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MATLAB GUI-Based RSSI and SNR Heatmap Visualisation for Maxis Network in Parit Raja, Johor

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The increasing demand for reliable LTE (4G) connectivity in semi-urban environments necessitates a comprehensive understanding of spatial variations in network performance. Despite continuous infrastructure enhancements, signal degradation caused by terrain characteristics, environmental obstructions, and suboptimal base station placement remains a critical issue, highlighting the need for efficient analysis and visualisation tools. This study presents a MATLAB Graphical User Interface (GUI)-based framework for spatial analysis of Received Signal Strength Indicator (RSSI) and Signal-to-Noise Ratio (SNR) in Parit Raja, Johor, which supports effective network diagnostics and data-driven optimisation for improved cellular performance. Field measurements were acquired using a MikroTik LtAP LR8G LTE6 kit with integrated GPS, enabling accurate geo-referenced data collection. The proposed system automates data preprocessing, spatial interpolation, and heatmap visualisation to facilitate efficient and intuitive performance evaluation. The analysis of Maxis cellular coverage in Parit Raja shows that RSSI values range from −45 dBm to −85 dBm, while SNR varies between −10 dB and 30 dB. Strong signal conditions are observed in open areas, whereas weaker performance is evident in dense and obstructed environments, demonstrating significant spatial variability.

Keywords: RSSI; SNR; heatmap; MATLAB GUI; wireless communication; cellular network

I. INTRODUCTION

Maxis is among Malaysia's leading mobile network operators and has consistently invested in the deployment and upgrading of LTE and 4G infrastructure to enhance nationwide coverage, network capacity and overall service quality (Maxis Berhad, 2025; Chan, 2025; OpenSignal, 2024). Despite these sustained investments and technological advancements, prior studies have demonstrated that wireless signal degradation can still occur, even in areas that are generally considered well-covered. Such degradation is often attributed to factors including terrain variability, physical obstructions such as buildings and vegetation and suboptimal base placement or density (Dreifuerst *et al.*, 2020; Rohde & Schwarz, 2018; Mishra, 2007). Consequently, the quality and reliability of cellular signal performance may vary significantly across different geographic locations, with more pronounced fluctuations commonly observed in semi urban and rural environments.

Parit Raja, located in the Batu Pahat district of Johor, Malaysia, is a rapidly developing academic and residential hub anchored by Universiti Tun Hussein Onn Malaysia (UTHM). With increasing mobile data demand from students, residents, and businesses, reliable cellular performance has become essential (MetaGeek, n.d.; Malaysian Communications and Multimedia Commission, 2020; Ramlan, 2019). Hence, understanding the spatial

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distribution of signal strength is critical for ensuring adequate service quality and guiding network enhancements.

In wireless communication system, Received Signal Strength Indicator (RSSI) is widely adopted for evaluating wireless link quality, coverage mapping, and network optimisation (Dreifuerst *et al.*, 2020; Ramlan, 2019; Bandri, 2013; Telecom Trainer, n.d.; Imran *et al.*, 2014). RSSI, typically expressed in decibel-milliwatts (dBm), provides a practical representation of received signal power and is influenced by environmental conditions such as building density, vegetation, interference, and distance from base stations (Rong *et al.*, 2025; Amaldi *et al.*, 2006; Nature Research Intelligence, n.d.). To complement RSSI, Signal-to-Noise Ratio (SNR) offers insight into signal clarity and reliability, particularly in noisy or interference prone environments.

Recent studies published between 2024 and 2025 have increasingly explored machine-learning-assisted prediction, optimisation, and visualisation of wireless signal metrics. Aarif *et al.* demonstrated the efficacy of artificial neural networks combined with evolutionary algorithms for optimising transmission power (Aarif *et al.*, 2025). Jassim and Kürner introduced a LightGBM-based prediction framework incorporating terrain and structural features (Jassim & Kürner, 2024), while Mancy and Ponkumar compared advanced Kalman filter variants for RSSI and SNR estimation (Mancy & Ponkumar, 2025). Kim *et al.* provided a comprehensive review of machine learning techniques for wireless channel prediction (Kim *et al.*, 2025), and Al-Ansari developed a MATLAB-based optimisation framework for next-generation cellular deployment (Al-Ansari, 2025). These recent findings confirm the relevance of GUI-based visualisation platforms for spatial network performance analysis.

