm)	-95.6	-97.4
	RSRQ (dB)	-6.6	-5.8
	SINR (dB)	8.6	14.8
Point 3	RSSI (dBm)	-88.0	-89.0
	RSRP (dBm)	-88.0	-88.0
	RSRQ (dB)	-7.2	-7.0
	SINR (dB)	7.8	8.4
Point 4	RSSI (dBm)	-89.4	-91.8
	RSRP (dBm)	-89.4	-91.6
	RSRQ (dB)	-8.8	-10.2
	SINR (dB)	11.4	15.0
Point 5	RSSI (dBm)	-88.0	-87.0
	RSRP (dBm)	-88.0	-86.2
	RSRQ (dB)	-7.4	-11.2
	SINR (dB)	17.0	5.8
Point 6	RSSI (dBm)	-87.0	-88.2
	RSRP (dBm)	-87.0	-87.4
	RSRQ (dB)	-6.8	-7.6
	SINR (dB)	10.8	8.8

The developed application recorded average RSSI values that were generally in line with those from commercial applications. At Point 1, the developed application recorded an average RSSI of -83.8 dBm, compared to -98.6 dBm by the commercial applications, showing a variation that could be attributed to the specific testing environment. The average RSRQ values measured by the developed application were close to those recorded by the commercial applications, with minor variations. For instance, at Point 5, the developed application recorded an average RSRQ of -7.4 dB, compared to -11.2 dB by the commercial applications, indicating slight differences in signal quality measurement. The average RSRP values obtained from the developed application were consistently higher in some cases, suggesting slight variations in signal power readings. At Point 4, for example, the developed application recorded -89.4 dBm, while the commercial applications recorded -91.6 dBm. The average SINR measurements varied between the developed and commercial applications, with the developed application showing higher values at certain points. At Point 5, it recorded an average SINR of 17 dB, compared to 5.8 dB by the commercial applications, which could indicate differences in how each application handles interference.

3.1.2 5G Radio Parameters

For 5G, the developed application demonstrated performance that was largely consistent with the commercial applications in measuring SS-RSRQ, SS-RSRP, and SS-SINR, with only minor discrepancies observed. The values presented in Table 2 represent the average measurements taken at each test point. The SS-RSRQ values recorded by the developed application closely matched the average values from the commercial applications. For instance, at Point 1, both recorded an SS-RSRQ of -10 dB, indicating similar signal quality assessments. The SS-RSRP average measurements from the developed application were slightly stronger in some cases compared to commercial applications. At Point 5, the developed application recorded -74 dBm, compared to -71.4 dBm by the commercial applications. The SS-SINR values were generally consistent between the developed and commercial applications. At Point 6, for instance, the developed application recorded 22 dB, which was very close to the 21.8 dB recorded by the commercial applications, reflecting its reliability in signal quality measurement.

Table 2 Average 5G Radio Parameters

Test Point	Parameter	Developed application	Commercial application
Point 1	SS-RSRP (dBm)	-70.45	-69.81
	SS-RSRQ (dB)	-10.0	-10.0
	SS-SINR (dB)	21.5	21.37
Point 2	SS-RSRP(dBm)	-76.2	-79.0
	SS-RSRQ (dB)	-10.2	-10.4
	SS-SINR (dB)	20.0	19.2
Point 3	SS-RSRP (dBm)	-79.4	-68.6
	SS-RSRQ (dB)	-10.4	-10.8
	SS-SINR (dB)	15.6	13.0
Point 4	SS-RSRP(dBm)	-79.4	-78.4
	SS-RSRQ (dB)	-10.8	-10.4
	SS-SINR (dB)	14.2	18.4
Point 5	SS-RSRP(dBm)	-74.0	-71.4
	SS-RSRQ (dB)	-10.6	-10.0
	SS-SINR (dB)	16.2	19.2
Point 6	SS-RSRP(dBm)	-72.2	-73.8
	SS-RSRQ (dB)	-10.0	-10.0
	SS-SINR (dB)	22.0	21.8

3.2 End Parameters Analysis

The performance of the developed application in measuring both 4G and 5G Radio Parameters was evaluated against the average results from commercial applications. The key metrics assessed included RSSI, RSRQ, RSRP, and SINR for 4G, and SS-RSRQ, SS-RSRP, and SS-SINR for 5G. Below is a detailed comparison across six test points.

3.2.1 4G End Parameters

Across the six test locations, the developed application and commercial applications demonstrated varying results in measuring Download Speed, Upload Speed, and Ping. The values presented in Table 3 show the average measurements taken at each test point.

