DEVELOPMENT OF A WI-FI 6 (802.11AX) WIRELESS LOCAL AREA NETWORK (WLAN) SYSTEM

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DECLARATION

We, **Vaishnavee BV, V Rajashree & Jeevika Karuppaswamy** of the **CS with Bioscience,** Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, hereby declare that the Capstone Project Work entitled "**DEVELOPMENT OF A WI-FI 6 (802.11AX) WIRELESS LOCAL AREA NETWORK (WLAN) SYSTEM"** is the result of our own bonafide efforts. To the best of our knowledge, the work presented herein is original, accurate, and has been carried out in accordance with principles of engineering ethics.

Place: Chennai

Date: 28.11.2025

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BONAFIDE CERTIFICATE

This is to certify that the Capstone Project entitled "**Development of a Wi-Fi 6 (802.11ax) Wireless Local Area Network (WLAN) System**" has been carried out by **Vaishnavee BV, V Rajashree, Jeevika Karuppaswamy** under the supervision of **Dr. Rajaram Pichamuthu & Dr.K.Senthil** and is submitted in partial fulfilment of the requirements for the current semester of the **B.Tech - CS with Bioscience** program at Saveetha Institute of Medical and Technical Sciences, Chennai.

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ABSTRACT

The rapid expansion of high-density digital environments, smart campuses, enterprise offices, and public spaces demands wireless networks capable of delivering higher throughput, lower latency, and improved spectral efficiency. This project focuses on the development of a Wi-Fi 6 (802.11ax) Wireless Local Area Network (WLAN) system engineered to address the limitations of previous wireless standards in high-traffic environments. The goal is to design, configure, optimize, and test a Wi-Fi 6 network capable of supporting modern data-intensive applications, ensuring reliability, scalability, and enhanced performance.The project examines the core technological advancements of Wi-Fi 6, including OFDMA, MU-MIMO, BSS Coloring, and Target Wake Time (TWT), and applies them in a practical deployment scenario. A comprehensive design plan was created, accompanied by simulation-based and real-device configuration. The outcomes demonstrate increased throughput, improved latency handling, and better channel efficiency compared to Wi-Fi 5 environments. The proposed system serves as a reference design for future WLAN deployments in academic and enterprise settings.

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Background Information

Wireless communication has evolved into the backbone of modern digital interaction, supporting countless applications across education, enterprise, entertainment, and personal use. The dramatic rise in cloud computing, video conferencing, digital learning platforms, and smart technologies has placed unprecedented pressure on traditional WLAN systems. Earlier standards such as 802.11n and 802.11ac were designed for far lighter bandwidth demands and fewer connected devices, making them increasingly inadequate in today's high-density environments. As user expectations continue to rise, performance degradation, interference, and congestion have become major challenges in many institutional networks. This technological gap made it necessary for the IEEE to develop a more efficient and resilient WLAN standard.

Wi-Fi 6 (802.11ax) represents a fundamental redesign of wireless networking principles, focusing not just on raw speed but on efficiency and multi-user capability. Its introduction of Orthogonal Frequency Division Multiple Access (OFDMA) divides channels into smaller subunits, enabling multiple devices to transmit data simultaneously without congesting the medium. Enhanced MU-MIMO capability allows access points to serve more users concurrently, reducing the queuing delays that previously slowed down networks in busy environments. These innovations help Wi-Fi 6 maintain steady performance even when large numbers of devices compete for bandwidth.

The rapid expansion of IoT ecosystems further highlights the relevance of Wi-Fi 6. Modern campuses and workplaces now incorporate smart sensors, automated systems, digital ID devices, and countless wireless endpoints that require constant connectivity. Many of these devices operate under strict power constraints, making energy efficiency essential for long-term operation. Wi-Fi 6 addresses this through Target Wake Time (TWT), which schedules when devices wake to transmit, greatly reducing unnecessary energy consumption and channel usage. This improves overall network efficiency and reliability, especially in large-scale deployments.

Ultimately, Wi-Fi 6 does not only provide faster throughput—it redefines network behaviour under load. In high-density environments such as classrooms, laboratories, offices, or event spaces, older Wi-Fi standards become congested and unresponsive. Wi-Fi 6 introduces mechanisms that allow access points to manage spectrum more intelligently, ensuring stability even when the network is saturated with users. The shift to Wi-Fi 6 is therefore not simply an upgrade but a strategic modernization, aligning wireless infrastructure with the realities of contemporary digital ecosystems.