RSSI and SNR heatmaps have emerged as effective tools for visualising spatial connectivity patterns and identifying coverage deficiencies (Wang *et al.*, 2024; MATLAB, n.d.). In parallel, MATLAB App Designer provides a flexible environment for developing interactive visualisation tools suitable for academic and engineering applications (Salvucci and Prehn, 2019; MathWorks, 2020; Sesia *et al.*, 2011).

II. RSSI AND SNR HEATMAP FUNDAMENTALS

This section outlines the fundamental metrics and concepts underpinning the RSSI and SNR heatmap visualisation approach adopted in this study. A clear understanding of Received Signal Strength Indicator (RSSI), Signal-to-Noise Ratio (SNR), and geolocation principles is essential for interpreting spatial variations in wireless signal performance and for validating the reliability of the generated heatmaps. These metrics form the theoretical basis for mapping cellular network coverage, identifying signal degradation zones, and assessing communication reliability in real-world environments. By presenting the definitions, mathematical formulations, and practical considerations associated with RSSI and SNR, this section establishes a foundation for the subsequent development of the MATLAB GUI system and the analysis of field measurement results presented in later sections.

A. Received Signal Strength Indicator (RSSI)

Received Signal Strength Indicator (RSSI) is a critical metric used in wireless communication systems to quantify the power level of signals received by a device from a transmitter. It serves as an indirect indicator of link quality and network reliability, especially in environments where signal attenuation and interference play significant roles. RSSI is typically measured in decibel-milliwatts (dBm), representing a logarithmic ratio of received power. In most wireless systems, including Wi-Fi, ZigBee, and cellular networks, RSSI values range from approximately −30 dBm (excellent reception) to −90 dBm (weak or unusable signal). These values are often obtained through the device's firmware or network interface hardware. Although RSSI values are frequently read directly from devices, theoretical models such as the Log-distance Path Loss Model provide a more analytical approach to estimating RSSI as a function of distance and environmental factors. The general form of the model is:

$$RSSI = P_{Tx} - 10 * n * Log_{10}(d) + L \quad (1)$$

where:

P_{Tx} is the transmit power in dBm, n is the path-loss exponent, dependent on the propagation environment (typically between 2 and 4), d is the distance between transmitter and receiver in meters and L is a system loss factor accounting for connector, cable, and environmental losses.

This model assumes a free-space or semi-obstructed environment and can be further refined through empirical calibration using field measurements. RSSI is widely utilised in telecommunications and signal analytics for purposes such as coverage mapping and heatmap generation, especially in indoor positioning systems, network performance diagnostics, including identifying dead zones or areas of interference and signal strength optimisation, useful in antenna placement and frequency planning. Despite its practicality, RSSI interpretation lacks standardisation across hardware vendors and may be subject to chipset-specific scaling. Moreover, a strong RSSI does not always equate to high data throughput due to possible interference or multipath fading. Therefore, RSSI is best used in conjunction with other performance metrics such as Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER) for robust analysis.

B. Signal-to-Noise Ratio (SNR)

To complement RSSI visualisation, Signal-to-Noise Ratio (SNR) can be estimated for each geo-tagged data point using raw signal and background noise metrics collected during field measurements. SNR quantifies signal clarity in noisy environments, providing insight into connectivity reliability. SNR in decibels (dB) was calculated using:

$$SNR = 10 * Log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) \tag{2}$$

where P_{signal} is the power of the received LTE signal and P_{noise} is ambient noise power. Alternatively, voltage-based readings can use:

$$SNR = 20 * Log_{10}\left(\frac{V_{signal}}{V_{noise}}\right) \tag{3}$$

where V_{signal} is the power of the received LTE signal and V_{noise} is ambient noise power.

In this study, noise baseline was estimated during idle mobile states and subtracted from peak RSSI zones. Zones with SNR ≥ 25 dB were categorised as ‘Reliable’, 10–20 dB as ‘Moderate’, and <-10 dB as ‘Unreliable’. In this study SNR values were embedded into the MATLAB GUI, enabling dynamic visualisation alongside RSSI maps to support robust field diagnostics.