The developed application recorded Download Speeds that were generally consistent with commercial applications, though some variations were observed. For example, at Point 3, the developed application recorded 66.98 Mbps, compared to 105.19 Mbps by the commercial applications. Upload Speed measurements were also fairly consistent, with minor discrepancies. At

Point 2, the developed application recorded 26.28 Mbps, compared to 24.57 Mbps by the commercial applications. The Ping values showed notable variations, with the developed application sometimes recording significantly lower latency. For instance, at Point 1, the developed application recorded 28.83 ms, while the commercial applications recorded 420.27 ms.

Table 3 Average 4G End Parameters

Test Point	Parameter	Developed application	Commercial application
Point 1	Download (Mbps) Upload (Mbps) Ping(ms)	58.32 11.41 28.83	56.54 11.80 420.27
Point 2	Download (Mbps) Upload (Mbps) Ping(ms)	59.88 26.28 20.44	67.94 24.57 26.60
Point 3	Download (Mbps) Upload (Mbps) Ping(ms)	66.98 2.14 28.28	105.19 5.02 27.47
Point 4	Download (Mbps) Upload (Mbps) Ping(ms)	22.83 3.08 32.87	37.54 11.47 52.13
Point 5	Download (Mbps) Upload (Mbps) Ping(ms)	19.56 2.67 35.35	24.53 5.73 28.40
Point 6	Download (Mbps) Upload (Mbps) Ping(ms)	97.86 19.37 32.33	89.04 28.60 168.60

3.2.2 5G End Parameters

For 5G, the developed application's performance in measuring Download Speed, Upload Speed, and Ping was largely consistent with commercial applications, with slight variations observed. The values presented in Table 4 represent the average measurements taken at each test point.

Table 4 Average 5G End Parameters

Test Point	Parameter	Developed application	Commercial application
Point 1	Download(Mbps) Upload (Mbps) Ping(ms)	172.47 30.28 25.55	291.60 37.03 27.60
Point 2	Download(Mbps) Upload (Mbps) Ping(ms)	181.14 25.54 30.26	224.60 29.58 40.93
Point 3	Download(Mbps) Upload (Mbps) Ping(ms)	106.70 21.23 35.68	210.82 33.94 29.80
Point 4	Download(Mbps) Upload (Mbps) Ping(ms)	176.28 28.95 32.21	181.46 30.07 29.87
Point 5	Download(Mbps) Upload (Mbps) Ping(ms)	160.66 27.91 31.96	292.22 41.70 28.07
Point 6	Download(Mbps) Upload (Mbps) Ping(ms)	173.34 29.56 32.27	292.59 36.02 30.67

3.3 Standard Deviation Analysis

The consistency of the developed application was further assessed by analyzing the standard deviation (SD) of the collected data for both 4G and 5G Radio Parameters. The results, summarized in Fig. 2 for 4G and Fig. 3 for 5G, compare the average SD values across all test points between the developed application and commercial applications.

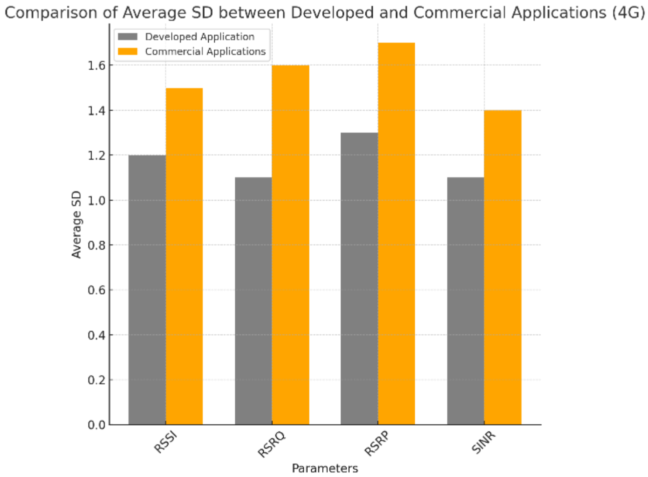

Fig. 2 Comparison of Average Standard Deviation for 4G Radio Parameters.

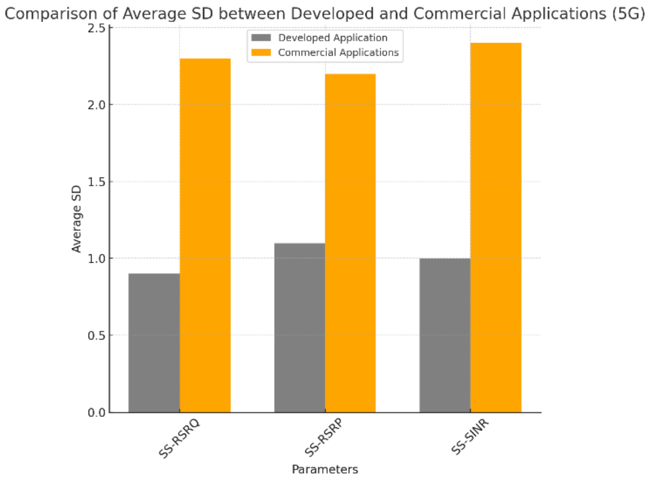

Fig. 3 An Comparison of Average Standard Deviation for 5G Radio Parameters.

