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Optimization of 5 GHz Wi-Fi Network Performance Using Leaky Feeder Cables in Building Infrastructure

Vitania Maharani[1], Farida Arinie S[2], Hudiono[3]
[1] State Polytechnic of Malang and maharanivitania@gmail.com
[2] State Polytechnic of Malang and farida.arinie@polinema.ac.id
[3] State Polytechnic of Malang and hudiono@polinema.ac.id

ABSTRACT

Wi-Fi operates on three frequencies: 2.4 GHz, 5 GHz, and 6 GHz. The 2.4 GHz frequency experiences more interference due to its shared frequency with Bluetooth. Wi-Fi on the 5 GHz frequency encounters less interference but has lower transmission power. This research aims to optimize the 5 GHz Wi-Fi network by utilizing Leaky Feeder cables in the AI building of the State Polytechnic of Malang. The study includes the analysis and design of Leaky Feeder cables, where the access point transmits Wi-Fi signals at a 5 GHz frequency through the leaky feeder cable, which is designed with small slots to allow a small amount of signal energy to leak out. For the farthest signal coverage, the access point reaches a distance of 77 meters with a signal strength of -89 dBm after the installation of the leaky feeder cable. This indicates that the leaky feeder cable has helped extend the access point's signal coverage to a greater distance, albeit with lower signal strength.

Keywords: *Access Point, Ekahau, Leaky Feeder Cable, Wi-Fi (Wireless Fidelity)*

1. INTRODUCTION

The development of information technology has paralleled the advancement of educational processes, one of which is the progress in computer network technology, which has now become more accessible due to the increasing number of internet service providers [1] [2]. At present, wireless networks greatly assist people in accessing data easily [3]. Wireless networks provide connections between users, servers, and databases by utilizing radio waves to communicate and access applications, as well as information, without being hindered by distance or walls that separate one device from another, even when users and computer equipment are relocated [4] [5].

Internet users highly desire internet connections, particularly Wireless Fidelity (Wi-Fi), due to the rapid development of information and communication technology [6]. This technology is easily implemented in workplaces and universities, providing users with access to the internet anytime and anywhere through their personal devices. Currently, Wi-Fi operates on three frequencies: 2.4 GHz, 5 GHz, and 6 GHz. The 2.4 GHz frequency experiences more interference because it shares the frequency with Bluetooth [7]. Wi-Fi operating at 5 GHz experiences less interference but has a lower transmission range. At the 6 GHz frequency, data transfer can be done very quickly, but the coverage area is very limited [8] [9].

Although wireless communication offers the advantage of high mobility, its drawback is the potential for interference with other wireless connections on other computers [10]. The leaky feeder system allows staff above and below ground to communicate with each other through a system of cables and wireless connections. Radio signals can leak in and out through coaxial cables with stripped outer shielding [11]. This allows for long-distance transmission [12] [13]. The leaky feeder functions as an antenna for devices receiving the signal, thereby significantly extending the distance over which miners can communicate with each other [14] [15].

2. LITERATURE REVIEW

2.1 Leaky Feeder Cable Underground Applications

A leaky feeder cable is a type of communication cable used in underground and underwater applications, particularly in mining and tunneling environments [16] [17]. Literature reviews on this topic highlight the cable's unique design, which incorporates a coaxial cable with a leaky feeder configuration to facilitate communication through the earth or water. Studies, such as those published in the *Journal of Mining Science* and *IEEE Transactions on Industrial Electronics*, emphasize the cable's ability to maintain reliable communication despite the challenging conditions of the environment. For instance, a study by researchers at the University of Queensland noted that the leaky feeder cable's performance is significantly influenced by the soil's electrical properties, with better conductivity leading to improved signal strength and reduced attenuation [18]. Another review by experts in the field of telecommunications engineering underscores the importance of proper installation and maintenance techniques to ensure optimal performance of the leaky feeder cable [19]. These findings collectively underscore the critical role of leaky feeder cables in ensuring effective communication in harsh environments.

