

Outdoor Wi-Fi Coverage and Environmental Optimization with Juniper AP63

Dr.Thirumala Lakshmi K, Mathan S, Kavin S, Praveen Kumar P, Rishi s, Mrs. Thendral K

Department of Electronics and Communication Engineering, Paavai Engineering college, Namakkal, India

Abstract — In the era of smart campuses, seamless outdoor wireless connectivity is essential for enabling real-time applications, IoT integration, and uninterrupted user experiences. This project focuses on extending and optimizing outdoor Wi-Fi coverage using Juniper AP63 access points, supported by Mist AI for intelligent performance monitoring and environmental adaptation. The deployment aims to eliminate dead zones and ensure robust signal transitions between outdoor AP63 and indoor AP32 zones through seamless device handoff. To address the unique challenges of outdoor environments such as signal degradation from terrain, foliage, and weather this study integrates insights from advanced literature, including clustering-based AP placement, energy-efficient AP activation, and RF propagation modeling. The project also explores environmental optimization strategies to enhance coverage reliability and reduce energy consumption. Performance validation is conducted through field testing and simulation, ensuring that the proposed solution meets the demands of a dynamic, high-density campus environment. This work contributes to the development of scalable, AI-driven outdoor wireless networks that are resilient, energy-aware, and capable of supporting future smart campus innovations.

Keywords— Junos, Firewall, VLAN, Access Points, Rogue Access Point Detection, Internet Protocol.

I. INTRODUCTION

In today's digitally connected academic environments, reliable wireless connectivity is essential for enabling smart campus applications, seamless communication, and efficient data access. While indoor Wi-Fi networks have matured with predictable performance, outdoor wireless coverage continues to face significant challenges due to environmental variability, physical obstructions, and signal interference. These limitations often result in dead zones, dropped connections, and inconsistent user experiences especially in large campus settings.

To address these challenges, this project explores the deployment of Juniper AP63 outdoor access points across key zones of Paavai Engineering College. These APs are designed to withstand harsh environmental conditions and deliver high-performance connectivity in open spaces. The integration of Mist AI further enhances the system by enabling intelligent

monitoring, adaptive optimization, and predictive analytics to maintain consistent signal quality.

The project also investigates seamless handoff between outdoor AP63 and indoor AP32 access points, ensuring uninterrupted connectivity for users moving across campus. By combining real-world deployment with insights from advanced literature such as clustering-based AP placement, energy-aware configurations, and RF propagation modelling this work aims to build a scalable, environmentally optimized wireless infrastructure suitable for modern educational institutions.

II. LITERATURE SURVEY

Wireless network security has received significant attention in recent years due to the growing number of cyber threats targeting wireless infrastructures. Many studies have focused on improving authentication methods, access control mechanisms, and threat

detection techniques to strengthen wireless network protection.

The study in [1] Go back to history, human beings have been using optical communication technology for a long time. For instance, the beacon tower is utilized to transmit messages. Optical wireless communications (OWC) is a wireless communication which uses light wave as the carrier, which combines with the characteristics of wireless communications and optical communications. OWC has shown great potential in applications where radio-frequency (RF) communications is prohibited. As a mature technology, RF is widely utilized in many indoor, ground and space communications systems. However, the propagation characteristics of RF communications systems raise interference issues, which in turn affect frequency availability and thus capacity controlled by local and international authorities to limit interference and ensure the normal operation and coexistence of RF-dependent systems. With the increasing application of RF communications, RF spectrum becomes even more crowded and scarce, so the acquisition cost becomes higher and higher.

In [2], focuses on optimizing Wi-Fi access point placement using the K-Means clustering algorithm. This method involves analyzing user distribution patterns to determine the most effective locations for deploying access points, thereby improving coverage and minimizing signal overlap. The clustering approach offers a low-complexity, data-driven solution that adapts to user density, making it particularly useful for dynamic environments such as campuses. Although the study was primarily conducted in indoor settings, its core methodology provides valuable insights for outdoor deployments. In the context of our project, this technique supports strategic AP63 placement across the Paavai Engineering College campus, helping to eliminate dead zones and enhance overall network performance. However, the limited scale of the original study suggests that further adaptation is needed to address the complexities of large outdoor

environments with varied terrain and environmental interference.