3.4 Performance Evaluation Based on NBTC Standards

The primary objective of these tests is to assess whether the network performance in various areas meets the standards set by the NBTC. According to regulations, the

public should receive network services that comply with the minimum standards established by NBTC. The measurements in this study focus on End and Radio Parameters such as Download Speed, Upload Speed , Ping, RSRP, SINR, SS-RSRQ, SS-RSRP for both 4G and 5G networks.

The results indicate that the developed application successfully evaluated all test locations, and the measured parameters consistently met NBTC standards across the board. This can be summarized in the following Fig. 4-7 These findings demonstrate that the developed application can reliably evaluate network performance and confirm that each tested area met the NBTC standards. This ensures compliance with legal requirements, verifying that the public is receiving network services that meet the expected quality standards.

Fig. 4 Visualization of 4G Radio Parameters

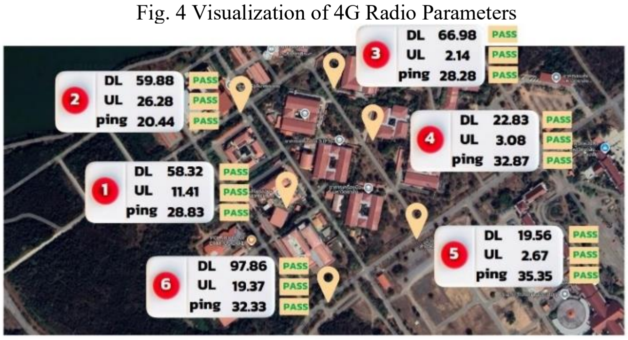

Fig. 5 Visualization of 4G End Parameters

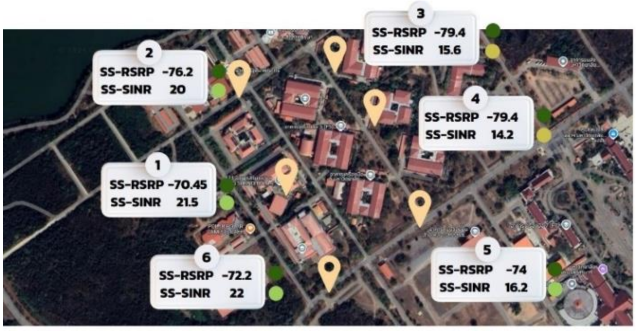

Fig. 6 Visualization of 5G Radio Parameters

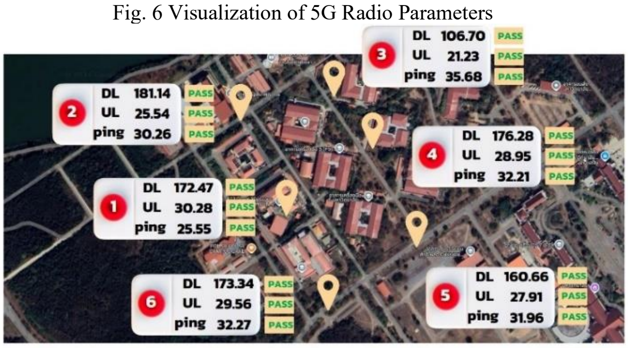

Fig. 7 Visualization of 5G End Parameters

3.5 Overall Performance Summary

The comparative analysis of both 4G and 5G Radio and End Parameters indicates that the developed application

performs similarly to established commercial applications, particularly in the measurement of Radio Parameters. The results show strong alignment in metrics such as RSSI, RSRQ, RSRP, and SINR for 4G, as well as SS-RSRQ, SS-RSRP, and SS-SINR for 5G. This consistency suggests that the developed application is effective in assessing network signal quality and strength across various environments.

However, the analysis of End Parameters specifically Download Speed, Upload Speed, and Ping revealed some differences between the developed application and commercial applications. These discrepancies are likely influenced by variations in the communication protocols and server connections used during testing. Commercial applications may connect to different servers with varying proximities or loads, which can significantly affect recorded speeds and latency. These factors highlight the inherent complexity of network performance measurement and emphasize the importance of considering server location and protocol differences when interpreting these results.

Despite these observed differences, the developed application has proven to be a reliable tool for measuring both Radio and End Parameters, providing valuable insights into network performance. The consistency, particularly in Radio Parameters, supports the application's accuracy and robustness, positioning it as a credible option in the domain of mobile network testing.

