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INVESTIGATION OF INDOOR WI-FI STABILITY BASED ON THE RECEIVED SIGNAL STRENGTH INDICATOR (RSSI): A CASE STUDY AT UC TATI HOSTEL

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Abstract:

Wi-Fi has become indispensable in today's digital era, enabling connectivity in homes, workplaces, and educational institutions. However, ensuring stable indoor Wi-Fi remains a challenge due to factors such as structural obstacles, interference, and varying user loads, all of which impact signal strength. This study examines indoor Wi-Fi stability at UC TATI Hostel, aiming to achieve an optimal RSSI value of -67 dBm using Ekahau AI Pro and the WiFiman app for analysis. Various scenarios were assessed, including different AP types, placements, and user loads. Findings revealed that wall-mounted APs outperformed ceiling-mounted ones, and modern APs with advanced features were more effective than older models, particularly under heavy user loads. Additionally, environmental factors like interference from lighting influenced performance. The study offers practical recommendations for enhancing Wi-Fi in similar indoor settings, emphasizing the importance of upgrading to modern APs, strategic AP placement, and reducing interference.

Keywords:

Access Points; Wi-Fi; RSSI, RF, dBm

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Introduction

In today's digital age, Wireless Fidelity (Wi-Fi) is essential, serving as the backbone of internet connectivity in homes, offices, and educational institutions (Minoli and Dressendofer 2021). As the number of connected devices continues to rise, the demand for stable and reliable Wi-Fi networks has become more critical than ever. A Wi-Fi utilizing radio frequency (RF) communication, has become a key technology in educational institutions, in fully wireless campuses, wireless networks replace wired ones, ensuring seamless, anytime-anywhere access for users (Chi and Zhang 2023). Wi-Fi stability is paramount for ensuring seamless communication, streaming, and data transfer, all of which are integral to modern living and work environments. Higher Education Providers (HEPs), such as universities and colleges, play a pivotal role in ensuring optimal network connectivity for students and staff, fostering effective learning and supporting educational activities on Wi-Fi-enabled devices (Ohei and Brink 2021). However, maintaining stable Wi-Fi coverage, particularly in indoor environments, presents several challenges.Wi-Fi signals are susceptible to various factors, including structural obstacles like walls and floors, interference from other electronic devices, and competing networks. These factors lead to signal degradation, dead zones, and fluctuating performance, often resulting in user frustration and diminished productivity. One of the key metrics used to assess and diagnose Wi-Fi performance is the Received Signal Strength Indicator (RSSI) (Nakprasit and Phongcharoenpanich 2019) . RSSI measures the power level received from a Wi-Fi access point (AP) and is a crucial indicator of connection quality and reliability. Factors influencing RSSI include the AP type, its physical placement, user load, and the surrounding network environment. Understanding these factors is essential for optimizing Wi-Fi networks to achieve consistent, strong signal coverage (Kamdee and Apavatjrut 2021). This study investigates indoor Wi-Fi stability at University College TATI (UC TATI) Hostel by analyzing RSSI under different conditions. Using Ekahau AI Pro and the WiFiman app, we evaluate RSSI across various scenarios, aiming to identify configurations yielding the most optimal RSSI, with a target of -67 dBm for stable signal strength across all hostel rooms. The significance of this study lies in its potential to provide actionable insights for improving Wi-Fi network design in similar environments. By understanding how factors like AP type, placement, user load, and measurement tools affect RSSI, network administrators and engineers can make informed decisions to enhance Wi-Fi performance. This research contributes to academic discourse in wireless networking while offering practical recommendations for achieving stable, reliable Wi-Fi in indoor settings.