C. Geolocation in RSSI and SNR Heatmap

Geolocation refers to the process of identifying the physical location of a device using spatial data, such as GPS coordinates, signal triangulation, or proximity to known signal sources. Geolocation data may play a vital role in enhancing the precision and interpretability of RSSI and SNR measurements. The integration of geolocation with RSSI and SNR allows spatial contextualisation of signal strength, providing insights into coverage distribution, signal fading patterns, and potential interference zones. This spatial framework relies on several functions such as latitude and longitude coordinates where each measurement point is mapped to GPS coordinates (e.g., captured via mobile device or survey-grade GPS receiver), environmental metadata where building density, elevation, vegetation, and urban structures affect signal propagation and must be considered in modelling and temporal tags where timestamping RSSI, SNR and geolocation data enables time-series analysis and identification of dynamic signal conditions (e.g., peak usage hours or weather effects).

III. SYSTEM ARCHITERURE AND SOFTWARE WORKFLOW

This section describes the overall system design and software workflow developed in this study to enable efficient acquisition, processing, and visualisation of RSSI and SNR measurements. The proposed architecture integrates LTE signal logging hardware, geolocation capability, MATLAB-based data processing, and an interactive graphical user interface (GUI) into a unified framework. By clearly defining the interaction between hardware components and software modules, this section establishes the implementation foundation for the RSSI and SNR heatmap generation procedure presented in the subsequent section. The architectural overview also ensures transparency, reproducibility, and scalability of the proposed system for deployment in different geographical environments and future network technologies.

A. Overall System Architecture

The overall system architecture employed in this study is illustrated conceptually in Figure 1. The framework consists of four main layers: (i) LTE signal acquisition layer, (ii) geolocation and logging layer, (iii) data processing layer, and (iv) visualisation and user interaction layer. Each layer performs a dedicated function to ensure accurate, reliable, and scalable spatial signal analysis.

At the signal acquisition layer, the MikroTik LtAP LR8G LTE6 Kit functions as a mobile end-node, continuously receiving LTE downlink signals transmitted from the Maxis base station. Concurrently, GPS coordinates are captured using an external antenna to ensure precise geo-referencing of all signal measurements. RouterOS commands enable synchronised logging of RSSI, SNR, Cell ID, and location data.

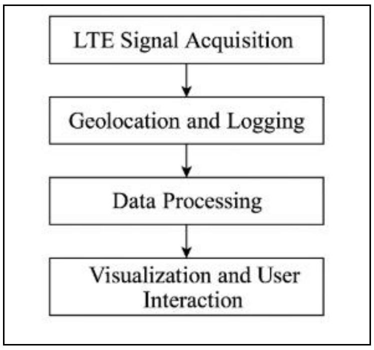

Figure 1. *System Architecture*

B. Software Workflow and GUI Logic

The MATLAB GUI software workflow is divided into four functional stages: data input, preprocessing, spatial interpolation, and visualisation rendering. Upon launching the GUI, users are prompted to import measurement datasets in CSV format. The preprocessing module automatically validates the dataset structure, checks for missing fields, and removes erroneous entries.

Following validation, spatial mapping is performed using MATLAB's geoscatter and interpolation routines. Colour mapping is dynamically adjusted based on predefined RSSI and SNR thresholds, enabling consistent visual interpretation across datasets. The modular design ensures adaptability to larger geographical regions or future cellular technologies. This workflow significantly reduces analysis time while minimising human error compared to manual plotting methods.

IV. PROCEDURE FOR RSSI AND SNR HEATMAP GENERATION

In this study, the RSSI and SNR heatmaps have been generated based on MATLAB workflow. The heatmap will appear once the designed MATLAB code has been activated by addressing the specific RSSI and SNR data measurement in CSV format. The MATLAB-based workflow of this study can be referred to as:

Step 1: Data Collection

(i) Use MikroTik LtAP LR8G LTE6 kit to capture RSSI and SNR values.

(ii) Ensure simultaneous logging of:

(a) RSSI (dBm) and SNR (dB)

(b) Geolocation coordinates (latitude and longitude)

(c) Timestamp (optional for temporal analysis)

(iii) Conduct sampling in various environments: academic zones, residential areas, roadside stretches.