3.6 Statistical Testing with Paired t-test

To verify whether there were statistically significant differences between the developed application and commercial applications, a Paired Sample t-test was conducted on four core Radio Parameters: RSSI, RSRP, RSRQ, and SINR. The analysis used data collected from six test locations (n = 6 pairs per parameter).

Table 5 Paired t-test Results Comparing Radio Parameters between Developed and Commercial Applications

Parameter	t-statistic	p-value
RSSI	1.4422	0.2088
RSRP	1.1797	0.2912
RSRQ	1.3661	0.2301
SINR	0.6018	0.5736

As shown in the table 5, all p-values are greater than 0.05, indicating that there is no statistically significant difference between the developed and commercial applications for any of the parameters at the 95% confidence level.

These results support the conclusion that the developed application provides accurate and consistent measurements comparable to those obtained from established commercial tools when evaluating 5G radio signal quality.

4. Discussion

This The results of this study provide significant insights into the effectiveness of the developed application in evaluating 5G network performance, particularly in comparison with commercial alternatives. The application demonstrated high accuracy in measuring both Radio Parameters (RSSI, RSRQ, RSRP, SINR, SS-

RSRQ, SS-RSRP, SS-SINR) and End Parameters (Download Speed, Upload Speed, Ping, Jitter), aligning well with established commercial applications such as nPerf, OpenSignal, Speedtest by Ookla, and NetMonster. The observed consistency in Radio Parameter measurements indicates the reliability of the developed tool in assessing network signal strength and quality. However, some discrepancies in End Parameter measurements, particularly in download and upload speeds, suggest potential differences in measurement methodologies, server locations, and network traffic conditions. One of the key findings is that the developed application exhibited a lower standard deviation (SD) in Radio Parameters, indicating greater stability in measurement outcomes. This suggests that the application minimizes fluctuations and provides a more precise assessment of network performance under varying environmental conditions. The application's ability to integrate both Radio and End Parameters into a single measurement tool addresses a crucial gap in existing commercial applications, which often focus on only one aspect of network evaluation. The study also assessed whether the measured parameters met the quality standards set by Thailand's NBTC. The findings confirm that all test locations complied with NBTC's QoS regulations, reinforcing the application's effectiveness as a regulatory monitoring tool. However, the study did not explicitly benchmark results against international standards such as those established by the International Telecommunication Union (ITU) or the Federal Communications Commission (FCC). Future studies should include a broader regulatory framework to position the developed application as a globally relevant tool for network performance assessment. Despite its strengths, the study has certain limitations. The tests were conducted in only six locations within Suranaree University of Technology, which may not fully represent the diverse range of real world 5G environments, such as high density urban areas, rural regions, and underground infrastructure. Expanding the test locations to a broader geographic scope would provide a more comprehensive evaluation of the application's effectiveness across different network conditions. Additionally, while the study incorporated basic statistical measures such as means and standard deviations, future work could enhance the analysis by incorporating hypothesis testing, correlation analysis, or regression models to further validate the statistical significance of the observed differences. Moreover, the manual data recording process presents a potential limitation. Although this approach ensured data accuracy and consistency, it is prone to human error and may not be scalable for large scale network evaluations. Future iterations of the application could integrate an automated data logging system to enhance efficiency and reduce the risk of manual recording inconsistencies. Lastly, while the application performed well in evaluating 5G Radio Parameters, some End Parameter measurements (such as download speed and latency) showed slight deviations from commercial applications. This may be attributed to differences in server connections, data processing methodologies, or underlying network congestion during testing. Future research should explore alternative measurement algorithms and server selection techniques to improve the accuracy of End Parameter assessments.

5. Conclusion

This work presents the development and comprehensive evaluation of a single application for 4G/5G network performance measurement, focusing on both Radio and End Parameters. This research aims to develop a user centric application that enhances user convenience. It addresses the limitations of existing methods, which require multiple applications to measure signal quality in terms of radio parameters and end parameters, leading to inefficiencies as users have to switch between several apps. Additionally, the developed application serves as an easy to use tool to help users understand the nature of 4G/5G networks. Furthermore, it functions as a signal quality assessment tool based on NBTC QOS standards. The application was tested across six distinct locations within Suranaree University of Technology and compared against several established commercial applications to assess its accuracy and reliability. Finally, proposed application reduces testing time of related users. Moreover, user flexibility increases due to proposed application. These demonstrate the application's capability to deliver reliable and stable network performance evaluations, positioning it as a valuable tool for advancing 5G network management and optimization. Furthermore, development of the proposed application will involve the integration of AI/ML to predict the performance of connected networks, as well as provide simple recommendations to users. This will help improve the signal quality received by User Equipment, allowing users to achieve better QoS on their own.

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