Comparing global system for mobile and G-NetTrack signal strength in drive test study

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ABSTRACT

The quality of wireless signals is determined by the received signal strength indicator (RSSI), which can be measured using various tools, including Android apps and global system for mobile (GSM) modules. To enhance the measurement of signal quality and communication reliability, this study aimed to develop a complementary instrument consisting of a microcontroller, global positioning system (GPS) module, GSM module, and microSD card. The firmware was developed using C++ code and compiled using the Arduino integrated development environment (IDE). In addition, this study utilized the Kolmogorov-Smirnov test (K-S test) normality and the Mann-Whitney U test to investigate any differences in RSSI quality between the GSM module and global positioning system network track (G-NetTrack). The results showed that the GSM module consistently produced higher RSSI values than G-NetTrack in most locations along the route. Furthermore, the K-S test normality suggested that the RSSI values obtained from both tools were not normally distributed, and the Mann-Whitney U test revealed a significant difference between the two samples, with G-NetTrack having lower values than the GSM module ($U=14730$, $p<0.05$). This study demonstrated that the GSM module provides stronger signal strength measurements than G-NetTrack during the drive test, and highlighted the importance of using appropriate statistical tests to analyze RSSI data.

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1. INTRODUCTION

Mobile communication has revolutionized the way we communicate and interact with each other, with billions of people worldwide relying on wireless networks to stay connected. Wireless networks are widely used in various applications, including mobile communication, data transfer, and the internet of things (IoT) [1]-[3]. Mobile devices, such as smartphones and tablets, are equipped with various sensors and parameters that enable them to communicate with the network, providing users with multiple services, including voice and data communications, location-based services, and multimedia streaming [4]-[6].

The received signal strength indicator (RSSI) is a key parameter determining wireless signal quality [7]. The RSSI value indicates the signal strength between a mobile device and a base station [8], [9], providing information about the quality of the communication channel. Therefore, accurate measurement of the RSSI is essential for optimizing the performance of wireless networks, such as signal transmission and reception.

The RSSI value represents the power level of the received signal relative to a reference level. RSSI values are typically measured in decibels (dBm, referring to one milliwatt) and can range from -113 dBm (poor signal quality) to -51 dBm (excellent signal quality) [10]. Mobile devices, such as smartphones or tablets, can measure RSSI by utilizing Android apps like global positioning system network track (G-NetTrack), which provides detailed information about network performance and signal quality [11], [12]. In addition, by comparing the data collected with established standards such as telecommunications and internet protocol harmonization over network (TIPHON), researchers can evaluate the performance of different telecommunication service providers [11], [13], [14].

RSSI can also be measured using global system for mobile (GSM) modules such as Simcom and Quectel [15], [16]. These modules are widely used in mobile communication devices, such as smartphones and IoT devices, and they provide a reliable and cost-effective way to measure the signal strength of the communication link. For instance, these GSM/general packet radio service (GSM/GPRS) modules come equipped with an RSSI measurement feature that allows users to monitor the signal strength of the cellular network. The attention+command signal quality (AT+CSQ) command can be used to obtain the RSSI value of the current cell, which is reported in dBm [17]. A study from Giwa *et al.* [9] successfully built an Arduino-based instrument to record the GSM RSSI from SIM808 and analyzed the data using an analysis of variance (ANOVA) test.

However, it is essential to test the normality of the data before conducting an ANOVA. If the data is not normally distributed, an ANOVA may not be appropriate, and researchers should consider using non-parametric tests instead [18]. Using proper statistical tests, researchers can ensure that their analyses are accurate and reliable, providing insights into the performance of GSM networks and identifying areas for improvement. Therefore, the goal of this study is to develop a complementary instrument for measuring RSSI, which will be beneficial in assessing signal quality and communication reliability. This study also investigates whether there are any differences in RSSI quality between the GSM module and G-NetTrack Pro using normality tests and proper statistical tests.

2. METHOD

2.1. Instrument setup

This study used an instrument to measure the RSSI values and provide positional information. The setup consisted of a global positioning system (GPS) module, the U-Blox Neo6m, an ESP32 microcontroller, a GSM module, the SIM900A, and a power bank to supply power to the components (Figure 1). The GPS module was used to provide accurate positional information for the study. It was connected to the ESP32 microcontroller, enabling it to interface with the other setup components. The ESP32 was responsible for processing the GPS data and controlling the communication between the GPS and GSM modules. The GSM module, the SIM900A, was used to measure the RSSI values of the signals received by the setup. The AT+CSQ command retrieved the RSSI value from the telecommunications operator.