Literature Review

The rapid advancement of wireless communication technologies has led to a growing body of research focused on optimizing Wi-Fi networks, particularly in indoor environments where signal stability is crucial. Wi-Fi stability, a key aspect of network performance, is essential for maintaining reliable connectivity in settings such as homes, offices, and educational institutions. Central to the evaluation of Wi-Fi performance is the Received Signal Strength Indicator (RSSI), which serves as a quantitative measure of the power level that a device receives from a Wi-Fi access point (AP). Studies have consistently highlighted the importance of RSSI as a primary metric for assessing Wi-Fi signal strength and overall network reliability (Nauvaldi, Pontia, and Tjahjamooniarsih 2023). For instance, Xue et al. (2017), emphasize that RSSI directly impacts the quality of the Wi-Fi connection, influencing factors such as data throughput, latency, and user experience. This underscores the need for achieving a stable RSSI to ensure optimal network performance.

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Table 1
Summary of Research on Factors Influencing RSSI

Authors	Factors Influencing RSSI	Methods/Tools	Findings
(SaloniKasture, 2018)	- **Background noise.** - **Number of people in network** - **Hardware dependency**	- Use **TWO (2)** laptops with different processor, generation, and speed. - InSSIDer and WiFiAnalyzer	- Signal strength of a single access point measured with different hardware is having different values. - Difficult to get same signal strengths on each device since both Wi-Fi cards and Processors were different. - prove the hardware dependency of the Wi-Fi signal strength. - signal strength is less than -80 dBm is classify as dead zone, need to add new AP
(Sasiwat Et Al., 2019)	- **Human Presence and Movement** - **Distance** - **Human Movement Patterns**	- Experiment in laboratory - Measure RSSI human stands at each predefined distance within/and nearby the wireless links. - MSP430F2617 low-power microcontroller - CC2420 transceiver	- Human movement causes noticeable fluctuations in RSSI levels, with more significant drops in signal strength observed when people move closer to the communication link. - RSSI levels vary depending on the - Different human movement patterns lead to different RSSI variations
(Chapre et al., 2013)	- **Hardware Orientation** - Distance, between the transmitter (AP) and receiver - **Interference** radio channels. - **Human Presence** - **Environmental Factors**	- NetSurveyor: A Wi-Fi surveying software - Dell Latitude E5400 Laptop with Intel WiFi Link 5100 AGN Card - Experimental Setup	- Significant fluctuations in RSSI were observed due to factors like hardware orientation and environmental conditions. - Different orientations of the receiving device resulted in at least 2 dBm deviation in mean RSSI values. - A 1-meter difference in distance between the transmitter and receiver led to up to a 6 dBm fluctuation in mean RSSI values. - Building materials and user presence

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(Wang et al., 2021)	- **Distance**: The signal strength decreases with increased distance - **Environmental Obstacles** - **Multipath Effect**	- Wi-Fi Access Point (ipTIME N3004 - Mobile Devices: Used to collect RSSI measurements at various distances. - Gaussian Filter and Bootstrap Filter:	- RSSI value decrease with the increase of distance in indoor environment - The proposed filtering algorithms (Gaussian and Bootstrap filters) significantly reduced noise and errors in the RSSI measurements, leading to more accurate indoor positioning.
(Puckdeevongs, 2021)	- **Walls and barriers** - **Distances**	- Investigate the possibility of applying RSSI fingerprinting based Artificial Neural Network (ANN) jointly.	- Location fingerprinting most effective of the many indoor positioning techniques due to its accuracy and low cost. - Not able to receive the signal when it was away from the signal transmitter.
(Chen et al., 2020)	- **Temperature** - **Humidity** - **Atmospheric pressure** - **Wind speed.**	- Hygrometers, thermometers, and humidity and temperature sensors - Signal Measurement: Cable Access Television Analyzers and Spectrum Analyzers	- Correlation between temperature, humidity, and RSSI. - Higher humidity generally resulted in a decrease in signal strength, while higher temperatures often increased it. - The signal strength experienced losses as temperature and humidity levels changed. - Humidity having a more significant impact on weakening the signal.
(Hanbay et al., 2017)	- **Number of Users** - **Wi-Fi Channel Usage**	- HPE 560 802.11ac Wi-Fi Modem - Wi-Fi Analyzer Application - Fing Application - SRM-3006 Selective Radiation Meter	- Signal strength drops as more users connect, averaging -54.72 dBm on channel 6. - Maximum throughput reached 20.26 Mbps, with an average of 10.07 Mbps. - The modem supports up to 64 users before significant performance decline.
(Aileen et al., 2021)	- **Building Materials** (concrete, wood, and plastic affect) - **Material Thickness** - **Distance**	- Wi-Fi Monitor Application: (Android apps) - Data Collection Method (signal was measured before and after placing materials)	- Concrete caused the most significant reduction in Wi-Fi signal strength, followed by wooden doors and plastic. - Hollow plywood walls had the least impact on signal strength.