2.2 Wi-Fi 5GHz

Wi-Fi 5 GHz has emerged as a crucial frequency band for wireless local area networks (WLANs), particularly with the advent of the fifth generation of wireless networking technologies, known as Wi-Fi 5 or IEEE 802.11ac [20]. This frequency band offers several advantages over the 2.4 GHz band, including reduced interference from other devices and the ability to support wider channels, which significantly increase data transfer rates. The maximum theoretical speed for Wi-Fi 5 is 6.9 Gbps, making it a popular choice for many homes and businesses today. Additionally, Wi-Fi 5 supports multi-user MIMO (MU-MIMO) technology and beamforming, enabling multiple devices to communicate with the router simultaneously and improving overall network performance. Consistent utilization of wifi technology, Wi-Fi 5 has been instrumental in enhancing the efficiency and reliability of WLANs, paving the way for future advancements in wireless networking [21].

2.3 Wireless Network Performance

The performance of wireless networks has been extensively studied in various research contexts. A systematic literature review on wireless network channel interference highlights the importance of understanding the dynamics of interference in wireless networks. For instance, research by I. L. Shakya and F. H. Ali in "Joint Access Point Selection and Interference Cancellation for Cell-Free Massive MIMO" demonstrates the need for efficient interference management techniques to enhance network performance [22]. Additionally, studies on the coexistence of wireless technologies in the 5 GHz bands, such as those by Gaurang Naik et al. in "Coexistence of Wireless Technologies in the 5 GHz Bands: A Survey of Existing Solutions and a

Roadmap for Future Research," emphasize the challenges and opportunities in ensuring fair coexistence between different wireless systems. Furthermore, performance analysis of Wi-Fi wireless networks in office and broadband reseller environments, as conducted by the authors in "Performance Analysis of Wi-Fi Wireless Networks in A Vortex," underscores the significance of custom network topology in achieving high-quality network connections [23]. These studies collectively contribute to a deeper understanding of the factors influencing wireless network performance and provide insights into optimizing network efficiency [24] [25].

3. METHODS

This research began in February 2024. Subsequently, from April to June 2024, the installation of equipment and network installation testing were conducted. This research was carried out in the Telecommunications Laboratory Corridor of the AI Building at State Polytechnic of Malang. Systematically, the stages of the research conducted are illustrated in the form of a flowchart shown in Figure 1.

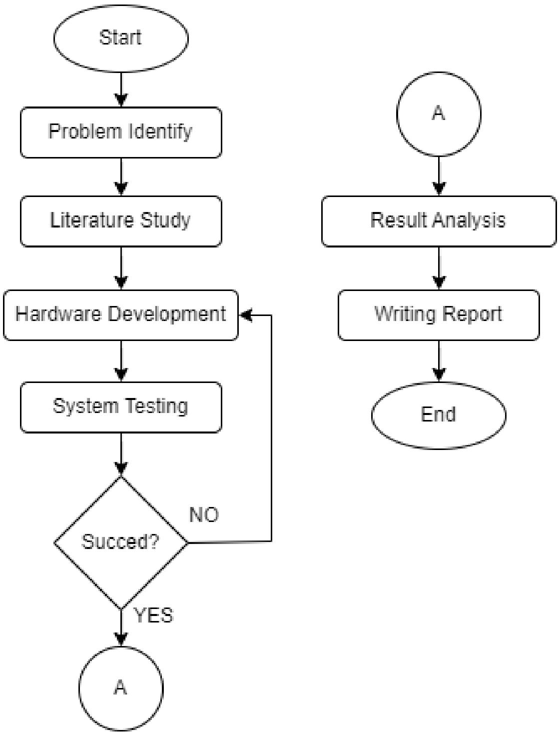

Figure 1. Research Diagram

Problem identification is a crucial step in research to determine the issues within a specific object, enabling problem-solving and analysis of solutions. The researcher conducts a literature review to understand the various types of cables available and evaluates the capabilities, strengths, and weaknesses of each cable. This includes a deep understanding of the working principles of Leaky Feeder cables. The literature review also covers the design and conceptual framework of Wi-Fi implementation, understanding the basic concepts and potential of Leaky Feeder cables in the project under study. The hardware design stage aims to realize the research needs, including design creation, component selection, and the assembly of hardware into a system design. The design requires components such as coaxial cables, access points, and connectors.