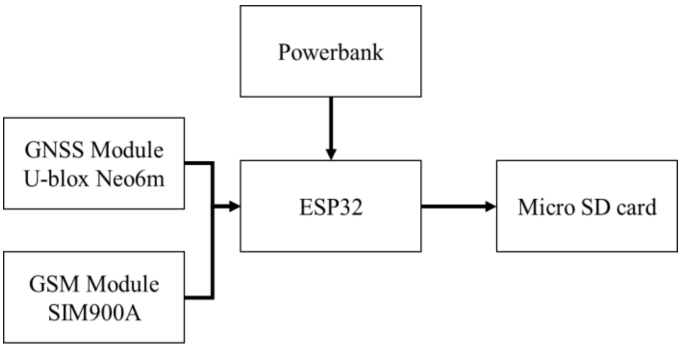

Figure 1. Instrument component and setup diagram

The power bank was used to supply power to the setup, ensuring it remained operational throughout the study. In addition, it provided a stable power source for the components, reducing the risk of power fluctuations that could affect the measurements' accuracy. In addition, a microSD card was used in the setup to store the data collected during the study. The microSD card was connected to the ESP32 microcontroller and was a non-volatile memory storage device for the data. Using the microSD card in the instrumentation setup provided a reliable and secure method of storing the data collected during the study. It also made data easy to retrieve and analyze after the study and ensured data accuracy and integrity.

2.2. Firmware development

The firmware development process was an important component of developing this instrumentation setup. It allowed the setup components to work together seamlessly and efficiently, ensuring the accuracy and reliability of the data collected during the study. The firmware used in this instrument was developed to ensure that the setup components worked together seamlessly and efficiently. The firmware was developed for the ESP32 microcontroller, responsible for controlling the GPS and GSM modules, measuring the RSSI values, and storing the data collected on the microSD card.

The firmware development process involved writing code in C++, which was then compiled and uploaded to the microcontroller using the Arduino integrated development environment (IDE). The code was designed to communicate with the GPS module, retrieve positional data, communicate with the GSM module, and retrieve RSSI values using the AT+CSQ command. The code was also designed to store the data collected on the microSD card. The flowchart is shown in Figure 2. The code can be accessed from GitHub: https://github.com/hollandakusuma/RSSitest/blob/main/RSSItest.ino [19].