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(Sonawane et al., 2017)	- **Distance from the Wi-Fi Source** - **Obstacle** - **Wi-Fi Network Configuration**:	- WPA-WPS Tester: An Android application - Asus Zenfone 5 - Mapping and Analysis	- Signal weakens with distance and obstacles; some areas had no signal, creating dead zones. - Adjusting router placement and settings can boost signal strength and reduce dead zones. -
(Baguda, 2018)	- **Electromagnetic noise from Microwave oven**	- Spectrum analyzer, - Cisco Aeronet 1200 AP, - Microwave oven and - Personal computer equipped with wireshark software	- Electromagnetic noise radiation from microwave oven can seriously affect the performance of other devices operating in 2.4 GHz frequency band, especially, delay sensitive applications and services. - Microwave oven is a major source of electromagnetic radiation noise in ISM band
(Rosli et al., 2018)	- **Obstruction** in the Line of Sight (LOS) - **Human crossing** significantly attenuates the RSSI, causing negative peaks in the signal	- Experimentation with Obstructions - Sampling Rate and Human Movement - ESP8266 Wi-Fi Serial Transceiver Module	- Signal reading will heavily be affected by obstruction. - Human crossing between transmitter and receiver will attenuates the signal significantly - Environmental factors like obstructions and human movement can significantly affect its accuracy and reliability
(Aideed Fadzilla et al., 2018)	- **Propagation Factors** - **Environmental Factors** - **Antenna and Positioning**	- Indoor RSSI analysis in building using XBEE. - XBEE S2 Wireless Modules - XCTU Developer Software	- Strength of signal fluctuates with object and material of office such as wall door, tables, chair, sofa. - Lower antenna height resulted in weaker signal strength due to increased diffraction and reflection from nearby objects. - Strategic antenna positioning is essential to optimize signal strength and reduce interference.
(Shi et al., 2020)	- **Obstacles** - **Antenna placement** and transmission power. - **Temperature**. - **Interference** from other devices and Wi-Fi channels.	- Trilateration-based positioning system. - MATLAB for data analysis. - Filtering algorithms	- The new filtering method improved positioning accuracy by 20.5% with an error margin under 1.46 meters.

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(Naif et al., 2018)	- **Distance** from the AP - **Physical obstacles** like walls - AP placement and density	- WiFi Analyzer: Measured signal strength (RSSI). - Ekahau HeatMapper: Mapped Wi-Fi coverage.	- Signal strength weakens with distance and obstacles, ranging from -40 dBm to -79 dBm. - Areas closer to the AP have better coverage; more APs are needed for full coverage in obstructed areas.
(Yeshalem et al., 2022)	- Electromagnetic Emissions - **Ballast Circuit Design**	- LTSpice Simulation Software - Laboratory Measurement Setup - Digital Oscilloscope	- The inclusion of an EMI filter in the ballast circuit effectively reduced the high-frequency emissions by up to 20 dBuA. - The impact of ballast design on electromagnetic interference. - The study showed that conducted emissions harm power quality, highlighting the need for proper filtering in ballast designs**.** - Electronic ballasts significantly influence signal strength - The design and components of the electronic ballast, including the presence of an EMI filter
(Nakprasit & Phongcharoenpanich, 2019)	- **Distance** from node - **Obstacles** and building Structure - **Overlapping** Wi-Fi channels in the 2.4 GHz	- InSSIDer software - Xirrus Wi-Fi Inspector - WirelessMon Professional:	- RSSI values decreased with increasing distance and obstacles, ranging from -37 dBm to -45 dBm. - Importance of proper antenna placement. - Non-overlapping channels (1, 6, and 11) reduced interference and improved indoor signal quality.
(Andjamba et al., 2017)	- **Physical obstructions** such as building structures made of bricks and metal. - **Proximity of wireless devices.** - **Overlapping channels** and incorrect channel allocation. - **Incorrect placement** of access points.	- Cisco Prime Infrastructure - Wireless LAN Controller (WLC) - Data was collected over a period of two months	- There is excessive signal interference at the Namibia University of Science and Technology (NUST), particularly in areas closer to the city campus. - The interference is more prominent on the 2.4 GHz frequency band due to many devices operating on the same frequency. - Incorrect placement of access points - Poor wireless channel allocation contributes significantly to the interference. - The 5 GHz frequency band experiences less interference

