

Development of a Dashboard for Drone-Assisted High-Altitude Cellular Network Coverage

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Abstract

The continuous demand for enhanced cellular networks has driven crucial improvements in network assessment methods. Traditional drive and walk tests, however, face challenges such as limited altitude assessment and difficulty in accessing hard-to-reach areas. To overcome these limitations, this project concentrated on developing a drone-assisted system for real-time cellular coverage monitoring. This system features a dashboard, built with Python's PyQt5 and PyQtGraph libraries, for visualizing LTE parameters like RSRP, RSRQ, and SINR in real-time. Heatmaps were generated using the Folium library to visualize network coverage on an interactive map. A comprehensive drive test was conducted around Parit Raja using G-NetTrack Lite and Mikrotik LtAP LTE6 Kit to collect LTE data, and a comparison between both tools was performed. A drone integrated with the Mikrotik LtAP LTE6 Kit was utilized for high-altitude LTE data collection at 10 meters and 20 meters. The dashboard was then integrated into a software user interface for ease of usability. Based on the results, it was concluded that the average percentage difference between RSRP values from G-NetTrack Lite and the Mikrotik LtAP LTE6 Kit was 7.93%. Furthermore, drone-assisted data collection revealed an overall trend suggesting a more consistent and pronounced improvement in RSRP at 20 meters altitude compared to 10 meters. Finally, the dashboard successfully fetched and visualized LTE data at one-second intervals.

1. Introduction

The continuous demand for improvement in cellular networks has been a crucial drive for the development of telecommunications technology for years, which ultimately produces the most recent technologies such as 4G and 5G networks that offer significant improvement in speed, latency as well as capacity. According to Malaysia Telecoms Industry Report: 2024 – 3031, 4G networks coverage has reached over 97% of the population in Malaysia, with improvement in speed as over 50% of 4G sites now equipped with fiber backhaul [1]. However, despite the significant advantages of 5G, 4G networks are still capable of consistently delivering superior average performance, indicating how relevant it is in areas where 5G deployments are limited [2]. Hence, 4G networks coverage monitoring is still relevant nowadays for decision-making in the telecommunications industry. In this case, the usage of wireless graphs and heat maps as visual representation of the networks can come in handy for future upgrade or resolving issues arise, leading to efficiency in network management [3]. Next, as of 2024, drones have gained significant popularity in various industries due to the benefits being offered, especially their ability to access hard-to-reach areas. The applications of drones in telecommunication applications are also increasing, such as temporary communications networks and real-time video surveillance over 4G LTE [4] – [5]. By

understanding the limitations of traditional systems in cellular network testing, drones can be used in this case for greater flexibility and altitude tracking, providing a better insight of the network in various environments.

2. Literature Review

This section analyzes previous papers that have focused on utilizing drones for cellular network assessment. These studies significantly contribute to the development of this project by exploring unique methodologies, equipment configurations, and data analysis approaches.

Paper [3] focuses on 5G coverage autonomous measurements, utilizing a drone equipped with four smartphones running the Keysight's NEMO mobile application. These measurements were conducted on a large scale with automated flight planning. However, the authors noted a possible inaccuracy in received power due to the drone's random movement at each waypoint and wind gusts.

Similarly, paper [6] concentrates on cellular network coverage prediction using drone measurements. In this study, the drone was equipped with a single smartphone running the G-NetTrack mobile application. The significant highlight of this paper was its use of machine learning algorithms, though its dataset was limited to a specific environment.

Paper [7] focuses on the creation of a drone-based system for cellular network output analysis and visualization. This system utilized a drone equipped with a smartphone running the Network Cell Info application, complemented by MATLAB's GUIDE tool for visualization. Furthermore, a Graphical User Interface (GUI) was developed to present the collected data in a way that is accessible to end users, regardless of their technical knowledge. However, the authors specifically highlighted that there were minor errors in terms of location accuracy and signal power.

Papers [3]- [7] demonstrate the potential and advantages of utilizing drones for various cellular network assessment tasks, such as coverage mapping and interference analysis. Each study presents unique aims and methodologies, thereby highlighting the capability of drones for diverse applications within cellular network assessment. While showcasing their strengths, each study also reveals specific weaknesses, often related to environmental factors and limitations in measurement accuracy. Consequently, these articles suggest that drones are well-suited for a wide range of cellular network assessment applications. Furthermore, paper [7] emphasizes the importance of effective data visualization for end users, which aligns with the development of dashboard for this project.