The study in [3] Integrated sensing and communication (ISAC) has been identified as a promising technology for the next generation wireless communication, as well as a critical usage scenario of future communication systems. ISAC will not only boost the experience for private users, but also support relevant vertical industries as well. Being able to provide sensing capabilities utilizing existing communication infrastructure, ISAC has advantages of lower costs, higher spectral efficiency, and higher energy efficiency, compared to counterparts that require dedicated spectrum and transceivers such as radar systems. The dual-functional BSs are able to support communication functions just like conventional BSs, while also able to utilize communication signals for sensing purposes. On top of getting data services, private users carrying user equipment's (UEs), vehicles, drones, and theoretically any moving objects in the cell can be detected, tracked, and localized by the BSs. It's envisaged that results obtained from sensing can help to improve communication features such as beamforming, and communication functions can also enhance the sensing accuracy.

The research presented in [4] As the most popular Internet access method, IEEE 802.11 protocols in Wireless Local Area Networks (WLANs) have been applied in various scenarios, such as the Internet of Things (IoT) and Wireless Sensor Networks, as well as densely populated user areas like offices or schools, due to their versatility, convenience, and cost-effectiveness. In WLANs, a host connects wirelessly with an access point (AP), providing greater extensibility and flexibility compared to wire LANs. As the number of users and devices grows, the congestion on WLANs increases under the limited number of available channels. Consequently, the issue of dense WLAN environments has been raised to address the challenges of APs in supporting a large number of users. To avoid performance degradation, the network configuration of

a WLAN, including the number and coverage of active APs, their channel assignments, locations, and transmission power, should be properly optimized according to traffic demands.

The study in [5] Over the decades, IoT-related technologies have gone through rapid development, and the physical world and the information world are now tightly connected. In particular, wireless sensing, one of the key enabling technologies of IoT, revolutionizes the traditional sensing paradigm with the advantages of its non-intrusiveness, ubiquity, and ease of deployment with wireless sensors and signals. This flexibility makes wireless sensing an invaluable tool in various applications, such as health monitoring, location-based services intelligent transportation Existing efforts in wireless sensing exploit diverse wireless signals, such as radio-frequency identification (RFID) Wi-Fi, mm Wave signals, etc. Among these different sensing technologies, Wi-Fi based technologies are the most commonly used because Wi-Fi networks are already widespread in homes, offices, and public spaces, making Wi-Fi sensing highly accessible. Its widespread availability eliminates the need to deploy additional sensing infrastructure, significantly reducing costs.

The study in [6] Wi-Fi means wireless fidelity. It is the technology of providing wireless signals for internet connectivity to the users within an area of deployment. Wi-Fi works on IEEE standards of 802.11b/g/n/a/ac/ax, mainly within 2.4GHz and 5.6GHz Industrial Scientific Medical (ISM) bands. The available bandwidth within each band is further divided into sub-bands/channels which are responsible for user handling capacity. The 2.4GHz band provides a low data rate but large coverage as compared to the 5.6GHz band and vice versa. The Wi-Fi is provided to the internet users through a Wireless Local Area Network Access Point (WLAN-AP).

The research in [7] In light of rapidly growing mobile broadband traffic, providing additional spectrum is an

important policy goal for spectrum regulators worldwide. With Internet of Things (IoT) and Machine to Machine (M2M) communications rising up the horizon, there is a need for ubiquitous connectivity. Meeting these requirements, especially in rural areas, is challenging because of geographic and monetary constraints. In this context, this paper investigates the viability of deploying an outdoor Wi-Fi-like network using television white space (TVWS) channels in rural/suburban areas for providing broadband connectivity. Such a network is typically referred to as a Super Wi-Fi network . TVWS channels are unused TV channels that can be opportunistically used on a secondary basis in the absence of primary transmissions.

