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Analysis of received signal strength in indoor environment of telecommunication system

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Abstract: To improve the performance of wireless communications in indoor environment, it is important to optimize the signal quality by reducing the error rate between the received signal strength based on experimental data and estimating data. Due to the complexity of modern building layouts and construction materials, estimating signal strength values based on these structural elements is challenging. The aim of this paper is to analyse received signal strength of the specific area by using the path loss exponent model of ray tracing techniques. In indoor environments, modelling radio wave propagation involves estimating the received signal strength at various points based on the layout and geometry of the space. This study involved three placements of 1.8 GHz AAU5940 Wall Mounted transmitters at height with 11.12 m and at different distances with 44.81 m, 95.4 m, and 108.2 m of specific receiver building. The Received Signal Strength Indicator (RSSI) readings are typically recorded to analyse and understand the ray tracing technique characteristics in a wireless communication environment. This paper presents analytical results of some practical experiments that help to build an optimized signal quality for indoor environment using mathematical modelling with the help of MATLAB software.

Keywords: wireless communication; received signal strength; ray tracing techniques; signal quality; MATLAB software

1. Introduction

The wireless telecommunication field is one of the most pay off and rapidly expanding industries because of the rising demand for mobile devices (Wang et al., 2018). By the end of 2026, it is estimated that 20 billion devices will be connected to the mobile network, rising the number of wireless devices (Pimienta-del-Valle et al., 2021). The increasing mobile users and complex structure of building force us to become to upgrade from 1st generation (1G) to 5th generation (5G) according to the supported characteristics such analog data, digital data, bandwidth, data transfer rate and so on (Maccartney et al., 2015). Wireless data transfer has also augmented as a result of the improvement of the Internet of Things (IoT), which composes applications for smart urban areas, smart health care, smart forming, climate monitoring, perceptive transportation, etc (Geok et al., 2018; Ira et al., 2022).

Due to the crowded and modern design of buildings, it is difficult to estimate and to recommend the received signal level at the receiver (Zhang et al., 2020). Most modern buildings are constructed from materials that reflect mobile signals. Metal, glass and concrete are notoriously difficult for mobile signals to penetrate (Xing et al., 2021). This also causes more received signal strength losses variety of solutions that can improve signal, that is why it forces to conduct the research work to overcome the received signal strength losses problem in indoor environment by improving channel model performance (Getahun & Rajkumar, 2023; Sun et al., 2018; Xing & Rappaport, 2021).

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The purpose of this paper is to optimize the received signal strength in indoor environments by minimizing the error rate between experimental and estimated data. Experimental modelling of indoor radio wave propagation is conducted, and the measured data are compared with predicted results based on the proposed models, taking into account the reflection coefficient. This research also addresses the problem of mobile signal disconnection in indoor environments by analysing the existing channel models for mobile telecommunication systems at Polytechnic University (Maubin). The optimized path loss model is expected to improve signal strength in indoor wireless communication systems.

2. Material and methods

The following steps for doing research on mathematical modelling are based on the design of wireless propagation channel. The research directions are literature review and problem statement, conduct experiments, analyse the wireless channel propagation models, improve and optimize propagation model and performance evaluation and accuracy. Firstly, conducting literature studies, namely conducting research and data documentation related to the problems in this final project, articles, references, journals, or other sources related to discussions. And then, installing applications, namely installing software applications, G-Net Track Lite as supporting software in this study. After that, conducting a location survey, which is a research location at the Polytechnic University (Maubin). Then, determine the operators widely used by users, namely Atom, MyTel, Ooredoo and MPT operators. However, from these three providers, there are problems with the signal quality generated at the route point on the Polytechnic University (Maubin) campus. Therefore, the test experiments of MPT operators are doing with android phone. And then analysed the results of data from experiments. Finally, explain the results that have been achieved, along with suggestions for the development of further research.