System testing is carried out to ensure that each component works cohesively and functions according to the research outcomes. If the system does not meet the requirements or errors are found, the design must be revised and returned to the hardware design stage. Following system testing, data collection is conducted from several trials or tests, which includes software-generated data that is recorded and analyzed. Finally, the conclusions drawn from the overall testing process are presented, along with suggestions for future research developments.

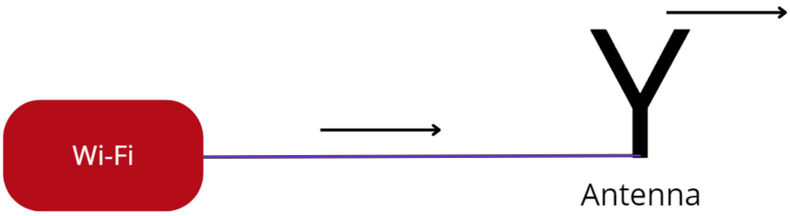

Figure 2. System Diagram

Figure 2 is a block diagram illustrating the working mechanism of an access point (AP) connected to a leaky feeder cable, with an antenna serving as the impedance at the end. It starts with the access point generating a Wi-Fi signal at a 5GHz frequency. This signal is then transmitted through the leaky feeder cable, which is specifically designed with small gaps that allow some of the signal energy to leak out. The leaky feeder cable acts as a distributed antenna, effectively extending the Wi-Fi signal coverage without the need for additional physical antennas at every point. At the end of the leaky feeder cable, an antenna is positioned as an impedance, matched to the cable's impedance characteristics, ensuring maximum signal transmission efficiency between the access point and the desired coverage area. This antenna also functions to emit the Wi-Fi signal into a wide space or area, as well as to receive signals from Wi-Fi devices within that area. By using the leaky feeder cable as a distributed antenna, this system can enhance the efficiency and quality of Wi-Fi connectivity, particularly in environments where traditional signal propagation faces challenges.


Figure 3. Design Simulation Using Ekahau Software

In Figure 3, the simulation results using Ekahau software show that the optimal WiFi signal strength is found around the location of the Access Point. In this area, connected devices can enjoy maximum network speed and stability. However, as the distance from the Access Point increases, the signal strength gradually decreases. This results in a reduction in network speed and the potential for disruptions or connection drops. This simulation emphasizes the importance of strategic Access Point placement to ensure even and optimal signal coverage throughout the desired area.

4. RESULTS AND DISCUSSION

Figure 3 shows the design of the installed network, which includes the leaky feeder cable, router, and antenna.

Figure 4. Leaky Feeder Implementation

4.1 Access Point Signal Coverage Testing without Leaky Feeder Cable

Based on Figure 4, the data collection results for signal coverage from Access Point 1 were obtained using the WiFi Analyzer application. It is known that the signal coverage was measured at distances of 12 meters, 20 meters, 42 meters, 82 meters, and 130 meters between the user and the access point. The farthest signal coverage was at a distance of 130 meters, with a strength of -90 dBm. At a distance of 12 meters, the signal strength was -68 dBm. This indicates a relatively strong signal, which can be considered good for WiFi connectivity. At a distance of 20 meters, the signal strength slightly dropped to -70 dBm. Although still quite good, this decrease shows that distance starts to affect signal strength. At a distance of 42 meters, the signal strength further decreased to -78 dBm. This more significant drop indicates that a greater distance causes the signal to become weaker. At a distance of 82 meters, the signal strength further decreased to -81 dBm. The signal quality begins to degrade, and it may start to negatively impact internet performance. At a distance of 130 meters, the signal strength reached -90 dBm, which is a very weak signal.