Step 2: Data Preprocessing in MATLAB

(i) Import the CSV file of the RSSI and SNR values, including geolocation coordinates as collected in Step 1 using MATLAB function of:

data = readtable('rssi_data.csv');

(ii) Clean the data:

(a) Remove outliers or entries with missing GPS/RSSI/SNR values

(b) Apply filters or averaging if needed (e.g., moving average for RSSI smoothing)

Step 3: GUI-Based Heatmap Visualisation

(i) Create a GUI application system using MATLAB App Designer / MATLAB guide toolbox to allow:

(a) File selection

(b) Heatmap generation trigger

(c) Category wise display options

(ii) Apply interpolation of MATLAB function "*geoscatter*"

In this study, spatial visualisation is performed using the MATLAB *geoscatter* function, which maps discrete geo-tagged RSSI and SNR measurements onto geographic coordinates. Although *geoscatter* primarily provides point-based visualisation, a continuous heatmap appearance is achieved through colour scaling and marker density representation. It is important to note that this approach does not implement advanced interpolation techniques such as kriging or inverse distance weighting (IDW). Therefore, the resulting heatmaps represent visual approximations of signal distribution based on sampled data points rather than fully interpolated spatial fields.

The visualisation parameters used include:

- Colour map: jet gradient for intensity representation
- Marker size: proportional to signal magnitude
- Colour scaling: normalised between minimum and maximum RSSI/SNR values

These parameters were selected to ensure clarity and consistency in visual interpretation across different datasets.

Step 4: Analysis and Export

(i) Include colour gradient interpretation:
  (a) Warm tones (yellow/red) - Strong signal
  (b) Cool tones (blue/green) - Weak signal

(ii) Save visual output as .png or .fig file format

(iii) Optionally export the GUI-generated map with title and coordinates overlay

The MATLAB snippet code in generating RSSI Heatmap as designed in this study can be referred to Figure 2 while SNR Heatmap can be referred to Figure 3. Based on these codes, the input parameters of the codes are the RSSI data, SNR data, latitude and longitude while the *geoscatter* MATLAB command was used to produce the RSSI and SNR Heatmap.

```
data=readtable([location file]);
lat=table2array(data(:,3));
lon=table2array(data(:,4));
rssi=table2array(data(:,13));
a=height(lat);

figure;
geoscatter(lat, lon, ones(1,a)*50, rssi);
colorbar
geobasemap streets
```

Figure 2. *MATLAB snipped code for RSSI Heatmap Generation*

```
data=readtable([location file]);
lat=table2array(data(:,3));
lon=table2array(data(:,4));
snr=table2array(data(:,8));
a=height(lat);

figure;
geoscatter(lat, lon, ones(1,a)*50, snr);
title('SNR Heatmap');
colorbar
geobasemap streets
```

Figure 3. *MATLAB snipped code for SNR Heatmap Generation*

A. LTE Field Device Configuration and Signal Type Clarification

In this study, to support RSSI and SNR measurements in outdoor environments, the MikroTik LtAP LR8G LTE6 Kit as shown in Figure 4, was deployed. This rugged, GPS-enabled device features LTE Category 6 connectivity, integrated Wi-Fi, and support for multiple SIM cards. A Maxis SIM card was inserted into Slot #2, allowing direct signal acquisition from the Maxis LTE/4G infrastructure. Real-time signal metrics including RSSI, RSRP, SNR, and Cell ID were obtained using RouterOS CLI commands, while GPS data was concurrently collected using an external SMA antenna, activated through RouterOS. Using this kit, all RSSI and SNR readings were geo-tagged and exported for analysis within the MATLAB GUI system. It is important to note that the LtAP LTE6 Kit supports only LTE networks (4G) and does not detect or measure 5G signals. Thus, all collected RSSI and SNR values pertain strictly to Maxis 4G LTE signal performance.

Figure 4. *MikroTik LtAP LR8G LTE6 Kit*

B. Measurement Area and Data Overview

The field measurement campaign was conducted across multiple representative locations in Parit Raja, Johor, including academic institutions, residential neighbourhoods, commercial districts, and roadside corridors. Primary measurement zones comprised the Universiti Tun Hussein Onn Malaysia (UTHM) campus, Taman Universiti, Taman Siswa, and major connecting roads such as Jalan Universiti. These areas were selected to ensure coverage diversity with respect to pedestrian density, building typology, vegetation coverage, and proximity to known base station infrastructure.