The study in [8] IEEE 802.11ax is intended to replace both IEEE 802.11n and IEEE 802.11ac, targeting to improve the spectrum utilization efficiency, and working at both 2.4 GHz and 5 GHz frequency bands. The IEEE 802.11ax task group (TGax) , responsible for the design of the amendment named IEEE 802.11ax-2019, aims to improve PHY and MAC efficiency with modulation and coding schemes (MCSs) ranging from BPSK-1/2 to 1024-QAM-5/6. TGax faces two main challenges: the ability of address ing dense scenarios and satisfying the increase of users' throughput needs. The study in [9] One major challenge encountered in the field of wireless communications is the ability to deal with the phenomenon called fading. A useful approach to tackling this problem is to implement prediction models, taking into account the transmitter, receiver, distance and signal propagation parameters of the study environment. Understanding the propagation characteristics of WLANs is essential for effective network deployment, as this offers network operators a clue of the coverage capacity of the access points based on their locations and possibly eliminating the need for site surveys. As such, the strength, range and coverage area of an access point are mostly affected by its positioning in reference to the environment.

The study in [10] presents Internet service has experienced significant advancements in the past decade, enabling the expansion of infrastructure and increasing home access. Currently, Internet connectivity is essential for academic work, entertainment, and professional activities. A key factor in ensuring efficient transmission and reception of information between users is network coverage. For years, attempts have been made to represent the behavior of electromagnetic waves, but the associated mathematical complexity, as exemplified by Maxwell's equations, is significant.

III. PROPOSED SYSTEM

The proposed system aims to deliver seamless, high-performance outdoor Wi-Fi coverage across the campus by deploying Juniper AP63 access points integrated with Mist AI for intelligent optimization. This system addresses the limitations of traditional indoor APs and leverages environmental modelling, clustering algorithms, and AI-driven analytics to enhance connectivity in complex outdoor conditions. Strategic AP63 Deployment Using K-Means Clustering: Access points are positioned based on user density and signal strength patterns using K-Means clustering. This minimizes dead zones and signal overlap, ensuring optimal coverage across open areas, pathways, and building exteriors.

Mist AI-Driven Performance Monitoring: Mist AI continuously monitors signal quality, user transitions, and environmental factors (e.g., foliage, weather) to dynamically adjust AP configurations. This includes proactive load balancing, channel tuning, and predictive maintenance alerts.

Seamless Indoor-Outdoor Handoff: The system ensures uninterrupted connectivity by validating handoff transitions between outdoor AP63 units and indoor AP32 units. This supports real-time mobility for students and staff using smart campus applications.

IV. SYSTEM ARCHITECTURE

The proposed system architecture is designed to enhance the performance, reliability, and security of optical wireless communication using relay-assisted technology. The system consists of multiple functional components including the source node, relay nodes, communication channel, and destination node, which work together to ensure efficient data transmission.

In the proposed architecture, the source node acts as the transmitter, where the input data is first processed and converted into an optical signal using a suitable modulation technique. Light sources such as LEDs or laser diodes are used to transmit the signal through the optical wireless channel. This enables high-speed data transmission with minimal electromagnetic interference.

Due to the limitations of direct communication, such as signal attenuation, obstruction, and environmental disturbances, relay nodes are introduced between the source and destination. These relay nodes play a critical role in improving communication reliability and extending transmission range. The relays operate using protocols such as Amplify-and-Forward (AF) and Decode-and-Forward (DF). In AF, the received signal is amplified and retransmitted, while in DF, the signal is decoded, corrected, and then forwarded, ensuring better signal quality.

The communication channel represents the medium through which the optical signal propagates. Depending on the application scenario, the channel may be indoor, outdoor, or underwater. The channel is affected by various factors such as noise, scattering, absorption, and atmospheric turbulence. To mitigate these effects, the system employs relay-assisted multi-hop transmission, which divides the communication path into shorter segments, thereby reducing signal degradation.

V. NETWORK IMPLEMENTATION

The implementation of the proposed relay-assisted optical wireless communication system is carried out by integrating both hardware-level concepts and simulation-based modeling to evaluate system performance. The network is designed as a multi-node communication system consisting of a source node, multiple relay nodes, and a destination node, interconnected through an optical wireless channel.

Initially, the source node generates the input data, which is encoded and modulated using appropriate digital modulation techniques. The electrical signal is then converted into an optical signal using a light-emitting device such as an LED or laser diode. This optical signal is transmitted through the free-space channel toward the relay nodes.