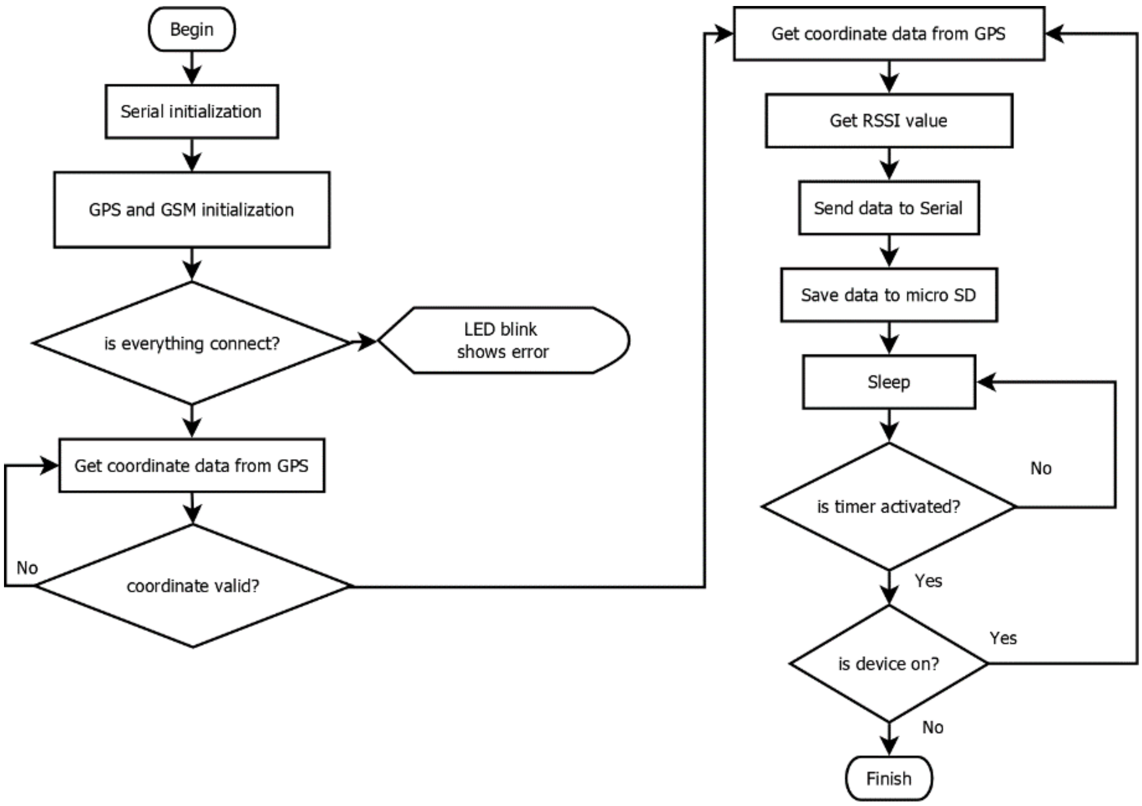

Figure 2. Instrument firmware flowchart

2.3. Experimental setup and data analysis

In this experiment, a drive test was conducted to collect RSSI data from a GSM module and G-NetTrack installed on a smartphone. The experiment aimed to assess the wireless signal quality in a real-world scenario. The GSM module and smartphone captured and recorded the RSSI values and coordinates during the drive test. During the drive test, RSSI data were collected at regular intervals along the route to capture the changes in signal strength and coordinate location. The collected data was then analyzed to determine the signal strength and quality in different locations.

The collected RSSI data was analyzed to determine the signal strength and quality in different locations. A normality test was first performed to determine if the RSSI values followed a normal distribution. The Kolmogorov-Smirnov test (K-S test) was used to assess normality, with a significance level of 0.05 [20], [21]. The K-S test can also be used to compare two data samples. The null hypothesis is that the two samples are drawn from the same distribution, and the alternative hypothesis is that the two samples come from different distributions. The K-S test is also used to test the normal distribution of the data. If the sample data closely fits the normal distribution, the test statistic (p-value) will be small. On the other hand, if the sample data significantly deviates from the normal distribution, the test statistic will be large.

A Mann-Whitney U test was used to compare the RSSI values obtained from the GSM module and G-NetTrack. This nonparametric statistical test is used to determine if there is a significant difference between two groups of data [22]. In this case, it was used to compare the signal strength obtained from the two sources.

The Mann-Whitney U test compares the observations' ranks in the two samples. It does this by ranking all the observations from both samples, adding up the ranks of both samples, and then finding the test statistic U. The value of U is equal to the sum of the ranks of the smaller sample or the observations in one sample if the samples are the same size. Depending on the sample size and significance level, the test statistic U is compared to a critical value. If the test statistic U is less than or equal to the critical value, the null hypothesis that the two samples have the same distribution is accepted. If the test statistic U is greater than the critical value, the null hypothesis is rejected, and it is concluded that the two samples have different distributions.

3. RESULTS AND DISCUSSION

3.1. Drive test results

This study compared the RSSI values obtained from a GSM module and G-NetTrack during a drive test. Maps of the drive test route with color-coded RSSI values were created to visualize the spatial differences in RSSI values between the two tools. A color scheme was used to represent the RSSI values, where red represented weak RSSI values, indicating poor signal strength, and green represented strong RSSI values, indicating excellent signal strength. The maps showed that the GSM module (Figure 3) had consistently higher RSSI values than G-NetTrack (Figure 4) at most locations along the route, indicating stronger signal strength, as indicated by the green color. However, there were also some locations where the RSSI values from G-NetTrack were higher than those from the GSM module, indicating better signal strength.