RSSI and SNR data were collected using the MikroTik LtAP LR8G LTE6 Kit, which enables simultaneous acquisition of LTE signal metrics and GPS coordinates. The measurements were carried out during daytime under stable weather conditions to minimise environmental bias. Data acquisition involved both walking and vehicular movement, ensuring sufficient spatial resolution and continuity across the study area. The collected dataset was exported in CSV format for preprocessing and visualisation within the MATLAB GUI environment.

Following data acquisition, preprocessing steps were applied to remove duplicate entries, outliers, and samples with incomplete GPS information. The resulting dataset provided a reliable basis for spatial interpolation and heatmap generation.

V. RESULTS

This section presents a comprehensive analysis of the RSSI and SNR measurements collected across Parit Raja, Johor, using the MATLAB GUI-based heatmap visualisation framework. The results presented provide both quantitative and visual insights into the performance characteristics of the Maxis LTE (4G) network in this semi-urban setting. Interpretation of the observed results is further elaborated in this section.

A. Wireless Performance Data Logging

Referring to the wireless signal configuration in this study, the MikroTik LtAP LR8G LTE6 Kit serves as a wireless end device (node) for RSSI and SNR logging during drive testing. A cellular gateway serves as the transmitter, sending wireless signals to the LtAP LR8G LTE6 device. This device logs the longitude, latitude, RSSI, SNR, as well as other performance parameters and GPS coordinates as shown in Figure 5. This configuration is required for testing wireless network performance across the campus environment. However, for this study, the longitude, latitude, SNR and RSSI are only the parameters that have been analysed.

	A	B	C	D	E	F	G	H
1	timestamp	altitude	latitude	longitude	telco	rsrp	rsrq	sinr
2	25/5/2025 11:25	-8.700000 m	1.852326	103.100651	MY MAXIS	-90	-10.5	7
3	25/5/2025 11:25	-8.800000 m	1.852326	103.100651	MY MAXIS	-90	-10.5	7
4	25/5/2025 11:25	-8.800000 m	1.852326	103.100651	MY MAXIS	-90	-10.5	7
5	25/5/2025 11:25	-8.600000 m	1.852326	103.100651	MY MAXIS	-89	-9.5	7
6	25/5/2025 11:25	-7.900000 m	1.852328	103.100651	MY MAXIS	-89	-9.5	7
7	25/5/2025 11:25	-8.200000 m	1.852326	103.100651	MY MAXIS	-89	-9.5	7
8	25/5/2025 11:25	-7.900000 m	1.852328	103.100651	MY MAXIS	-89	-9.5	7
9	25/5/2025 11:25	-8.100000 m	1.852326	103.100651	MY MAXIS	-90	-10	5
10	25/5/2025 11:25	-8.400000 m	1.852326	103.100651	MY MAXIS	-90	-10	5
11	25/5/2025 11:25	-8.600000 m	1.852326	103.100651	MY MAXIS	-90	-10	5
12	25/5/2025 11:25	-8.800000 m	1.852326	103.100651	MY MAXIS	-89	-9	7
13	25/5/2025 11:25	-8.900000 m	1.852325	103.100651	MY MAXIS	-89	-9	7
14	25/5/2025 11:25	-8.900000 m	1.852325	103.100651	MY MAXIS	-89	-9	7
15	25/5/2025 11:25	-9.100000 m	1.852325	103.100653	MY MAXIS	-89	-10	2
16	25/5/2025 11:25	-9.300000 m	1.852325	103.100653	MY MAXIS	-89	-10	2
17	25/5/2025 11:25	-9.500000 m	1.852318	103.100655	MY MAXIS	-89	-10	2
18	25/5/2025 11:25	-9.800000 m	1.852311	103.100656	MY MAXIS	-90	-9	0
19	25/5/2025 11:25	-10.000000 m	1.852308	103.100658	MY MAXIS	-90	-9	0
20	25/5/2025 11:25	-10.000000 m	1.852305	103.10066	MY MAXIS	-90	-9	0
21	25/5/2025 11:25	-10.400000 m	1.852303	103.10066	MY MAXIS	-92	-12	-2
22	25/5/2025 11:25	-10.700000 m	1.852305	103.100655	MY MAXIS	-92	-12	-2
23	25/5/2025 11:25	-10.900000 m	1.852306	103.100641	MY MAXIS	-92	-12	-2
24	25/5/2025 11:25	-11.200000 m	1.852305	103.100638	MY MAXIS	-92	-14.5	-2
25	25/5/2025 11:25	-11.400000 m	1.852305	103.100631	MY MAXIS	-92	-14.5	-2