3. Methodology

This section covers the details of the methods used to complete this project. Fig. 1 illustrates the general flowchart of the project, which indicates the whole process of developing this project. It can be noted that the project was conducted in two phases, which were data visualization and data collection. First, data visualization was carried out by developing a dashboard that included heatmaps and graphs to visualize the collected data. The developed dashboard was integrated into a software user interface, namely LTE Vision, developed using PyQt5. In the second phase, data collection was performed, involving hardware configurations of drive tests, Mikrotik LtAP LTE6 kit, and drone-based cellular network parameters collection.

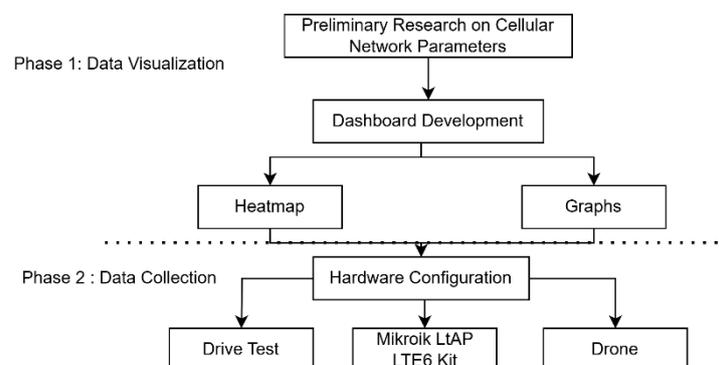


Fig. 1 General flowchart of the project

3.1 Key Performance Indicator for LTE Signal

Common parameters to be focused on evaluating cellular network performance are RSRP, RSRQ and SINR. Analyzing a combination of all three parameters provided an in-depth and accurate representation of overall network performance. This combined analysis could be used to classify network performance into distinct categories, namely excellent, good, mid- cell, and cell-edge. This approach offered a more intuitive understanding

of overall network performance rather than relying on individual analysis. Table 1 indicates the KPIs for LTE signal strength, which is used to determine the condition of the networks, starting from excellent to cell edge, which are classified based on several parameters [8]. Specifically, excellent condition represents the strongest signal, good condition indicates strong signal, mid-cell condition denotes a moderate signal, and cell edge condition signifies the weakest signal.

Table 1 LTE Signal Strength Classification [8]

RF Conditions	RSRP (dBm)	RSRQ (dB)	SINR (dB)
Excellent	≥ -80	≥ -10	≥ 20
Good	-80 to -90	-10 to -15	13 to 20
Mid Cell	-90 to -100	-15 to 0	0 to 13
Cell Edge	≤ -100	≤ -20	≤ 0

Reference Signal Received Power (RSRP) is the average power received from a single reference signal, Reference Signal Received Quality (RSRQ) indicates quality of the received signal while Signal-to-Interference-plus-Noise Ratio (SINR) shows the signal-to-noise ratio of the given signal. On top of that, there is another parameter which is Received Signal Strength Indicator (RSSI) that indicates the measurement of the power present in a received radio signal [8]. Table 1 shows the range of each parameter for each RF conditions, which is helpful to classify these signals.

3.2 Dashboard Development

Dashboards for cellular network assessment can come in handy for visualization of network parameters on a single screen, especially since there were multiple parameters to be observed simultaneously. This simultaneous view is crucial because monitoring cellular network performance is a complex task, requiring analysis of multiple data points. In this project, a dashboard was used to simplify the complexity of representing this data, by visualizing each parameter in intuitive formats such as graph and heatmap. In the case of cellular network assessment, there were multiple crucial parameters to be observed, such as RSRP, RSRQ, SINR and RSSI.

Heatmaps are effective tools to visualize cellular network coverage. These tools can help telecommunication operators gain an understanding of the performance of cellular networks in the targeted area. In this project, Folium was used to produce heatmaps to represent the coverage of the cellular network. Folium is a powerful Python library that can create interactive maps. It allows these heatmaps to be overlaid directly onto physical maps, providing a geographically accurate representation of signal strength. Fig. 2 displays the usage of a heatmap using Folium in Python, where the color represents the condition of the RSRP signal. Specifically, green represents excellent, yellow represents good, orange represents mid-cell, and red represents cell edge.