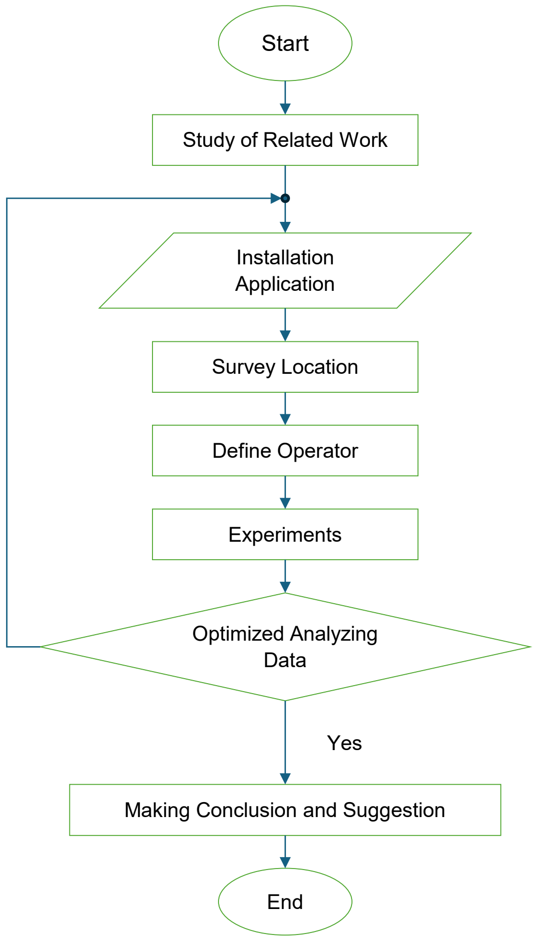

Figure 1. Flowchart of research work

The variation of RSRP value ranges can be attributed to cellular carriers. However, −80 dBm or high contributes to the excellent coverage area of a device with optimum signal strength. Table 1 shows the RSRP value range for LTE and 5G communication systems. Reference Signal Received Power (RSRP) is an important parameter in telecommunication system, especially in cellular networks like Long Term Evolution (LTE) and 5G (Li et al., 2019). It represents the strength of the signal as received by the user equipment (UE) from the serving cell's base station (eNodeB in LTE, gNodeB in 5G). RSRP is measured in dBm (decibels referenced to one milliwatt) and provides insights into the quality and strength of the connection between the UE and the base station. The RSRP value of a mobile receiver is preceded by a negative sign, and its unit is dBm (Nordin et al., 2019; Popovski et al., 2013).

Table 1. RSRP Value description with signal strength (Boccardi et al., 2014)

RSRP	Signal strength	Description
>= -80 dBm	Excellent	Strong signal with maximum data speeds
-80 dBm to -90 dBm	Good	Strong signal with good data speeds
-90dBm to -100 dBm	Fair to poor	Fair but useful, fast and reliable data speeds may be attained, but marginal data with dropouts is possible and performance will drop drastically.
<=-100 dBm	No signal	Disconnection

2.1 Implementation of path loss exponent model

The path loss exponent (PLE) is a fundamental parameter in wireless communication that affects how signal strength diminishes with distance between transmitter and receiver (Pimienta-del-Valle et al., 2021). The height of the transmitting and receiving antennas can affect the PLE. Understanding the PLE is vital for designing and optimizing wireless communication systems. The free-space path loss model is calculated based on Equation (1).

$$PL(dB) = 32.5 + 20\ \log_{10} f(MHz) + 20 \log_{10} d(km) \quad (1)$$

where f denotes the carrier frequency in MHz and d denotes the distance between the transmitter and receiver in km. The long-distance (one-slope) path loss model is expressed by Equation (2).

$$PL(dB) = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right) \quad (2)$$

where n denotes the path loss exponent; d is the distance between the transmitter and receiver in meters; d_0 is the close-in reference distance in meters; and $PL(d_0)$ is the free-space path loss, defined as $PL(d_0) = 20 \log(f) - 28$, where f is the frequency in MHz. The received signal power is calculated using Equation (3).

$$P_r = P_{total} - PL(d) + G_t + G_r \quad (3)$$

where P_r denotes the received signal power, *P_total* denotes the resultant transmitted power, *PL(d)* represents the long-distance path loss, *G_t* is the transmit antenna gain, and *G_r* is the receive antenna gain.

Experimental 3-storyed building at Polytechnic University (Maubin) (Mon et al., 2025) as selected for measuring the RSRP with the G-NetTrack Lite software, which is one of the various signals transmitted from the base station (MPT) using the mobile communication LTE network. At the ground floor, first floor and second floor of this building have four rooms respectively, the signal strength was measured at

390 points at a height of 3.5 feet from the floor with the same distances. The distance between every 2 points is 5 ft.