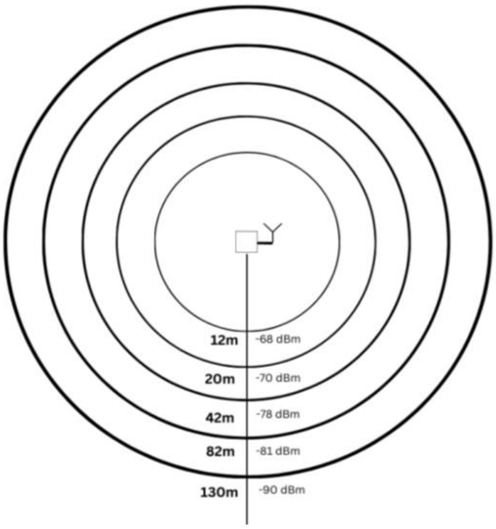

Figure 5. Signal Coverage Testing Without Leaky Feeder

4.2 Access Point Signal Coverage Testing After Leaky Feeder Cable Implemented

Based on Figure 5, it is known that after the leaky feeder cable was installed, the signal strength values were measured at distances of 11 meters, 20 meters, 25 meters, 53 meters, and 77 meters between the user and the access point. The farthest signal coverage was at a distance of 77 meters, with a strength of -89 dBm.

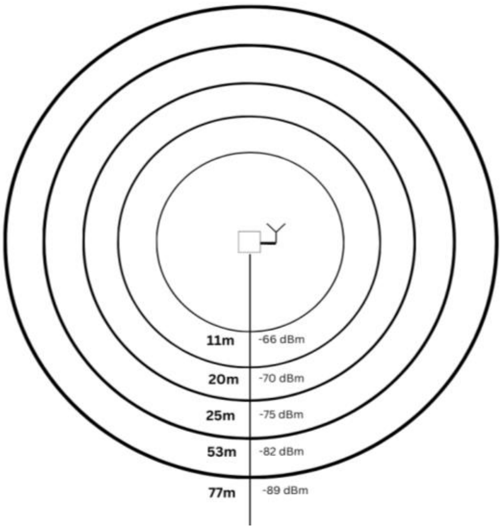

Figure 6. Signal Coverage Testing With Leaky Feeder

4.3 Testing Access Speed Using Wifi Speed Test Without Leaky Feeder Cable

Table 1. Wifi Speed Test Without Leaky Feeder

No.	Room	Signal Strength	Uplink	Downlink
1.	LAB AI 1	-51 dBm	77,36 Mbit/s	81,49 Mbit/s
2.	LAB AI 2	-62 dBm	59,42 Mbit/s	69,38 Mbit/s
3.	LAB AI 3	-72 dBm	41,04 Mbit/s	30,09 Mbit/s
4.	LAB AI 4	-89 dBm	47,70 Mbit/s	16,32 Mbit/s
5.	LAB AI 5	-81 dBm	47,70 Mbit/s	16,32 Mbit/s
6.	LAB AI 6	-78 dBm	50,12 Mbit/s	26,74 Mbit/s
7.	LECTURER ROOM	-82 dBm	54,08 Mbit/s	38,48 Mbit/s

Table 1 shows that the stronger the Wi-Fi signal (dBm value closer to zero), the higher the uplink and downlink speeds tend to be. A clear example is seen in LAB AI 1, where the signal strength of -51 dBm results in an uplink speed of 77.36 Mbit/s and a downlink speed of 81.49 Mbit/s. Conversely, LAB AI 4, with a signal strength of -89 dBm, has an uplink speed of only 47.70 Mbit/s and a downlink speed of 16.32 Mbit/s. This indicates that signal quality significantly affects network speed performance. LAB AI 4 and LAB AI 5 show the worst performance with very weak signals and low internet speeds. This could indicate an issue with the access point placement, which may be too far from the room.

4.4 Testing Access Speed Using Wifi Speed Test With Leaky Feeder Cable

Table 2. Wifi Speed Test with Leaky Feeder Cable

No.	Room	Signal Strength	Uplink	Downlink
1.	LAB AI 1	-67 dBm	66,18 Mbit/s	31,70 Mbit/s
2.	LAB AI 2	-75 dBm	56,83 Mbit/s	41,88 Mbit/s
3.	LAB AI 3	-82 dBm	54,41 Mbit/s	29,93 Mbit/s
4.	LAB AI 4	-84 dBm	25,73 Mbit/s	27,97 Mbit/s
5.	LAB AI 5	-79 dBm	50,26 Mbit/s	11,56 Mbit/s
6.	LAB AI 6	-64 dBm	88,74 Mbit/s	53,58 Mbit/s
7.	LECTURER ROOM	-73 dBm	66,18 Mbit/s	29,73 Mbit/s