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Several factors contribute to the variability of RSSI in indoor environments as shown on **Table 1**, with numerous studies identifying key determinants of signal strength fluctuations. One significant factor is the placement of Wi-Fi APs. Research has shown that ceiling-mounted APs generally provide more consistent coverage compared to wall-mounted units, due to their unobstructed line of sight and reduced interference from physical obstructions such as furniture (Andjamba, Zodi, and Jat 2017; Xing et al. 2019) . Additionally, the type of AP used plays a crucial role in determining RSSI. Newer AP models often incorporate advanced signal processing and beamforming capabilities, which can enhance both coverage and stability. increased user density can lead to signal degradation due to factors such as interference and bandwidth competition, which ultimately affects the RSSI values observed in various environments (Fauziah, Marpaung, and Imansyah 2023). This phenomenon is particularly noticeable in densely populated environments like hostels. Indoor wireless environments face numerous challenges due to their complexities, including the presence of moving objects, obstacles, and barriers (Zaal et al. 2020).

Tools

Accurate measurement and analysis of RSSI necessitates the use of specialized tools and methodologies. Among the most widely utilized tools are Ekahau AI Pro and the WiFiman app. Ekahau AI Pro is a professional-grade tool known for its advanced features in designing, analyzing, and optimizing Wi-Fi networks. It has been validated extensively in the literature for its accuracy and reliability in measuring RSSI and other performance metrics (Rasyiidin 2021). Conversely, the WiFiman app offers a more accessible option for mobile devices, providing real-time RSSI measurements and network diagnostics. Comparative studies have noted that Ekahau AI Pro offers comprehensive features suitable for detailed site surveys. The choice between these tools typically depends on the specific needs of the study, with Ekahau AI Pro preferred for in-depth analysis and WiFiman for preliminary assessments.

Case Study

Case studies focused on Wi-Fi optimization in residential and institutional environments provide further insights into effective strategies for enhancing network performance. For example, Dapeng et al. (2020), explored Wi-Fi deployment strategies in a gymnasium of Beijing Normal university , emphasizing the importance of AP placement and channel selection in mitigating interference and ensuring stable coverage.The case study on Wi-Fi performance in multi-room apartments reveals that structural factors significantly influence Received Signal Strength Indicator (RSSI) and overall network quality. Research indicates that the presence of walls, furniture, and other obstructions can lead to signal degradation due to reflection and diffraction, necessitating tailored solutions like access points and mesh networks to enhance coverage (Fauziah, Marpaung, and Imansyah 2023; A. Ubom, C. Akpanobong, and I. Abraham 2019). Building on this existing body of research, the current study seeks to fill a gap by providing a detailed analysis of indoor Wi-Fi stability in a hostile environment, specifically the UC TATI Hostel. By utilizing both Ekahau AI Pro and WiFiman for comprehensive RSSI measurement, this study aims to identify the most effective configurations for achieving stable Wi-Fi coverage. While previous research has explored various aspects of Wi-Fi performance, there remains a need for more targeted studies focused on environments like student accommodations, where reliable Wi-Fi is essential for both academic and recreational activities. The findings of this study are expected to contribute to the broader understanding of Wi-Fi network optimization, offering practical insights that can be applied in similar settings.

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According to Ladrón de Guevara Rodríguez et al. (2022), internet usage use for search information can contribute favor the maximization of outcomes of education.