Figure 2. Experimental environment at Polytechnic University (Maubin) (Mon et al., 2025)

Table 2. Path loss exponent value for different environment (Ali et al., 2022)

Environment	Path loss exponent, n
Free space	2
Urban area	2.7 to 3.5
Shadowed urban	3 to 5
In building line-of –site	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

Before evaluating the experimental data, the three-storey building of the Polytechnic University (Maubin) was first analysed (Mon et al., 2025) used to evaluate. There are three floors and four rooms on each floor, twelve rooms are used to measure. Experimental data and analysed data of four rooms on first floor are illustrated in this research work. In this experimental region, there may be some furniture, laboratory tables and chairs, classroom environment and others are already allocated. That is why there may not be any empty rooms available. An additional path loss due to many obstacles should be also considered. Before conducting all experiments, all measuring points are marked on each room, in which the distance between consecutive two points is 5 feet respectively. The following table shows the detailed information of experimental setup. All experiments are conducted in different times and on different days to collect more accurate and non-fluctuated values. At receiving point, the mobile phone is used to analyse 4G and 5G signal analyser is already installed (Nordin et al., 2019).

Table 3. Specification of experiments

No.	Description	Specification	Remark
1	Transmitter type	AUU5940	MPT
2	Transmitted power	16.8dBm	for Exp
3	Transmitter gain	14.5dBi	
4	Transmitter height	11.12m	from ground
5	Number of APs	3	
6	Receiver height	3.5ft	from floor
7	Building dimension	192'x 38'	
8	Working frequency	1.8 GHz	

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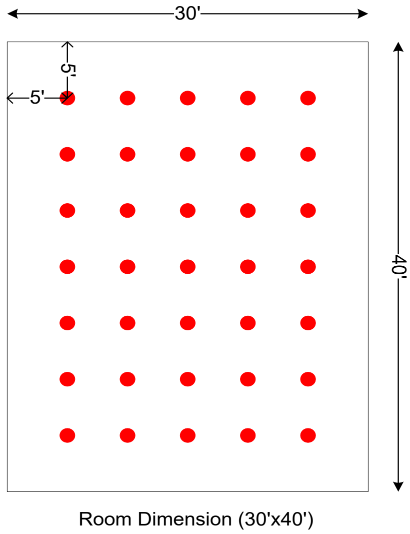


Figure 3. Allocation of experimental measuring points in a room

3. Results and discussion

In this section, we conduct experimental evaluations on the various analytical related to wireless communication channels. The simulation analysis was carried out based on the optimized path loss exponent value for specific rooms (obstructed in building range 4 to 6), f=1800 MHz and d_0= 1 m by using MATLAB programming language with the version of 2015.