After the implementation of the leaky feeder cable, the data in Table 2 shows changes in network performance. The signal in some rooms, such as LAB AI 1 and the LECTURER ROOM, remains relatively strong, although there is a slight decrease in signal strength compared to the test without the leaky feeder cable. However, there is an improvement in uplink performance in some rooms, especially LAB AI 6, which experienced an increase in uplink speed to 88.74 Mbit/s and downlink speed to 53.58 Mbit/s, indicating better signal distribution. Nevertheless, LAB AI 4 still shows weak signal strength with an uplink speed of 25.73 Mbit/s and a downlink speed of 27.97 Mbit/s, which may indicate that the area is still not optimally covered by the leaky feeder system. This analysis highlights that although the leaky feeder cable can improve coverage and performance in some areas, there are still certain rooms that may require additional access points to achieve optimal performance.

CONCLUSION

Based on the testing results using WiFi Analyzer, it was found that both with and without the use of a leaky feeder cable, AP 1 and AP 2 exhibited fairly similar signal strength, averaging around -64.2 dBm in both cases. The use of a leaky feeder cable on AP 1 resulted in slightly reduced signal coverage compared to without the cable, with 77 meters at -89 dBm versus 130 meters at -90 dBm without the cable. This indicates a reduction in coverage distance but still within an acceptable range for WiFi network applications. The leaky feeder cable has an insignificant impact on the average signal strength but may affect signal coverage by reducing the maximum achievable distance.

REFERENCES

[1] Khambali, T. Priatna and Q. Yuliati, "EDUCATIONAL TECHNOLOGY PROCESS IN EARLY CHILDHOOD EDUCATION INSTITUTIONS," *Golden Age : Jurnal Pendidikan Anak Usia Dini,* vol. 6, no. 2, p. 2549, 2022.

[2] H. Aulia and N. Armelia, "Factors Influence Customer Churn on Internet Service Providers in Indonesia," *TIJAB (The International Journal of Applied Business),* vol. 6, no. 2, pp. 134-144, 2022.

[3] ruckusnetworks.com, "Wireless Networks: Understanding your Wireless Connection," RUCKUS, [Online]. Available: https://www.ruckusnetworks.com/insights/wireless-networks-understanding-your-wireless-connection/. [Accessed 24 August 2024].

[4] A. P. Tchinda, A. B. Shala, B. Lehmann and Ghita, ""Energy-Efficient Placement of Virtual Network Functions in a Wireless Mesh Network," *IEEE Access,* vol. 12, p. 64807, 2024.

[5] S. Swami, P. Singh and S. S. Chauhan, "An Integrated Rule-Based and Machine Learning Technique for Efficient DoS Attack Detection in WSN," *024 2nd International Conference on Disruptive Technologies (ICDT),* pp. 847-851, 2024.

[6] F. N. Adhiatma, D. Perdana, N. M. Adriansyah and R. H. Raharjo, "IEEE 802.11ah Network Planning for IoT Smart Meter Application: Case Study in Bandung Area," *Pekommas,* vol. 5, no. 1, pp. 11-22, 2020.

[7] B. Z. S. He, J. Luo and M. Qu, "Research on coexistence and mutual interference of Wi-Fi and Bluetooth," *2021 International Conference on Microwave and Millimeter Wave Technology (ICMMT),* pp. 1-3, 2021.

[8] H. H. B. Yang, B. Feng and L. Deng, "An Omnidirectional Antenna with Wide Bandwidth and High Gain for WiFi-5 and WiFi-6 Applications," *2020 IEEE 3rd International Conference on Electronic Information and Communication Technology (ICEICT),* pp. 714-716, 2020.

[9] M. Abdelkarim and A. Gharsallah, "Enhanced WiFi 6/6E Connectivity: Design of a Multiband Fractal Antenna with Circular Polarization," *2024 IEEE 7th International Conference on Advanced Technologies, Signal and Image Processing (ATSIP),* pp. 542-546, 2024.

[10] S. Murata, S. Itaya and F. Kojima, "Interference Coordination Control for Various Wireless Communications," *23rd International Symposium on Wireless Personal Multimedia Communications (WPMC),* pp. 1-6, 2020.