Fig. 2 Heatmap using Folium in Python [9]

Graphs are important for visualizing cellular network performance, offering clear representations like lines, bars, and points to identify patterns and anomalies such as average values or sudden drops. In this case, PyQtGraph was utilized for plotting cellular network parameters. In this project, Scatter Plots (Dot Plots) were used to visualize several network parameters, which were RSRP, RSRQ, SINR, and RSSI. Line Graphs were used to represent bitrates, which had two data streams (receiver and transmitter) in a single plot. Next, gauge charts, color-coded (green for excellent, yellow for good, orange for mid-cell, and red for cell-edge), were used to represent the current network strength and average network strength, which were taken from RSRP values. Fig. 3 (a) and (b) illustrate the usage of gauge chart and scatter plot to visualize cellular network performance, where

the colors represent the RSRP signal condition, with green indicating excellent, yellow for good, orange for mid-cell, and red for cell edge.

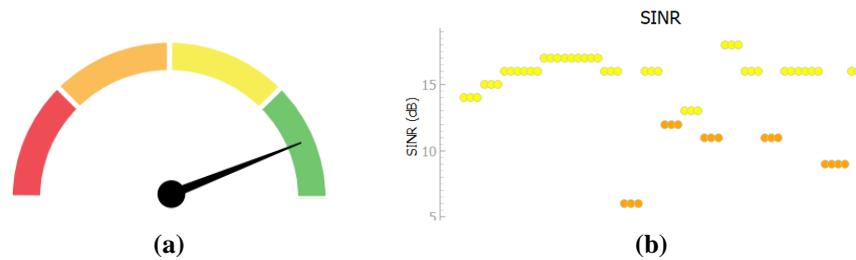


Fig. 3 Cellular network performance visualizations (a) Gauge chart for current network strengths; (b) Scatter plot for SINR measurements in Decibels (dB)

3.3 Hardware Configuration for Data Collection

Effective cellular network analysis relies on reliable data collection methods. This section explores the hardware configurations used to collect network performance data, focusing on two primary approaches, which are traditional drive testing using Mikrotik LtAP LTE6 Kit in motor vehicles, and drone testing, where the drones were equipped with the same equipment. These methods offered distinct advantages and were used to collect comparable data for an in-depth understanding of cellular network performance.

Mikrotik LtAP LTE6 kit is a compact 4G (LTE) capable weatherproof wireless access point. In this project, this kit was used for both drive tests and drone-based testing as equipment for collecting data on cellular network parameters. The device comes with a powerful built-in operating system called RouterOS. This combination provides a reliable platform for data collection, and its integration with Python scripting significantly enhances the project's capabilities.

To collect network data from the device, the server, which is a laptop, or a single-board computer runs a local Flask web server, which, after connecting to the Mikrotik's access point, receives collected network data through an HTTP POST request to its /upload endpoint. This received data is then logged into a file and stored in a CSV, making it available for further processing and analysis. Fig. 4 illustrates this data retrieval operation, where the LtAP LTE6 kit acts as a client pushing data to the laptop or single-board computer (the server) via HTTP, facilitated by RouterOS and HTTP protocols.



Fig. 4 Operation of retrieving data from LtAP LTE6 Kit to a laptop or single-board computer

RF drive testing is a method of assessing the coverage, capacity, and Quality of Service (QoS) of mobile radio networks. In this project, the equipment used for the drive test was the Mikrotik LtAP LTE6 Kit, which was placed inside a car during the drive test campaign. Fig. 5 displays this setup, showing the Mikrotik LtAP LTE6 Kit acting as a client to transmit LTE parameters collected every second, alongside a single-board computer, specifically the Banana Pi from Shenzhen SINOVOIP Company, which functions as a server to receive these parameters from the client. Both devices are powered by the car's battery through its auxiliary power outlet, providing 12V DC. A single-board computer was chosen over a laptop mainly due to energy consumption issues, as it only requires a significantly lower amount of power to operate. This is suitable for drive test which often requires a long period of data collection using a limited power supply, which is the car's battery.