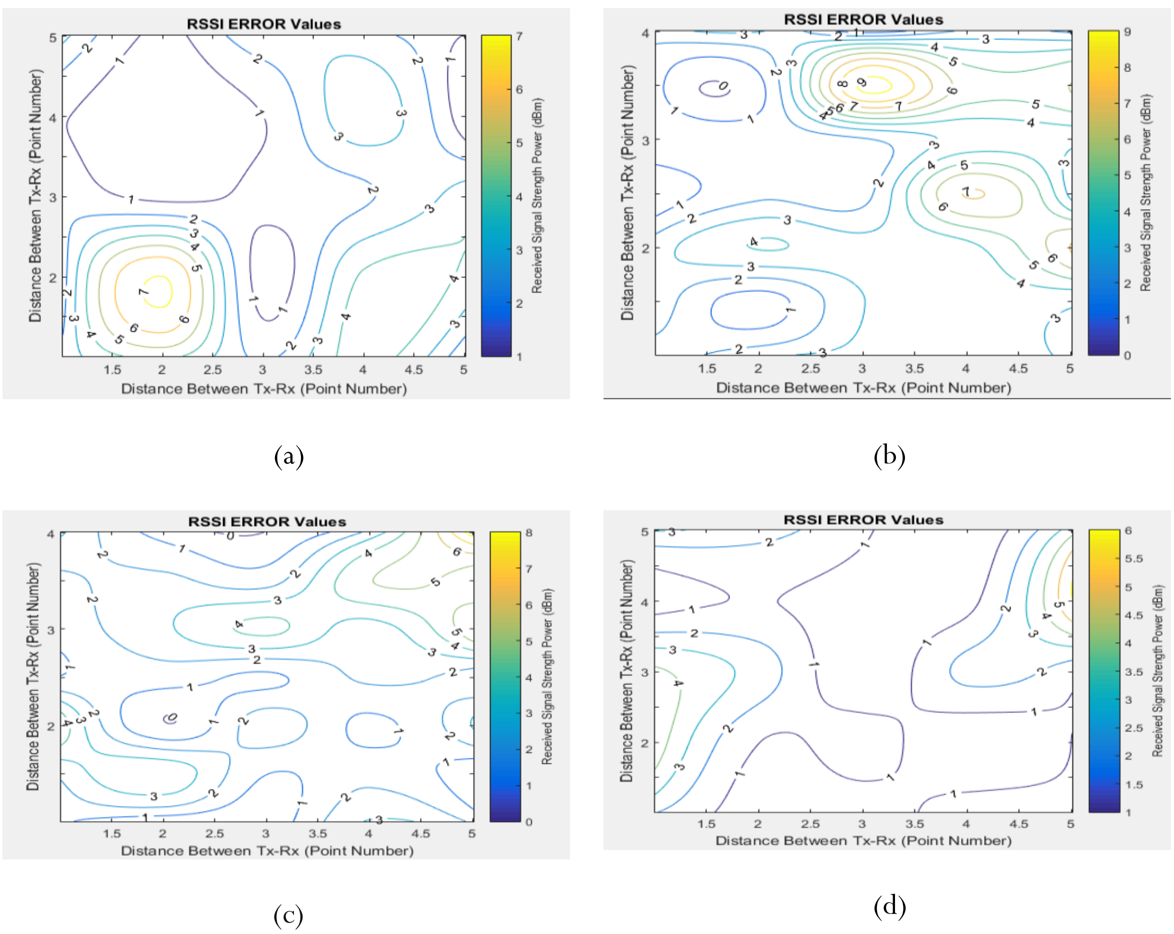
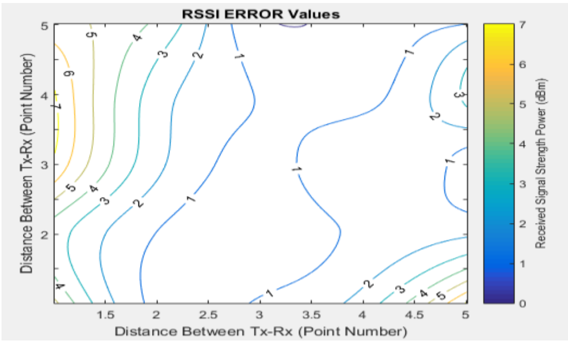
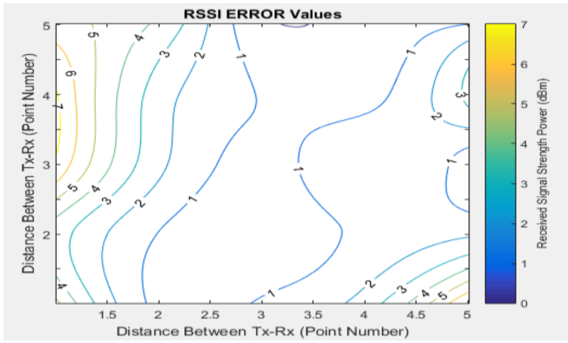


Figure 4. Minimum error value between experimental data and estimated data of ground floor. (a) A 1/1 room, (b) A 1/2 room, (c) A 1/3 room, and (d) A 1/4 room

This result shows the optimized minimum error values between RSSI values by path loss model and by experiments of twelve rooms of experimental building. This error rate can be accepted to recommend mobile signal losses. This simulation analysis was carried out based on the optimized path loss exponent value, n=4.675 which is the obstructed in building environment by using MATLAB language. These results show the difference between RSSI error values by path loss model and by experiments of twelve rooms at experimental building. Figure 4 (a) shows the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A1/1 room at ground floor of experimental 3-storyed building. Figure 4 (b) illustrates the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A1/2 room at ground floor of experimental 3-storyed building. Figure 4 (c) exhibits the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A1/3 room at ground floor of experimental 3-storyed building. Figure 4(d) demonstrates the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A1/4 room at ground floor of experimental 3-storyed building.