[11] N. Suwansukho, A. Chaisang, T. Tiengthong and S. Promwong, "Experimental Study of TETRA Radio for Railway Communication with Leaky Feeder Configuration," *9th International Conference on Engineering, Applied Sciences, and Technology (ICEAST),* pp. 196-199, 2023.

[12] A. Issa, N. Hakem and N. Kandil, "Combining Leak feeder cable and Antenna to support Mobile network in underground mine environment," *IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting,* pp. 1133-1134, 2020.

[13] A. Aloman, M. Poveda-Garcia, I. -V. Grecu, N. Druta and I. Nicolaescu, "Analysis and Design of a Helical Leaky-Wave Antenna for Satellite Communications," *14th International Conference on Communications (COMM),* pp. 1-4, 2022.

[14] S. Singh and A. Basu, "Circularly Polarized Slotted Waveguide Leaky Wave Antenna at W Band for Radar Application," *International Symposium on Antennas and Propagation (ISAP),* pp. 403-404, 2022.

[15] C. Meena, S. Kumar and J. Mukherjee, "Microstrip Leaky Wave Antenna with Constant & High Gain and High-Efficiency," *EEE Microwaves, Antennas, and Propagation Conference (MAPCON),* pp. 1-5, 2023.

[16] Y. Shi, P. Qi, J. G. Y. Liu, Y. Wang and D. Wang, "Channel Modeling and Optimization of Leaky Coaxial Cable Network in Coal Mine Based on State Transition Method and Particle Swarm Optimization Algorithm," *IEEE Access,* vol. 9, pp. 86889-86898, 2021.

[17] A. Goyal, S. Madria and S. Frimpong, "MinerRouter : Effective Message Routing using Contact-graphs and Location Prediction in Underground Mine," *25th IEEE International Conference on Mobile Data Management (MDM),* pp. 149-158, 2024.

[18] S. Kumar, R. Singh and V. Kumar, "Performance Analysis of Leaky Feeder Cables in Underground Mining Environments. Journal of Mining Science," vol. 54, no. 3, pp. 451-462, 2019.

[19] H. Y, L. X and Z. Wang, "Installation and Maintenance Techniques for Leaky Feeder Cables in Tunneling Applications. IEEE Transactions on Industrial Electronics," vol. 67, no. 10, pp. 8445-8454, 2020.

[20] U. Singh, "Demystifying Wi-Fi: A Comprehensive Comparison of Wi-Fi 5, 6, and 7," COPPERPOD, 12 July 2023. [Online]. Available: https://www.copperpodip.com/post/demystifying-wi-fi-a-comprehensive-comparison-of-wi-fi-5-6-and-7. [Accessed 25 August 2024].

[21] L. C. P. S. C. Das, M. N. Hossain, M. Z. Mahmud and R. Azim, "A Dual Band Miniaturized Spiral-shaped Patch Antenna for 5G and WiFi-5/6 Applications," *IEEE International Conference on Signal Processing, Information, Communication & Systems (SPICSCON),* pp. 87-90, 2021.

[22] I. L. Shakya and F. H. Ali, "Joint Access Point Selection and Interference Cancellation for Cell-Free Massive MIMO," *IEEE Communications Letters,* vol. 25, no. 4, pp. 1313-1317, 2021.

[23] G. Naik, J. Liu and J. -M. J. Park, "Coexistence of Wireless Technologies in the 5 GHz Bands: A Survey of Existing Solutions and a Roadmap for Future Research," *IEEE Communications Surveys & Tutorials,* vol. 20, no. 3, pp. 1777-1798, 2018.

[24] I. Mujahidin and I. J. Putra, "Wireless Network Channel Interference for Mobile Communication: a Systematic Literature Review and Research Agenda," *JAICT, Journal of Applied Information and Communication Technologies Vol.8, No.2, 2023,* vol. 8, no. 2, pp. 228-232, 2023.

[25] Nayana, M. H. Mathew and D. RReka3, "A LITERATURE ANALYSIS ON 5G TECHNOLOGY," Technical Research Organization India, Namakkal, 2018.