1.2 Project Objectives

The main objective of this project is to design and deploy a fully functional Wi-Fi 6 WLAN system tailored to a high-density environment. This involves selecting appropriate equipment, determining optimal access point placement, configuring the network to meet IEEE 802.11ax standards, and ensuring that the final system demonstrates the technological advantages expected of next-generation wireless infrastructure. Through this implementation, the project aims to evaluate real-world performance improvements associated with Wi-Fi 6, including increased throughput, reduced latency, enhanced spectral efficiency, and better support for concurrent users.

A second objective is to investigate the engineering considerations required for successful Wi-Fi 6 deployment. This includes analyzing the physical environment, identifying potential interference sources, performing coverage assessments, and applying appropriate radio frequency optimization strategies. The project seeks to determine how environmental and structural variables influence network performance, thereby producing a deployment strategy that reflects professional WLAN planning standards. Understanding these factors contributes to the development of effective, scalable, and reliable wireless network designs.

In addition to performance optimization, the project aims to incorporate modern security features associated with Wi-Fi 6. By implementing WPA3 and advanced authentication techniques, the study evaluates how the updated security framework enhances data protection compared to previous standards. This objective ensures that the deployed network is not only high-performing but also aligned with contemporary cybersecurity requirements. Testing these features provides valuable insight into the practical benefits and ease of adoption for institutions planning similar upgrades.

Lastly, the project aims to produce comprehensive documentation detailing the entire design, implementation, and evaluation process. This includes recording challenges encountered, solutions applied, and recommendations for future improvements. Such documentation supports knowledge transfer for students, network administrators, and researchers who may engage in similar WLAN projects. By presenting clear, structured findings, the project contributes both academically and practically to the field of wireless networking.

1.3 Significance of the Study

This study is significant because it addresses a critical technological demand: the need for wireless networks capable of supporting large numbers of devices simultaneously without sacrificing performance. As digital platforms become deeply integrated into everyday activities, network reliability and speed are essential for productivity and user satisfaction. Wi-Fi 6 provides features specifically engineered for these modern environments, such as enhanced multi-user handling and improved spectral efficiency. Evaluating these capabilities in a practical setting offers valuable insight into how institutions can benefit from transitioning to next-generation WLAN infrastructure.

The study also holds practical value for educational environments, where high device density and bandwidth-heavy applications are the norm. Students and staff frequently rely on wireless networks for online classes, research activities, digital submissions, cloud storage, and communication platforms. Older networks often fail under such loads, leading to disruptions and reduced academic efficiency. By examining the performance of Wi-Fi 6 in similar settings, the project provides evidence-based recommendations that can guide future institutional upgrades and improve overall digital learning experiences.

From an academic perspective, the study enriches existing literature on emerging wireless technologies by connecting theoretical advancements with real-world outcomes. Many discussions on 802.11ax focus heavily on technical specifications without demonstrating how these features behave in practice. By documenting implementation steps, performance tests, and observed challenges, this project contributes meaningful, applied knowledge to the field of communication engineering. Such contributions are valuable for students, researchers, and professionals seeking to deepen their understanding of modern WLAN management.

Finally, the study is significant because it aligns with growing global trends toward smart environments, IoT integration, and automation. As institutions and industries move toward data-driven operational models, the need for reliable, scalable wireless connectivity becomes even more important. Wi-Fi 6 provides the technological foundation necessary to support these developments. By evaluating its implementation and performance, this project helps organizations prepare for future digital demands and more complex wireless ecosystems.

1.4 Scope of the Study

This project focuses on the design, deployment, and evaluation of a Wi-Fi 6 (802.11ax) WLAN system within a high-density usage environment. It includes site assessment, hardware selection, access point placement, network configuration, and performance testing. The study emphasizes practical implementation using commercially available Wi-Fi 6 equipment, ensuring that the results are realistic and replicable in typical institutional or enterprise settings. The evaluation focuses on network throughput, latency, coverage, stability, and multi-user performance.

The project also includes a comparative analysis between Wi-Fi 6 and Wi-Fi 5 (802.11ac) to highlight measurable improvements and demonstrate the superiority of 802.11ax in dense environments. However, the scope does not extend to older legacy standards or upcoming standards like Wi-Fi 7. Additionally, the study does not examine wide-area network performance or internet service provider factors. The focus remains on the wireless local area network itself, ensuring a targeted and controlled approach to analysis.