(a)



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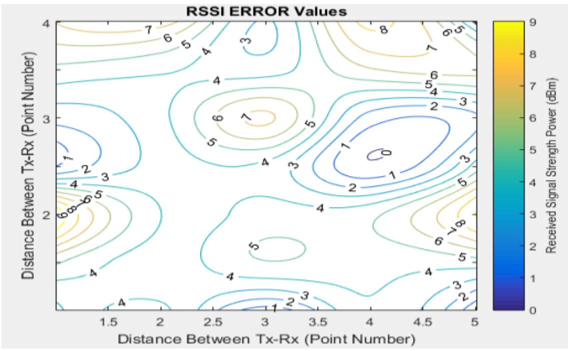

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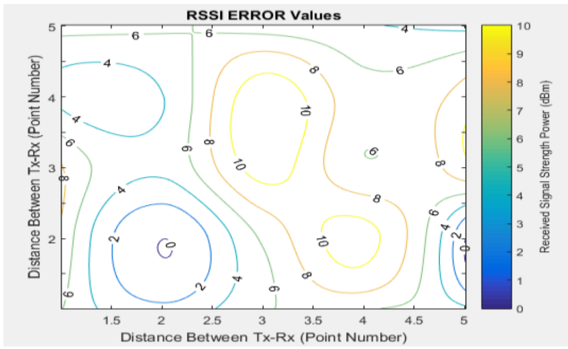

(d)

Figure 5. Minimum error value between experimental data and estimated data of first floor. (a) A 2/1 room, (b) A 2/2 room, (c) A 2/3 room, and (d) A2/4 room

Figure 5 (a) reveals the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A2/1 room at first floor of experimental 3-storyed building. Figure 5 (b) presents the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A2/2 room at first floor of experimental 3-storyed building. Figure 5 (c) indicates the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A2/3 room at first floor of experimental 3-storyed building. Figure 5 (d) depicts the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A2/4 room at first floor of experimental 3-storyed building.

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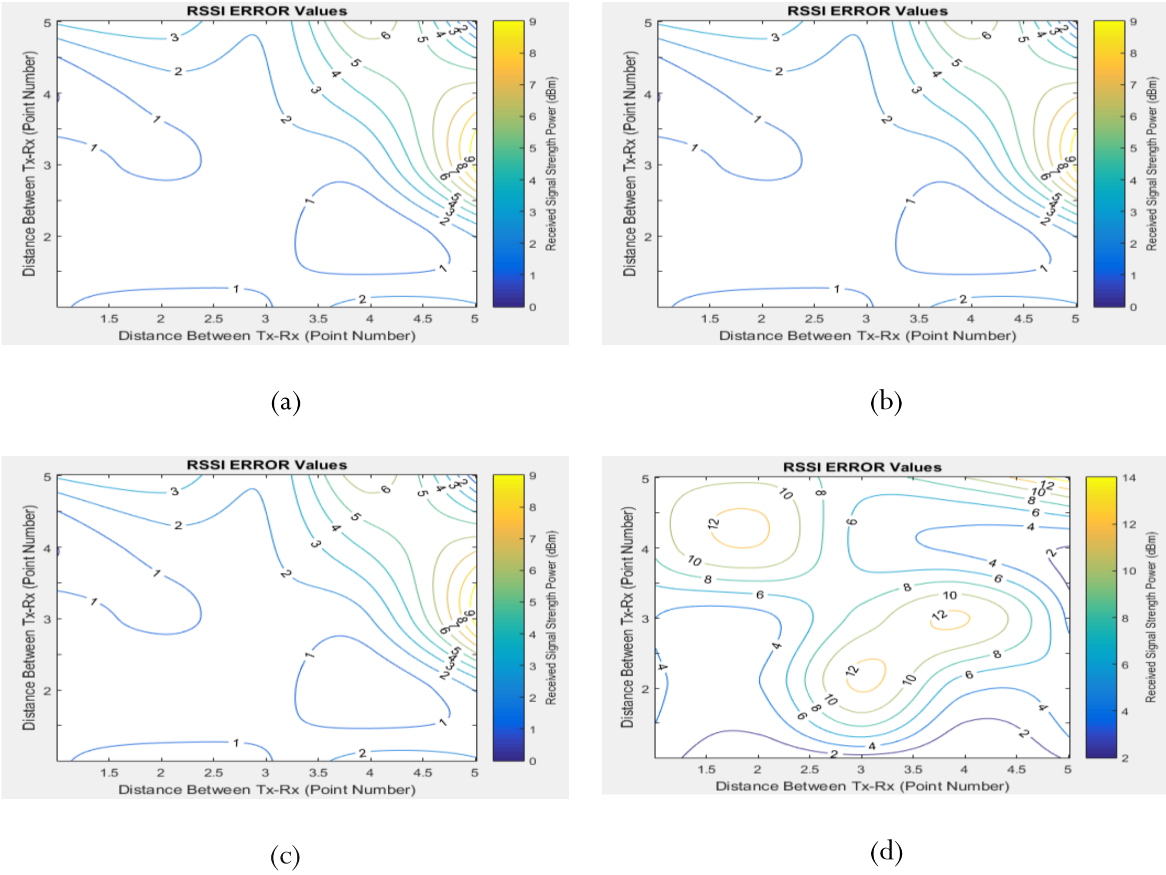