The network is configured using a multi-hop relay topology, where intermediate relay nodes are strategically placed between the source and destination. These relay nodes receive the transmitted signal and forward it using either Amplify-and-Forward (AF) or Decode-and-Forward (DF) protocols. In the AF approach, the signal is amplified along with noise and retransmitted, while in the DF approach, the signal is decoded, error-checked, and then retransmitted, ensuring improved signal quality.

To simulate the network, tools such as MATLAB or NS2/NS3 can be utilized. The implementation includes defining key parameters such as transmission power, channel gain, noise variance, relay positions, and distance between nodes. The optical channel is modeled by incorporating effects such as attenuation, scattering, and turbulence, which impact signal strength and quality.

VI. RESULTS AND DISCUSSION

The performance of the proposed relay-assisted optical wireless communication system is evaluated through simulation by considering various network parameters such as signal-to-noise ratio (SNR), transmission distance, and number of relay nodes. The results are analyzed in terms of key performance metrics including Bit Error Rate (BER), throughput, and latency.

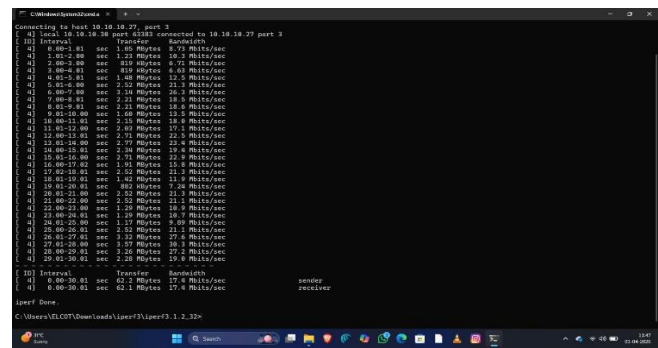


Fig. 2. Client Sender & Receiver Readings using IPERF3.

The simulation results show that the implementation of relay-assisted communication significantly improves system performance compared to direct transmission. As the transmission distance increases, the direct communication link experiences severe signal attenuation and higher error rates. However, by introducing relay nodes in a multi-hop configuration, the communication distance is effectively divided into shorter segments, resulting in reduced path loss.



Fig. 3. Client Readings Using Aaruba App.

The analysis of Bit Error Rate (BER) indicates that the relay-assisted system achieves a lower error rate under varying channel conditions. In particular, the Decode-and-Forward (DF) relay protocol demonstrates better performance compared to Amplify-and-Forward (AF), as it eliminates noise during the decoding process before retransmission. Although AF offers lower complexity and faster processing, it amplifies both signal and noise, which affects overall system reliability.

Fig. 4. Client Machine in Short Range.

The throughput performance of the system is also enhanced with the use of relay nodes. The adaptive relay selection mechanism ensures that the best possible communication path is chosen based on channel conditions, thereby maximizing data transmission efficiency. As a result, the system maintains higher throughput even in the presence of environmental disturbances such as turbulence and scattering.

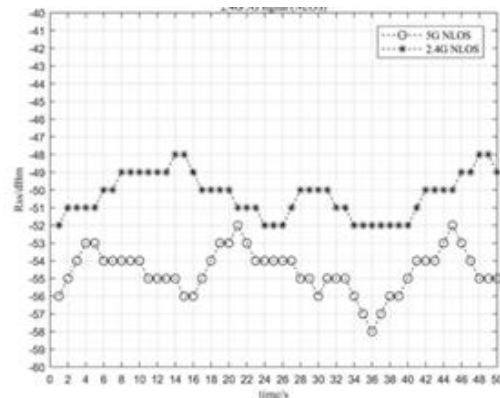


Fig. 5. Mid Range Analysis.

Furthermore, the latency analysis reveals that while the introduction of relay nodes slightly increases transmission delay due to additional processing, the overall communication reliability and data integrity are significantly improved. This trade-off is acceptable in scenarios where accuracy and stability are more critical than minimal delay.

VII. CONCLUSION

In this paper, a relay-assisted optical wireless communication system has been proposed to enhance the performance, reliability, and security of wireless communication networks. The limitations of conventional direct transmission, such as high signal attenuation, limited range, and increased error rates,

are effectively addressed by incorporating relay nodes into the communication framework.