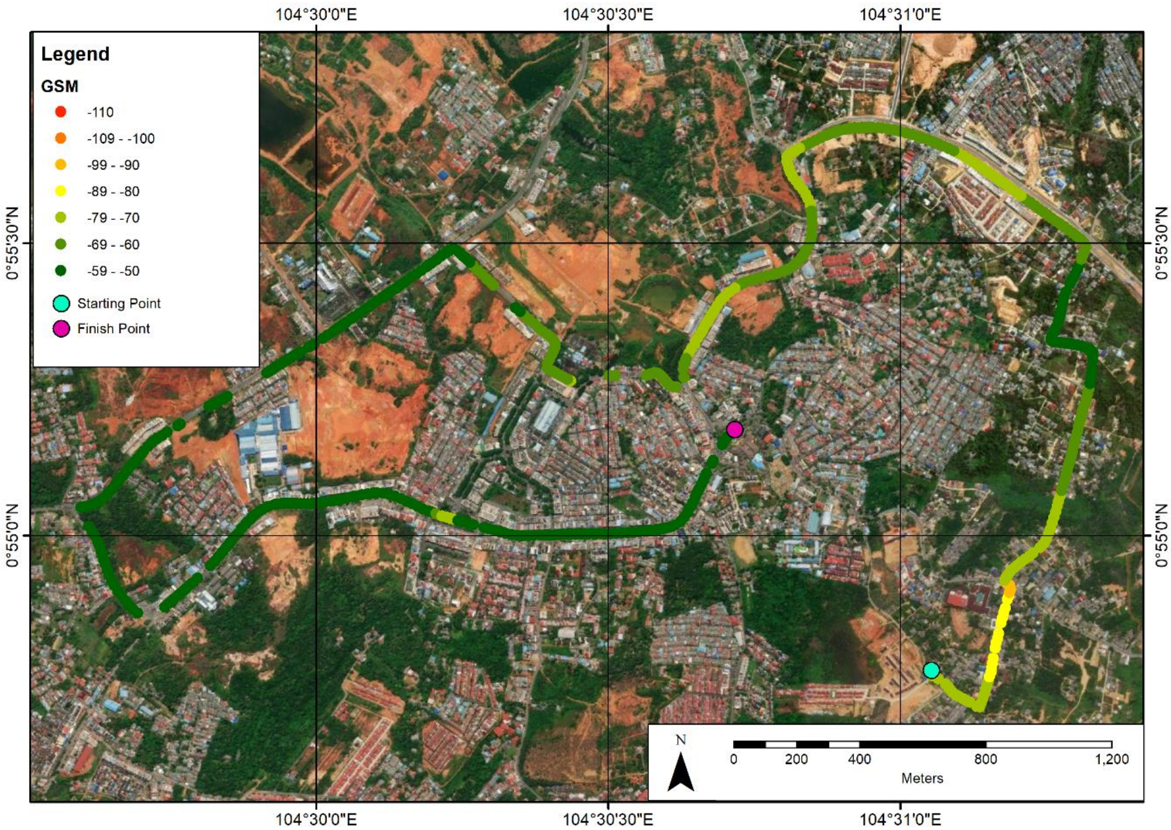

Figure 3. GSM module RSSI value (dBm) map from the drive test

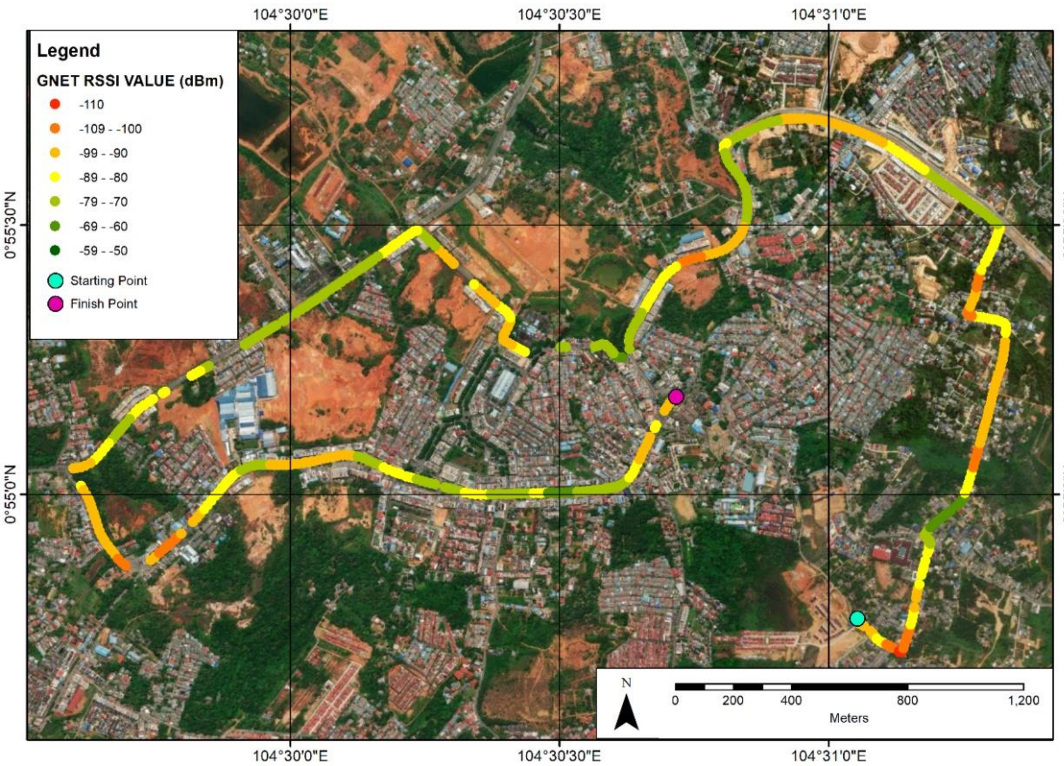

Figure 4. G-NetTrack RSSI value (dBm) map from the drive test

The descriptive statistics were used to figure out how much the RSSI values from the two tools differed by looking at 565 data points and figuring out the differences between them (Table 1). The mean RSSI value for the GSM module was 10 dB higher than that for G-NetTrack, indicating a significant difference in signal strength. The standard error suggests that the mean RSSI values for both tools were relatively stable and consistent across the drive test. The standard deviation of the RSSI values shows that the variability in RSSI values was relatively similar between the two tools. The minimum and maximum values suggest that the range of RSSI values for G-NetTrack was wider than that for the GSM module.

Table 1. Descriptive statistics from the drive test

Device	Descriptive statistic parameter						
	Mean	Standard error	Median	Mode	Standard deviation	Minimum	Maximum
G-NetTrack	-85.285	0.4179	-83	-90	9.9329	-110	-66
GSM module	-61.343	0.4264	-59	-51	10.1361	-95	-51

The box plot (Figure 5) provides a simple and effective visualization of the differences in RSSI values between the two tools. The plot clearly shows that the median and interquartile range for the GSM module are higher than those for G-NetTrack. This result is consistent with the mean RSSI values calculated in this study.

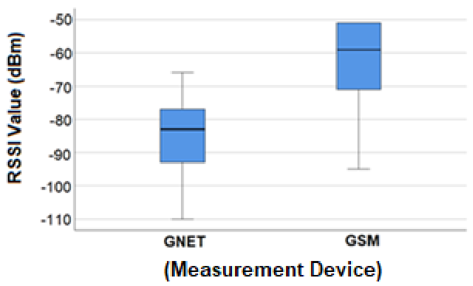