Fig. 5 Drive test setup

RF Drone-based testing is also a method of assessing the coverage, capacity, and Quality of Service (QoS) of mobile radio networks, which, in this case, refers to cellular networks. Drone testing was performed using a drone, equipped with Mikrotik LtAP LTE6 Kit for cellular network assessment within a specific area. Fig. 6 (a) displays the drone used for this purpose. Fig. 6 (b) shows the usage of a DC-DC step down adjustable voltage regulator module used to step down the voltage from the battery of the drone that is approximately 25 V to 20 V, so that it can power up the kit within its operating range. The kit was mounted beneath the drone to minimize potential magnetic interference that could affect the drone's systems.

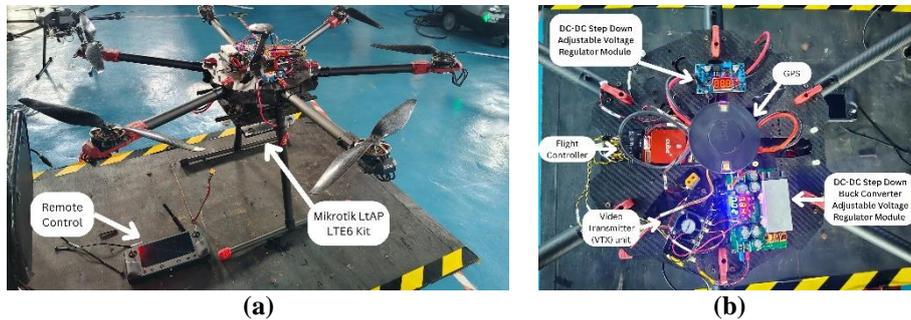


Fig. 6 Drone setup (a) Drone used for LTE network assessment; (b) Usage of a DC-DC step down adjustable voltage regulator module to power up Mikrotik LtAP LTE6 Kit

Fig. 7 displays the waypoints defining the drone's automated flight path for cellular network assessment. The Mission Planner software interface clearly shows a series of interconnected green circles representing the defined waypoints, with yellow lines illustrating the drone's planned trajectory. For this assessment, three flights were performed using the same waypoint set, but at different altitudes which were at 1.5 meters (ground level), 10 meters, and 20 meters.



Fig. 7 Mikrotik LtAP LTE6 Kit mounted beneath the drone

4. Results and Discussions

This section presents the results obtained from this project. It focuses on two phases as discussed in the methodology section, which are data visualization and data collection. This section details the key findings from

each of these phases, providing important evidence that supports the theoretical discussions presented in the previous sections.

4.1 Dashboard Development

The dashboard was developed on a single user interface software that consists of two distinct pages. The first page features various plots alongside multiple gauge meters for comprehensive LTE performance monitoring, while the second page employs a heatmap to visually represent the LTE signal strength, specifically the RSRP. As mentioned in the previous section, both pages utilize the LTE signal strength classification highlighted in Table 1. As the dashboard is designed for real-time monitoring of LTE parameters, both pages update their data at an interval of approximately 1 second.

Fig. 8 shows the first page of the dashboard, which displays plots of common LTE parameters which are RSRP, RSRQ, RSSI, SINR, download and upload bitrates, and altitude. Additionally, there are gauge charts illustrating the current network strength and the average network strength for the past few minutes. The page also includes other information regarding the LTE network, such as the telecommunication provider and details about the current cell tower being used.

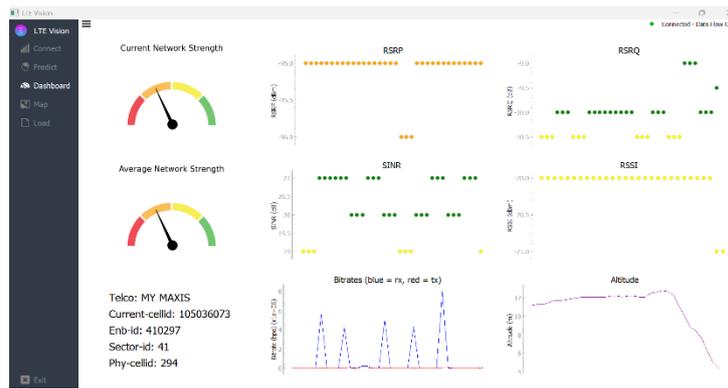


Fig. 8 First page of dashboard (Graphs)

Fig. 9 shows the second page of the dashboard, which is a real-time map displaying a heatmap. This heatmap visually represents the LTE signal strength, specifically RSRP, across a geographical area, depending on the current location of the user. Different colors on the map indicate varying levels of RSRP, allowing the user to easily identify areas with excellent, good, mid cell or cell edge, as discussed in Table 1. Since the dashboard updates data at approximately 1-second intervals, this heatmap provides a dynamic and quick overview of the LTE signal strength as it changes in real-time. This makes the dashboard an efficient tool for monitoring LTE network coverage, especially during drive tests due to its real-time capabilities.