Figure 5. Wireless performance data Logging using LtAP LR8G LTE6 KIT

B. MATLAB GUI-Based Visualisation System

To facilitate intuitive visualisation and analysis, a custom Graphical User Interface (GUI) was developed using MATLAB App Designer, as shown in Figure 6. The GUI allows users to upload pre-processed RSSI and SNR datasets, initiate heatmap generation, and visualise signal strength distributions across geographic coordinates.

The GUI integrates MATLAB's geoscatter function to perform spatial interpolation, generating continuous colour gradients that represent signal intensity across the study area. Warm colour tones (yellow to red) indicate stronger signal strength, while cooler tones (green to blue) represent weaker connectivity. This visualisation approach enables rapid identification of coverage trends and anomalous low-signal regions without requiring manual plotting or advanced programming skills.

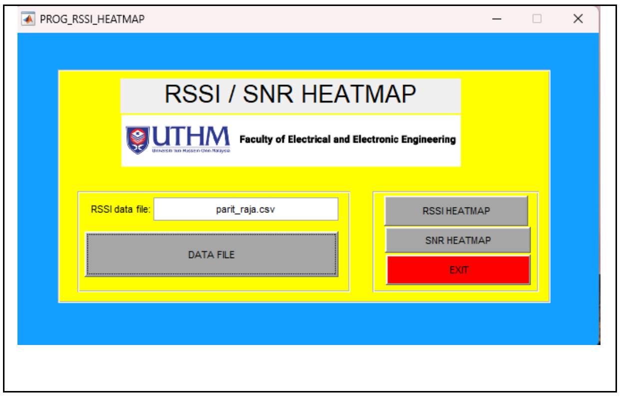

Figure 6. MATLAB GUI system for RSSI heatmap display

C. RSSI Heatmap Analysis

The RSSI heatmap generated for Parit Raja is illustrated in Figure 7, providing a spatial overview of received signal power across the measured locations. The RSSI values observed in this study ranged approximately from −45 dBm to −85 dBm, indicating varying levels of signal quality throughout the region.

Areas exhibiting strong RSSI levels (greater than −60 dBm) were primarily concentrated around open environments and major transportation routes, particularly within the UTHM campus and along Jalan Universiti. These locations benefit from reduced physical obstructions and closer proximity to Maxis LTE base stations, resulting in minimal propagation loss.

Moderate RSSI regions, defined within the range of −61 dBm to −75 dBm, were predominantly observed in residential zones such as Taman Universiti and Taman Siswa. These areas are characterised by low-rise buildings interspersed with vegetation, leading to partial attenuation due to diffraction and shadowing effects. Despite this, the RSSI values in these regions remained sufficient for standard mobile services, including voice communication and moderate data usage.

Conversely, weak signal zones with RSSI values below −76 dBm were identified in dense commercial clusters and vegetation rich areas. Such signal degradation is attributed to signal obstruction caused by building materials, foliage absorption, and increased distance from serving base stations. These areas are more susceptible to performance degradation during peak traffic periods or adverse propagation conditions.

In such environments, reflected and scattered signals increase the overall noise floor, thereby degrading link quality and reducing achievable data rates. These propagation impairments are more pronounced during peak traffic hours, where network congestion further exacerbates performance degradation, leading to intermittent connectivity and higher packet loss rates.