Figure 5. G-NetTrack RSSI value (dBm) map from the drive test

3.2. Statistical analysis

After analyzing the RSSI values obtained from the G-NetTrack and GSM modules during the drive test, it is important to determine whether the RSSI data is normally distributed. Therefore, a normality test determines whether the RSSI data is normally distributed. The K-S test normality compares the distribution of the RSSI values to a normal distribution. The K-S test result is shown in Table 2. A p-value of 0.000 indicates strong evidence against the null hypothesis that the two data sets are normally distributed. In other words, the p-value suggests that the RSSI values obtained from both tools are not normally distributed.

Table 2. K-S test result from the drive test

Instrument	Statistic	df	Significance
G-NetTrack	0.109	564	0.000
GSM module	0.208	564	0.000

The Mann-Whitney U test is a non-parametric test used to determine whether or not two independent samples come from the same distribution. It was used to compare the median values of the RSSI values from G-NetTrack and the GSM module during the drive test. The Mann-Whitney U test was used to do this. The results of the Mann-Whitney U test are presented in Table 3. Table 3 shows that the number of samples for both G-NetTrack and the GSM module is 565. The mean rank for G-NetTrack is 310.89, and the sum of ranks is 176895, while the mean rank for the GSM module is 828.11, and the sum of ranks is 471196. Therefore, the Mann-Whitney U value is 14730, and the p-value is 0.000 (significant at 0.05).