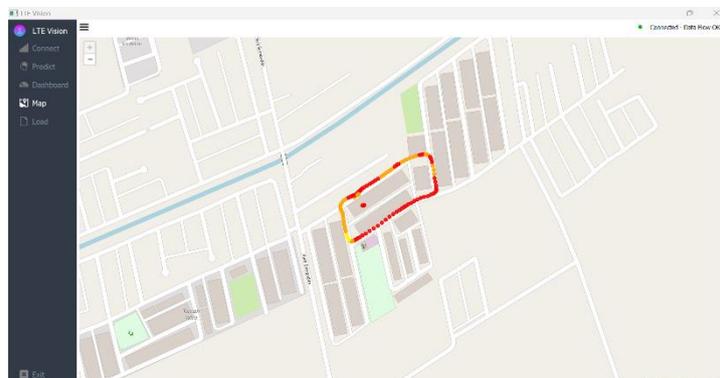


Fig. 9 Second page of dashboard (Heatmap)

4.2 Data Collection

To evaluate Maxis' cellular network performance, data was collected in Parit Raja, specifically around the Universiti Tun Hussein Onn Malaysia (UTHM) campus. This process was divided into two distinct phases, which were a drive test conducted by car, and data acquisition using a drone. For this data collection, two primary tools were employed, which were a mobile application called G-NetTrack Lite and a Mikrotik LtAP LTE6 kit.

For the drive test, two separate data collections were conducted, one using G-NetTrack Lite and another using the LtAP LTE6 kit. To ensure accurate comparison, both processes followed the same route around Parit Raja and focused on the Maxis telecommunication provider. Based on the results, while Maxis' LTE network generally provides coverage across the surveyed areas, the strength of that signal, as indicated by RSRP, varies significantly across the full range of RSRP values. In this case, while rural areas often experience poorer LTE coverage, the UTHM campus area consistently shows mostly excellent coverage. Fig. 10 illustrates the comparison between the RSRP of G-NetTrack Lite and Mikrotik LtAP LTE6 Kit. It can be observed that the RSRP values from G-NetTrack Lite (blue line) and the Mikrotik LtAP LTE6 Kit (red dotted line) generally follow similar trends, but there are noticeable deviations and fluctuations between them. The values from both sources mostly range from approximately -70 dBm to -110 dBm. The average percentage difference between RSRP values from G-NetTrack Lite and Mikrotik LtAP LTE6 Kit was calculated to be 7.93%.

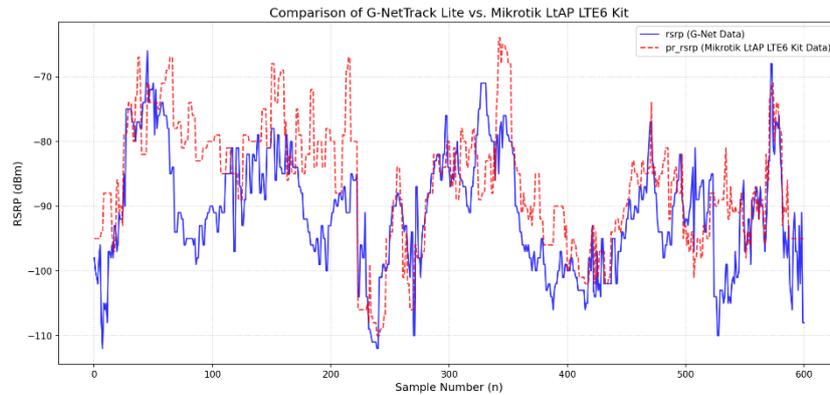


Fig. 10 Comparison between G-NetTrack Lite and Mikrotik LtAP LTE6 Kit (RSRP)

Drone-assisted data collection was performed by integrating the Mikrotik LtAP LTE6 kit with a drone. Due to limited authorization, this process was conducted only within a single designated field on the Universiti Tun Hussein Onn Malaysia (UTHM) campus. Consequently, unlike the comprehensive drive test, the LTE network range evaluated through this method is not as versatile or extensive in geographical coverage. The drone measurements were concentrated only on a smaller, specific area, providing detailed vertical and localized information.