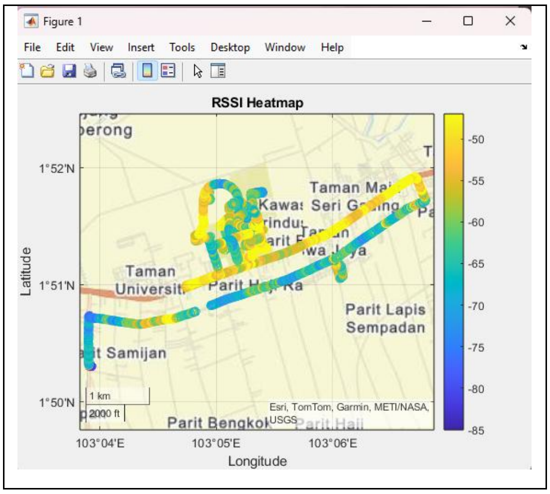

Figure 7. RSSI heatmap of Maxis signal across Parit Raja, generated using a custom MATLAB GUI. Warmer colours (e.g., yellow) indicate stronger signal strength, while cooler colours (e.g., blue and green) represent weaker connectivity. The heatmap provides a spatial overview of network performance and highlights areas requiring signal optimisation

D. SNR Heatmap Analysis

Complementary to the RSSI results, the SNR heatmap presented in Figure 8 provides insights into signal clarity and interference levels across Parit Raja. Recorded SNR values ranged from approximately 30 dB to −10 dB, demonstrating notable spatial variation.

Regions with high SNR values (greater than 25 dB) closely corresponded with areas of strong RSSI, particularly near open spaces and major roads. These regions are indicative of reliable communication links with minimal noise and interference, supporting high data throughput and stable connectivity.

Moderate SNR values between 10 dB and 20 dB were commonly observed within residential areas. Although these zones experienced some degree of noise and multipath interference, the signal quality remained adequate for general mobile usage. Slight variations within these regions may be attributed to differences in building density, terrain elevation, and localised interference sources.

Low SNR regions (below −5 dB) were predominantly detected in environments with dense vegetation, commercial buildings, and complex urban structures. In such conditions, reflected and scattered signals increase the noise floor, significantly degrading link quality. These areas are more prone to dropped connections and reduced data rates.

These observations are specific to the measured locations and conditions during data collection. While the results indicate spatial variability influenced by environmental and infrastructural factors, they should not be generalised to represent the entire Maxis network performance beyond the study area.

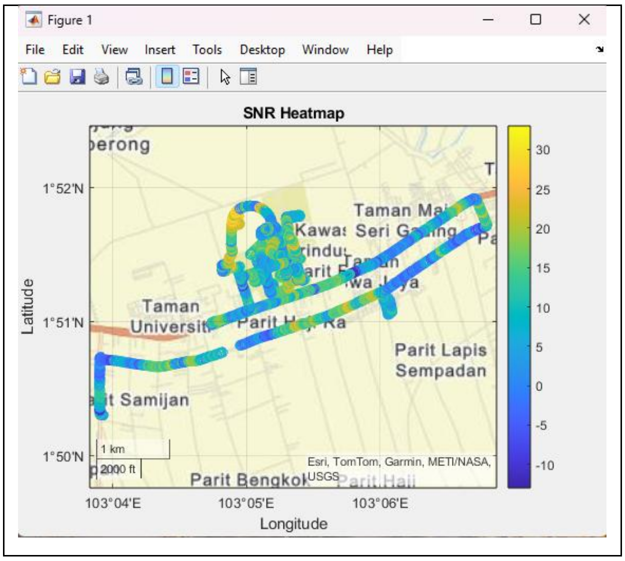

Figure 8. SNR heatmap of Maxis signal across Parit Raja, generated using a custom MATLAB GUI. Warmer colours (e.g., yellow) indicate stronger signal strength, while cooler colours (e.g., blue and green) represent weaker connectivity. The heatmap provides a spatial overview of network performance and highlights areas requiring signal optimisation

E. Comparative Analysis of RSSI and SNR Distributions

Comparison of RSSI and SNR heatmaps reveals a strong spatial correlation between signal strength and signal clarity, although discrepancies exist in certain zones. While high RSSI generally coincides with high SNR, some areas with acceptable RSSI values exhibited moderate or low SNR due to interference and multipath effects. This observation highlights the importance of evaluating both metrics concurrently rather than relying solely on RSSI for network performance assessment.