Research Methodology
This study employed the PPDIOO (Prepare, Plan, Design, Implement, Operate, Optimize) model to investigate indoor Wi-Fi stability at UC TATI Hostel systematically. (Rasyiidin 2021), emphasized incorporating wireless RSSI measurements at every stage to ensure the network system is effectively designed and optimized for a Smart Office environment. In the Prepare phase, key objectives were identified, focusing on achieving stable Wi-Fi signal strength of -67 dBm or better using RSSI as the primary metric. Methodology used by Zaal et al. (2020) that used laptop equipped with preinstalled software to measure the Received Signal Strength (RSS) at various points. During the Plan phase, the scope was defined, focusing on one house with four rooms in the hostel, with the 2.4 GHz frequency band chosen for its superior range. The scenarios involved variations in AP type (new vs. old), AP placement (ceiling vs. wall), user load (half vs. full), and measurement tools (Ekahau vs. WiFiMan). In the Design phase, a detailed measurement layout was created, specifying RSSI collection points (center, near AP, and farthest from AP) and ensuring controlled environmental conditions to minimize interference. The Implement phase included deploying APs in ceiling and wall positions, calibrating the measurement tools, and conducting three trials for each scenario to ensure reliable data. In the Operate phase, live monitoring was performed to verify consistent data collection, and troubleshooting was done for any anomalies observed during the measurements. According to Karakusak et al. (2022), it is essential to continuously monitor Wi-Fi network performance and analyze variations in RSSI values over time by utilizing captured RSSI signals. Finally, in the Optimize phase, RSSI data was analyzed statistically, with tools compared for accuracy, and heatmaps generated using Ekahau to visualize signal coverage and identify dead zones. The results of this structured methodology provided actionable insights into the optimal configurations for stable indoor Wi-Fi coverage.

Structure and Layout of KK3 Hostel
The Kolej Kediaman 3 (KK3) hostel at UC TATI was selected for this study due to its unique design and structural characteristics. Unlike other hostel blocks, KK3 was constructed in a different era, with each unit containing its own Wireless Access Point (WAP) to cover four rooms, each accommodating up to four students. The structure of KK3 is characterized by numerous brick walls and complex layouts, which can impact Wi-Fi signal propagation and stability. According to Naif et al. (2018), physical barriers such as walls and extended distances contribute to RSSI signal degradation. These structural attributes make KK3 an ideal subject for analyzing the effectiveness of indoor Wi-Fi coverage.

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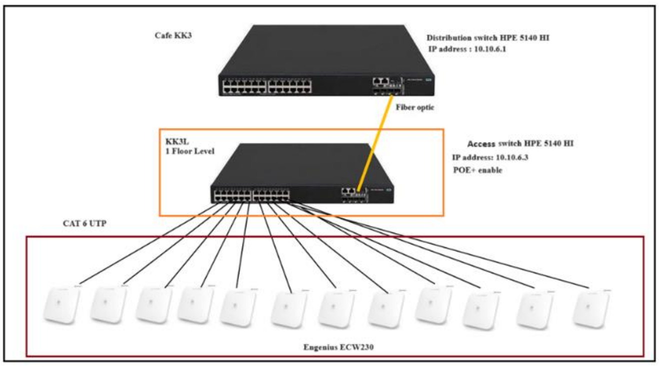