This phase of data collection was structured into three distinct altitude stages, which were 1.5 meters, 10 meters, and 20 meters. The 1.5 meters data was considered ground-level data, specifically because the field cannot be accessed by a car for traditional drive test methods. By using the same route, mapped using waypoints, for each of these flights, a consistent path was ensured across all altitude measurements. Fig. 11 (a) displays the drone-assisted data collection at a 20-meter altitude, while Fig. 11 (b) shows the same process but at a 10-meter altitude. For this data collection, the entire route followed the same waypoints.



Fig. 11 Drone-assisted data collection (a) 20-meter altitude; (b) 10-meter altitude

Based on data collected, Fig. 12 and Fig. 13 were illustrated. First, Fig. 12 displays the relationship between RSRP at 10 meters altitude and ground level (1.5 meters altitude). The blue solid line represents the RSRP measurements at 10 meters altitude while the red dotted line represents the RSRP at ground level. That said, it can be observed that the RSRP at 10 meters altitude generally displays higher (less negative) values compared to the RSRP at ground level. This indicates better signal strength at higher altitudes for most sample numbers. However, the overall trend suggests that while there is an improvement in RSRP at 10 meters altitude, the difference is not always significant.

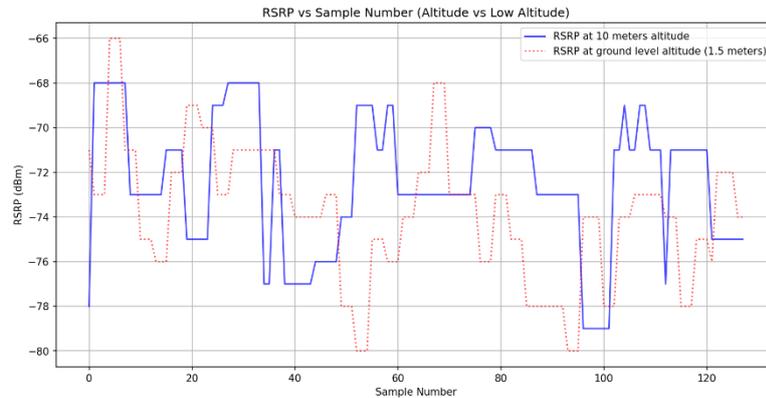


Fig. 12 Relationship between RSRP at 10 meters altitude and ground level (1.5 meters)

Fig. 13 illustrates the relationship between the RSRP at ground level (1.5 meters altitude) and at 20 meters altitude. In this case, the blue solid line represents the RSRP measurements at 20 meters altitude while the red dotted line represents the RSRP at ground level. That said, it can be concluded that the RSRP at 20 meters altitude generally displays significantly higher (less negative) values compared to the RSRP at low altitude. This indicates better signal strength at higher altitudes for most of the sample numbers. Unlike the 10-meter case, the overall trend clearly suggests a more consistent and pronounced improvement in RSRP at 20 meters altitude.

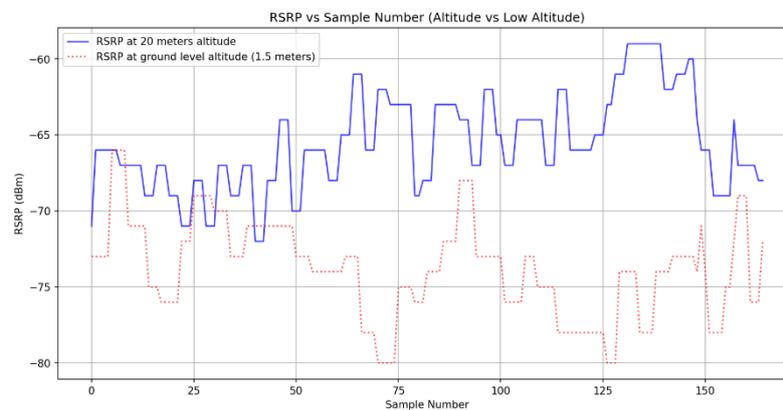


Fig. 13 Relationship between RSRP at 20 meters altitude and ground level (1.5 meters)