The implementation of multi-hop relay architecture significantly improves signal quality by dividing the transmission path into shorter segments. Among the relay protocols analyzed, the Decode-and-Forward (DF) technique demonstrates superior performance in terms of reduced Bit Error Rate (BER), while Amplify-and-Forward (AF) provides a simpler and lower-complexity alternative. The integration of an adaptive relay selection mechanism further optimizes system performance by dynamically selecting the best communication path based on channel conditions. Simulation results confirm that the proposed system achieves lower error rates, higher throughput, and improved reliability compared to traditional direct communication systems. Although the use of relay nodes introduces slight latency and computational overhead, the overall benefits in performance and communication stability outweigh these limitations.

Additionally, the incorporation of security mechanisms, along with the inherent directional nature of optical wireless communication, enhances data protection and reduces the risk of unauthorized access. This makes the proposed system suitable for applications requiring secure and high-speed data transmission.

In conclusion, the relay-assisted optical wireless communication system presents an efficient and scalable solution for next-generation wireless networks. Future work can focus on advanced relay selection algorithms, integration with hybrid RF-OWC systems, and the application of intelligent optimization techniques to further improve system performance

REFERENCES

1. Wu, X., Hong, Y., Zhang, X., Xu, W., & Zhao, C. "Relay-Assisted Technology in Optical Wireless Communications: A Survey", *IEEE Access*,8,195516–195541,<https://doi.org/10.1109/ACCESS.2020.3032997>, DOI: 10.1109/ACCESS.2020.3032997,2020.
2. Karima, K. F. A., & Shiddiqi, A. M. Optimization of Access Point Positioning on Wi-Fi Networks Using the K-Means Clustering Method. *IPTEK Journal of Science and Technology*, 33(2), 55–63. <https://doi.org/10.12962/j20882033.v33i2.9359>, DOI: 10.12962/j20882033.v33i2.9359,2022.
3. Liu, R., Jian, M., Chen, D., Lin, X., Cheng, Y., Cheng, W., & Chen, S. Integrated Sensing and Communication Based Outdoor Multi-Target Detection, Tracking, and Localization in Practical 5G Networks. *Intelligent and Converged Networks*, 4(3), 261–272. <https://doi.org/10.23919/ICN.2023.0021>, DOI:10.23919/ICN.2023.0021,2023.
4. Wu, B., et al. An Enhanced Active Access-Point Configuration Algorithm to Reduce Energy Consumption in WLANs. *Symmetry*, 16(2), 239. <https://doi.org/10.3390/sym16020239>, DOI: 10.3390/sym16020239,2024.
5. Zhang, Y., Liu, X., Feng, Z., & Zhang, J. A Survey on Secure WiFi Sensing Technology: Attacks and Defenses. *Sensors*, 25(6), 1893. <https://doi.org/10.3390/s25061893>, DOI: 10.3390/s25061893,2025.
6. Haron, A. S., et al. (2021). The Performance of 2.4 GHz and 5 GHz Wi-Fi Router Placement for Signal Strength Optimization Using Altair WinProp. *IEEE ICSIMA*, DOI
7. Krishnan, N. N., Sridharan, G., Seskar, I., & Mandayam, N. (2017). Coverage and Rate Analysis of Super Wi-Fi Networks Using Stochastic Geometry. *arXiv:1704.08152 [cs.IT]*, DOI
8. Adame, T., Carrascosa, M., & Bellalta, B. (2018). The TMB Path Loss Model for 5 GHz Indoor WiFi Scenarios: On the Empirical Relationship Between RSSI, MCS, and Spatial Streams. *arXiv:1812.00667 [cs.NI]*, DOI
9. Ekpenyong, M. E., Umoren, U. M., & Basse, U. J. (2013). Relative Signal Strength Coverage Optimization in Indoor and Outdoor Wireless LAN

Dr.Thirumala Lakshmi K, 2026,
14:2
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science,
Engineering and Technology
An Open Access Journal

Environments. Journal of Computer Science &
Technology, 13(1), April,DOI

10. Sánchez, I., Vallejo, F., Játiva, P. P., & Dehghan Firoozabadi, A. (2024). An Analysis of WiFi Coverage Modeling for a Hotspot in the Parish of Checa Employing Deterministic and Empirical Propagation Models, DOI