Fig. 1. WLAN Architecture of KK3

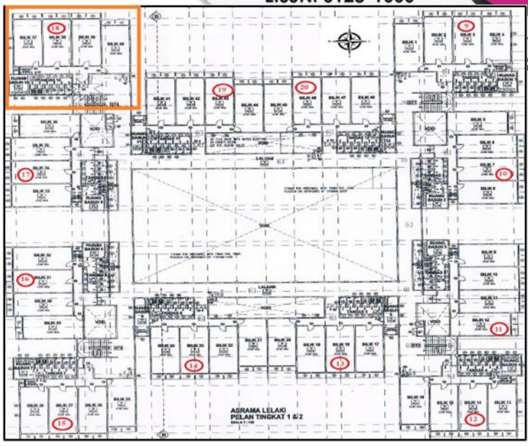

Fig. 2. House 18 Structure Layout

Experimental Environment: House 18

House 18 in KK3 hostel, shown in Figure 3, was chosen for this study due to its representative design, layout, materials, and identical user environment. Each room in House 18 is labelled from Room 1 to Room 4, and each has distinct locations for measuring Wi-Fi signal strength. Measurement devices were placed at the farthest points of each room to evaluate coverage across different positions. The original AP location was also noted to serve as a reference for identifying how effectively the Wi-Fi signal reaches various areas. This setup was critical for examining the impact of AP positioning on overall Wi-Fi stability in a typical room layout within KK3.

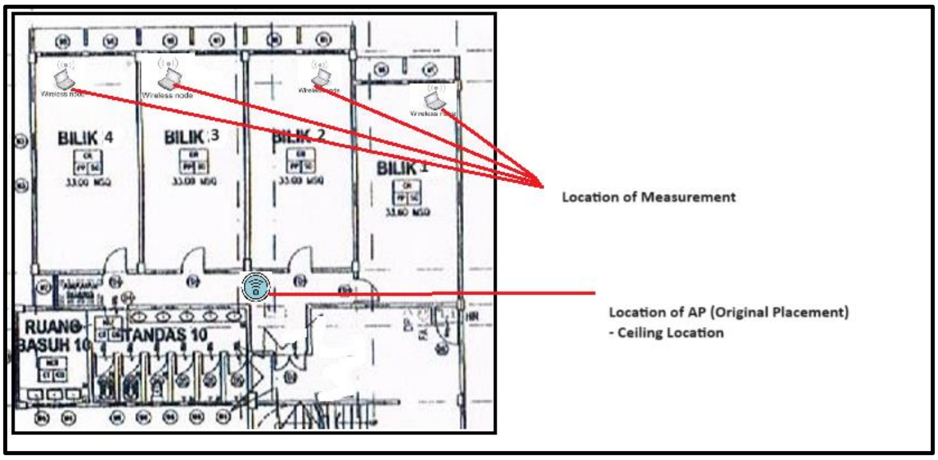

Fig. 3. Measurement Setup in House 18

AP Placement and Signal Measurement Protocol

The experimental setup in House 18 aimed to assess both signal strength and Wi-Fi coverage effectiveness based on AP placement. By evaluating the current AP positioning and its ability to maintain stable signal strength throughout the rooms, the study aimed to identify if alternative placements or additional APs were necessary. The measurements across the identical structural layout, wall materials, and consistent volume of users ensured controlled conditions to determine if signal degradation occurred due to the building design. This focused approach enables a clearer understanding of how signal coverage varies within such a dense and structurally complex environment. Others researchers indicates that methods requiring fewer reference signals, such as those based on received signal strength (RSS), can reliably determine device locations within defined areas, reinforcing the reliability of single-location measurements (Romanov and Succi 2018). A single representative measurement can indeed reflect broader signal performance across similar locations (Han et al. 2017)

Fig. 4. Ceiling Mounted (Left), Wall Mounted (Right)

This position helps examine the impact of physical building features on Wi-Fi signal quality and supports determining optimal AP placement strategies within dense, multi-room accommodations like KK3.

Result and Discussion

optimal configurations for achieving the target RSSI value of -67 dBm or better.

RSSI Performance Across Scenarios

AP Position

The results indicate that AP placement significantly affects RSSI performance. Wall-mounted APs consistently delivered stronger signal strength than ceiling-mounted APs. For example, with the lamp off, the New AP achieved RSSI values between -53 dBm and -61 dBm across rooms, while ceiling-mounted configurations exhibited a wider range with weaker signals, such as -61.5 dBm to -70.5 dBm. The Old AP struggled in both configurations, with values frequently dropping below -66 dBm and failing to sustain connectivity under full user load.