5. Conclusion

In conclusion, a drone-assisted system for real-time cellular coverage monitoring was successfully developed. The dashboard that was built with Python libraries such as PyQt5 and PyQtGraph has effectively displayed real-time LTE parameters like RSRP, RSRQ, and SINR, and generated heatmaps using the Folium library for interactive network coverage visualization. As the data was fetched and displayed every one second, it can be concluded that the dashboard was able to perform in real-time. Data collection involved both traditional drive tests and drone-assisted methods using the Mikrotik LtAP LTE6 Kit. A comparison between G-NetTrack Lite and the Mikrotik LtAP LTE6 Kit revealed an average percentage difference of 7.93% in RSRP values. Drone-assisted data collection at different altitudes proves that RSRP values are generally improved with increased altitude. A more consistent improvement in RSRP was observed at 20 meters altitude compared to 10 meters. Hence, this research highlights the utilization of drones in overcoming the limitations of traditional network assessment methods and provides an effective tool for network management and optimization.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contributions to the paper as follows: study conception and design: Muhammad Akif bin Mohd Shaid, Fauziahanim Binti Che Seman; data collection: Muhammad Akif bin Mohd Shaid; analysis and interpretation of results: Muhammad Akif bin Mohd Shaid; draft manuscript preparation: Muhammad Akif bin Mohd Shaid, Fauziahanim Binti Che Seman. All authors reviewed the results and approved the final version of the manuscript.

References

- [1] Finance.yahoo (2024). Malaysia Telecoms Industry Report 2024-2031: 4G Speeds Improved with Over 50% of 4G Sites now Equipped with Fibre Backhaul as well as 4G Coverage Reaching Over 97% of the Population. Retrieved on December 15, 2024.
- [2] Tsoulos, G., Athanasiadou, G., Zarbouti, D., Nikitopoulos, G., Tsoulos, V., Christopoulos, N. Comparative Field Trials for different 5G-4G Cellular Networks. 28-29 March 2024. Thessaloniki, Greece: Institute of Electrical and Electronics Engineers (IEEE). 2024. pp. 1-4.
- [3] Platzgummer, P., Raida, V., Krainz, G., Svoboda, P., Lerch, M., Rupp, M. UAV- Based Coverage Measurement Method for 5G. 2019 IEEE 90th Vehicular. 22-25 Sept. 2019. Hawaii, USA: Institute of Electrical and Electronics Engineers (IEEE). 2019. pp. 1-6.
- [4] Tran, G. K. Temporary Communication Network Using Millimeter-Wave Drone Base Stations. IEEE VTS Asia Pacific Wireless Communications Symposium (APWCS). 21-23 Aug. 2024. Tokyo, Japan: Institute of Electrical and Electronics Engineers (IEEE). 2024. pp. 1-5.
- [5] Qazi, S., Siddiqui, A. S., Wagan, A. I. UAV based real time video surveillance over 4G LTE. 2015 International Conference on Open Source Systems & Technologies (ICOSST). 17-19 December 2015. Lahore, Pakistan: Institute of Electrical and Electronics Engineers (IEEE). 2015. pp. 141-145.
- [6] Tarhuni, N., Saadi, I. A., Mesbah, M., Eldirdiry, O., Hossen, A. (2023). Machine- Learning-Based Ground-Level Mobile Network Coverage Prediction Using UAV Measurements. Journal of Sensor and Actuator Networks. 12(3), pp. 44.
- [7] Buggiani, V., Ortega, J. C. U., Silva, G., Rodríguez-Molina, J., Vilca, D. (2023). An Inexpensive Unmanned Aerial Vehicle-Based Tool for Mobile Network Output Analysis and Visualization. Sensors 2023. 23(3), pp. 1285.
- [8] Digi (2024). Understanding LTE Signal Strength Values. Retrieved on December 15, 2024, from <https://www.digi.com/support/knowledge-base/understanding-lte-signal-strength-values>
- [9] Supplychaindataanalytics (2020). Spatial heatmaps with Folium in Python. Retrieved December 15, 2024, from <https://www.supplychaindataanalytics.com/spatial-heatmaps-in-python-using-leaflet-js-via-folium-module/>