The Mann-Whitney U test was used in this study to compare the medians of the RSSI values obtained from G-NetTrack and the GSM module. The test revealed a significant difference between the two samples, with the G-NetTrack sample tending to have lower values than the GSM module sample ($U=14730$, $p<0.05$). Based on these results, the GSM module tends to provide higher RSSI values than G-NetTrack, indicating that the signal strength measured by the GSM module is stronger than that measured by G-NetTrack during the drive test.

Table 3. Mann-Whitney U test result from the drive test

Instrument	N	Mean rank	Sum of ranks	Mann-Whitney U	Asymp. Sig. (2-tailed)
G-NetTrack	565	310.89	176895	14730	0.000
GSM module	565	828.11	471196		
Total	1130				

3.3. Discussion

The study shows that the RSSI values gotten from a GSM module and G-NetTrack during a drive test are not the same. The spatial variation in signal strength between the two tools is evident in the maps generated from the drive test data. The GSM module generally provides stronger signal strength than G-NetTrack. These results are consistent with earlier research that has observed variations in RSSI values obtained from different tools and devices [23], [24]. Accurate RSSI measurements are essential for estimating the coverage and capacity of wireless networks. They are also utilized to enhance network performance and recognize areas with weak signal quality.

According to the study’s findings, significant differences exist in the RSSI values obtained from the GSM module and G-NetTrack during the drive test. The mean RSSI value for the GSM module was higher, indicating that it provided stronger signal strength compared to G-NetTrack. These results are consistent with previous studies that have also observed variations in RSSI values obtained from different tools [25], [26]. The standard error calculated in this study suggests that the mean RSSI values for both tools were relatively stable and consistent throughout the drive test.

The study also shows that the standard deviation of the RSSI values obtained from both tools was relatively similar, indicating that both tools can provide similar levels of accuracy in measuring signal strength. But G-NetTrack gave a wider range of RSSI values than the GSM module. This might be because the algorithms each tool uses to measure signal strength are different. Understanding these differences is crucial for accurate network planning and optimization, as RSSI measurements are used to estimate the coverage and capacity of wireless networks and identify areas of poor signal quality.

Various fields, such as telecommunication, wireless networks, and location-based services, have adopted RSSI values for wireless signal strength measurement. However, several previous studies have investigated the accuracy and reliability of different methods for measuring RSSI values. For example, one study compared the accuracy of RSSI measurements obtained from different mobile devices and found significant variations due to differences in hardware and software configurations [27]. Another study looked at RSSI readings from various RF sensors and discovered that the readings can be very different because of differences in antenna properties, signal loss, and noise [8], [27]. Therefore, the environmental factors and technical specifications of the tools used for RSSI measurements must be carefully considered.

Previous studies have highlighted the importance of statistical methods for analyzing and comparing RSSI values. For example, [8] used statistical tests to compare RSSI values measured for 3G and 4G networks and found a strong correlation between TX power and RSSI. Similarly, [28] used statistical tests to compare RSSI values measured by different types of frequency in RF modules and recommended using statistical tests to determine the best distribution.

4. CONCLUSION

This study offers valuable insights into the discrepancies in RSSI values between the GSM module and G-NetTrack during a drive test. The results suggest that while the GSM module provides stronger signal strength than G-NetTrack, both tools can produce reliable and consistent signal strength measurements over time. Furthermore, the wider range of RSSI values obtained from G-NetTrack may be due to differences in the algorithms each tool uses to measure signal strength. These findings have significant implications for network planning and optimization, underscoring the importance of using multiple tools to obtain accurate and dependable signal strength measurements. Furthermore, this study emphasizes the importance of carefully evaluating data distribution normality and selecting appropriate statistical tests to analyze RSSI data. By using suitable statistical tests, researchers and practitioners can better comprehend the strengths and limitations of various tools and make informed decisions about which to use in different circumstances. Future research could explore evaluating the influence of environmental factors such as weather and urban density on signal strength to enhance the understanding of network performance. Additionally, developing advanced algorithms to mitigate device-specific biases and improve accuracy is recommended. Longitudinal studies across diverse regions and terrains would provide deeper insights into RSSI variability. Finally, integrating machine learning models to predict signal strength based on network and geographic data could further optimize wireless network planning and performance.

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