Figure 6. Minimum error value between experimental data and estimated data of second floor. (a) A 3/1 room, (b) A 3/2 room, (c) A 3/3 room, and (d) A 3/4 room

Figure 6 (a) performs the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A3/1 room at second floor of experimental 3-storyed building. Figure 6 (b) shows the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A3/2 room at second floor of experimental 3-storyed building. Figure 6 (c) displays the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A3/3 room at second floor of experimental 3-storyed building. Figure 6 (d) demonstrates the simulation result of received signal strength power(dBm) with minimum error value between experimental data and estimated data of A3/4 room at second floor of experimental 3-storyed building.

This research work shows obviously the area of mobile phone signal strength levels for all rooms of standard experimental region. It helps mobile phone network design engineers to estimate for fulfillment of the required mobile computing area. Also, these outstanding research results recommend RSSI values for not only mobile phone customers but also network engineers. By using mentioned research results, the further researcher should have to use them to upgrade and to extend experimental region for later mobile communication system called later 5G system, 6G and so on and also need to compare with those results to recommend. In reference papers (Mon et al., 2025), the received signal strength was measured at receiver heights of 3 feet, 5 feet and so on. In this study, the receiver height was set at 3.5 feet and the received signal strength was measured. By comparing the obtained results, it was observed that the received signal strength is better when the receiver height is 3.5 feet. In summary, this study found that the received signal strength also depends on the receiver height. For all conduction experiments, interfere and path loss attenuation due to being human are not analysed. It should be extended for estimation. Also, mobility of receiver is not considered during conduction experiments. More complex indoor infrastructure is also used to conduct experiments and to estimate for further network design. As outdoor obstacles between Tx-Rx are totally not included to analyse RSSI values, weather conditions and outdoor barrier are also important for network engineers in designing the specific organization. Further researchers should conduct experiments and should estimate RSSI value in comparing these research outcomes with different experimental regions (organization) at different frequencies ranges. In all experiments, there are only 3 APs used in evaluation.

4. Conclusion

MIMO technology has rapidly developed recently. Estimation of received signal strength in wireless communication should be analysed in MIMO technology. The resultant transmitted power is calculated with respect to allocation of AP (Access Point) by using vector summation theory. As the distance between Tx-Rx are vary according to the allocation of different antennas, the related distance between Tx-Rx is assumed as average levels. At the receiving point (Rx), there may be more than one input signal according to the nearby many transmitters (Tx) allocation, as there are three APs in the given experimental region. That is why the resultant transmitted power affects every receiving point. Due to the analytical result, the RSSI error values are obviously decreased according to the optimization of resultant power. The received signal strength also depends on the environment of experimental region, that is the dimension of room and building structure. The ray tracing technic is more accurate in estimation of indoor received signal strength than any other estimating models. The dimension of room also affects the received and transmitted signals, as there is the fluctuation of complex structure.

Author's declaration

Author contribution

Myint Myint Mon: data collection, data analysis, methodology, draft preparation, correspondence. **Mya Mya Aye**: supervision, methodology, reviewing and editing. **Lei Lei Yin Win**: supervision, validation.

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Data availability

All data supporting the findings of this study are available from the authors upon reasonable request.

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Conflict of interest

No conflicts of interest in this research.

Ethical clearance

Not applicable

AI statement

This article is the original work of the author without using AI tools for writing sentences and/or creating/editing table and figures in this manuscript. The grammatical structure of this article was improved by using ChatGPT and the authors have rechecked the accuracy and correctness of the generated sentences with the topic and data of this study. The data and language use in this article have been validated and verified by an English language expert and none of the AI-generated sentences include in this article.

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Researcher and Lecturer Society as the publisher, and Editor of Journal of Computer-based Instructional Media state that there is no conflict of interest towards this article publication.

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