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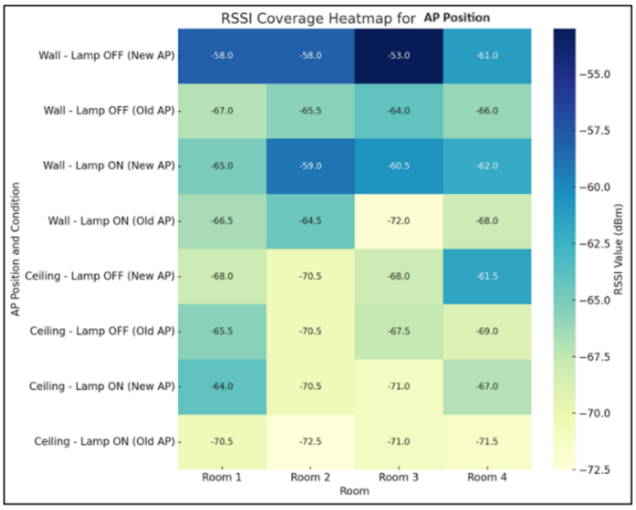

Fig. 5. Result for AP Position

AP Type

A comparison between the New AP and Old AP reveals that the New AP provided significantly stronger and more reliable RSSI values across all scenarios. Under full user load, the New AP maintained a stable signal, while the Old AP failed to support more than 18 users, as indicated by "None" in several measurements. The New AP's advanced 802.11ax technology ensured better performance, even under challenging conditions.

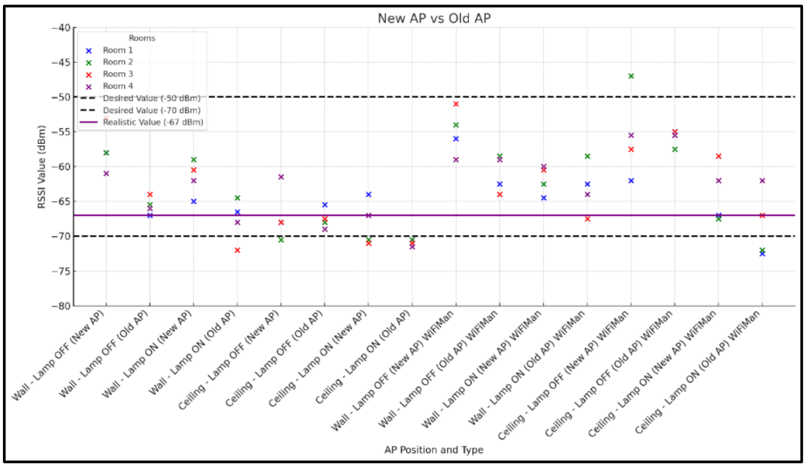

Fig. 6. Result for AP Type

User Load

User load had a noticeable impact on RSSI performance. With half user load, both APs performed relatively better, but the Old AP began to falter with full user load, dropping connections in most scenarios. The New AP showed resilience, maintaining acceptable RSSI values close to the target of -67 dBm, with a slight decline under full load. Figure 7 is the heatmap that represents the RSSI coverage across different conditions, with "NA" values clearly indicated where data is missing for Full Users with Old APs. Dark blue cells in the heatmap indicate the best RSSI values, which are closest to the desired range, representing strong signal coverage.

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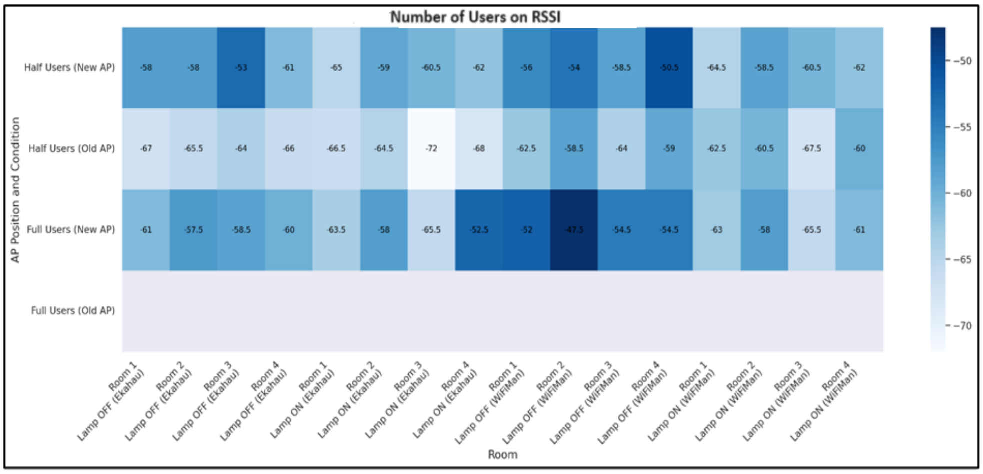