The complementary use of RSSI and SNR provides a more robust understanding of wireless link reliability and user experience. Areas classified as “good” based solely on RSSI may still experience degraded performance if SNR is compromised.

Overall, the integrated visualisation of RSSI and SNR metrics through the proposed MATLAB GUI provides a comprehensive representation of LTE network performance across Parit Raja. By combining signal strength and signal quality indicators within a spatial context, the developed heatmaps enable effective identification of coverage deficiencies and interference-prone zones, which are not easily discernible through numerical analysis alone. These findings form a practical foundation for the discussion on environmental impacts and system effectiveness presented in the following section.

VI. DISSCUSSION

This section interprets the results presented in section V by linking observed RSSI and SNR patterns with environmental, infrastructural, and deployment-related factors. The discussion also highlights the practical implications of the findings for cellular network planning and optimisation.

A. Influence of Environmental and Structural Factors

This section discusses the observed RSSI and SNR spatial patterns by correlating measurement results with environmental characteristics, infrastructure density, and signal propagation behaviour. The analysis further evaluates the effectiveness of the MATLAB GUI-based heatmap visualisation approach and outlines its implications for cellular network planning and optimisation in semi-urban environments.

The spatial distribution of RSSI and SNR across Parit Raja confirms established radio propagation principles. Strong signal regions were predominantly associated with open spaces and direct line-of-sight paths between transmitters and receivers. Conversely, areas with dense vegetation, commercial structures, and clustered buildings consistently exhibited degraded signal quality.

Vegetation introduces absorption and scattering losses, particularly at LTE frequency bands, while building materials such as concrete and metal significantly attenuate signals. Moreover, reflections and scattering from commercial buildings and roadside structures in the semi-urban environment of Parit Raja contribute to multipath propagation, thereby elevating the noise floor and reducing SNR.

B. Effective of MATLAB GUI-Based Heatmap Visualisation

The developed MATLAB GUI significantly enhanced the efficiency and interpretability of wireless signal analysis by transforming large numerical datasets into intuitive spatial visualisations. Unlike conventional tabular representations, the heatmap-based approach enables immediate identification of coverage trends, weak-signal zones, and performance anomalies.

By automating preprocessing, interpolation, and visualisation tasks, the GUI minimises manual effort and reduces the likelihood of human error. Furthermore, the modular design of the interface allows straightforward adaptation to larger datasets, extended geographical regions, and future cellular technologies. As such, the proposed system is well suited for academic research, engineering education, and preliminary network performance audits.

Beyond performance evaluation, the insights obtained from RSSI and SNR heatmaps offer practical value for infrastructure deployment and optimisation strategies, as discussed in the following subsection.

C. Practical Implications for Network Planning

From a network planning perspective, the heatmap results provide actionable insights for infrastructure optimisation. Areas with persistently low RSSI and SNR should be prioritised for enhancement strategies such as additional base stations, antenna reorientation, or the deployment of repeaters and small cells.

Collaboration between service providers and local authorities could further facilitate infrastructure deployment in strategically advantageous locations, including elevated public buildings and community facilities. Additionally, periodic signal audits using GUI-based visualisation tools would enable continuous monitoring of network performance as urban development evolves.

D. Limitation and Future Research Direction

Although the proposed framework effectively visualizes LTE network performance, several limitations are acknowledged. The study focuses exclusively on a single operator and LTE (4G) technology, excluding 5G and multi-operator comparisons. Furthermore, temporal variations such as peak-hour traffic and weather-induced propagation changes were not considered.

Future research could extend this work by incorporating real-time data streams, multi-operator measurements, and advanced spatial modelling techniques such as kriging or machine learning-based prediction. Integration with GIS and temporal analytics would further enhance the predictive and diagnostic capabilities of the system.

VII. CONCLUSION

This study successfully demonstrated a MATLAB GUI-based framework for visualising RSSI and SNR distributions of the Maxis LTE network in Parit Raja, Johor. The integration of real-time field measurements with automated heatmap generation enabled clear identification of spatial connectivity trends and coverage gaps. The findings support network planning and optimisation efforts by translating complex wireless metrics into actionable visual insights. The proposed framework offers a scalable and replicable approach applicable to future research, multi-operator studies, and next-generation cellular performance analysis.

VIII. ACKNOWLEDGEMENT

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