Fig. 7. Result for User Load

Environmental Interference

The presence of a lamp significantly influenced signal strength, particularly for the Old AP. When the lamp was turned on, RSSI values for the Old AP dropped below acceptable thresholds in several rooms, such as -72 dBm in Room 3. The New AP demonstrated better tolerance to interference, though it also experienced minor degradation.

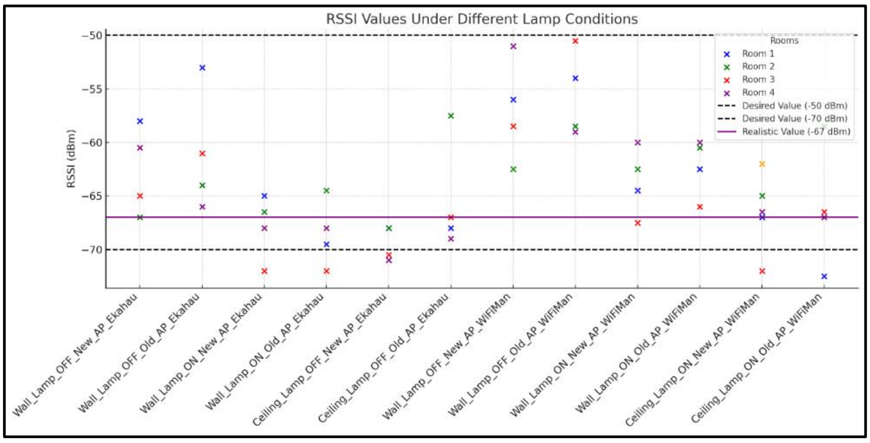

Fig. 8. Environment Interference Result

Key Findings

1. **Optimal AP Position**: Wall-mounted APs proved to be more effective in maintaining robust signal strength across rooms, minimizing dead zones.
2. **Superiority of New AP**: The New AP consistently outperformed the Old AP, achieving stronger and more stable RSSI values under all conditions.
3. **Impact of User Load**: Increased user density negatively impacted RSSI, with the Old AP unable to support high loads, while the New AP maintained performance with minor degradation.

4. **Environmental Factors**: Fluorescent lamp interference posed a significant challenge for older APs, underscoring the need for strategic AP placement and EMI mitigation.

Recommendations

1. **Upgrade to Modern APs**: Transitioning to newer APs with 802.11ax technology is critical to handling higher user loads and mitigating signal degradation.
2. **Strategic AP Placement**: Wall-mounted positions to maximize coverage and signal strength in dense, multi-room environments.
3. **Mitigation of Interference**: Replace high-EMI lighting such as fluorescent lamps with LED alternatives to reduce environmental interference.
4. **Capacity Planning:** Deploy high-capacity APs in areas with dense user activity to ensure reliable connectivity.

Conclusions

This research analyzed factors affecting indoor Wi-Fi stability at UC TATI Hostel, focusing on RSSI as a key performance metric. Furthermore, using Ekahau and WiFiMan tools, it evaluated AP type, placement, user load, and environmental interference. Findings show wall-mounted APs and modern 802.11ax technology outperform ceiling-mounted and older APs, delivering stronger and more reliable RSSI values. Recommendations include upgrading to advanced APs, adopting wall-mounted setups, and replacing high-EMI fluorescent lights with LEDs to achieve the target RSSI of -67 dBm. This study offers insights for optimizing Wi-Fi in residential and institutional settings, with future research suggested for 5 GHz and larger environments.

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