Environmental variables such as physical barriers, interference from neighbouring networks, and overlapping coverage zones are considered because they influence real-world WLAN performance. However, large-scale RF modelling, multi-building deployments, and advanced propagation simulations fall outside the project’s limitations due to time and resource constraints. Instead, the project concentrates on realistic deployment conditions typical of many organizational environments.

Although WPA3 and updated security measures are implemented as part of the Wi-Fi 6 configuration, the study does not explore deep cryptographic mechanisms or conduct penetration testing. Security evaluation is limited to assessing ease of deployment, compatibility, and general improvements over WPA2. By clearly defining these boundaries, the project remains focused, manageable, and aligned with the goals of practical WLAN implementation.

1.5 Methodology Overview

The methodology begins with a comprehensive literature review covering Wi-Fi 6 technologies, IEEE 802.11ax specifications, deployment strategies, and best practices in WLAN engineering. This review ensures a strong theoretical foundation for the design choices made throughout the project. Sources include academic research papers, industry white papers, vendor documentation, and technical standards published by IEEE. Understanding these materials is essential for developing a WLAN solution that aligns with modern performance expectations and professional design principles.

After establishing the theoretical basis, the project proceeds to the planning and site assessment phase. Here, the environment is analyzed to determine user density, potential interference sources, physical obstacles, and coverage requirements. These factors guide decisions about access point selection, placement, channel allocation, and radio frequency configuration. Planning tools and basic coverage estimation techniques are employed to design a topology that balances performance, efficiency, and reliability.

The implementation phase involves configuring Wi-Fi 6 access points, applying WPA3 security, adjusting RF settings, and optimizing channel usage. During this stage, initial performance checks and fine-tuning are conducted to address issues such as dead zones, overlapping channels, or interference. Adjustments to access point orientation, power levels, and channel width ensure that the deployed network operates efficiently.

Finally, the evaluation phase involves conducting throughput tests, latency measurements, multi-user simulations, and coverage assessments. These tests allow the project to quantify the performance of the Wi-Fi 6 deployment and compare it against Wi-Fi 5 benchmarks. The results are analyzed to determine the strengths, limitations, and practical implications of using Wi-Fi 6 in high-density environments. The methodology concludes with documentation and interpretation of findings.

CHAPTER 2
PROBLEM IDENTIFICATION AND ANALYSIS

2.1 Overview of Wireless Local Area Networks (WLANs)

Wireless Local Area Networks have become indispensable within modern technological ecosystems, enabling high-speed communication without the limitations of wired infrastructure. WLANs support mobility, flexible deployment, and scalability, making them foundational in schools, enterprises, and public environments. Early WLAN implementations relied on basic spread spectrum techniques and offered limited throughput, primarily serving simple communication tasks. As user expectations evolved, the need for more capable and efficient WLAN standards increased, especially as multimedia applications, cloud-based systems, and collaboration platforms became integral to daily operations. This evolution pushed wireless technologies forward in response to rising bandwidth and connectivity demands.

Over time, WLANs expanded from basic campus networks to complex systems supporting thousands of simultaneous connections. Industries increasingly depend on WLAN infrastructure to power diverse applications such as voice over IP, video streaming, intelligent building systems, and mobile access to enterprise resources. This shift required newer standards to address reliability, interference, and security challenges. The need for consistent performance across densely populated environments pushed network engineers to refine WLAN design, optimizing factors such as channel allocation, access point density, and radio frequency management. These refinements continue to shape how WLANs are planned and deployed.

The rapid growth of IoT has further transformed the WLAN landscape. A single environment may now host sensors, wearables, smart appliances, biomedical devices, and industrial automation systems — all relying on wireless networks. Traditional WLANs were not built to manage the sheer number and heterogeneity of these devices, which introduced new congestion and interference sources. These limitations prompted the development of advanced standards capable of supporting large-scale connectivity with minimal degradation. Wi-Fi 6, in particular, emerged as a response to these evolving requirements.

Despite the complexity of modern WLANs, their fundamental purpose remains consistent: to deliver reliable wireless connectivity that supports efficient information exchange. As operating environments grow more dynamic and demanding, WLAN standards continue to incorporate new technologies aimed at improving performance, enhancing security, and supporting future digital infrastructures. Understanding the evolution of WLANs provides essential context for evaluating the significance of Wi-Fi 6 and its role in modern connectivity.

2.2 Evolution of Wi-Fi Standards

The evolution of Wi-Fi standards reflects continuous advancements in wireless communication aimed at improving throughput, stability, and user experience. The 802.11 family began with modest data rates and limited functionality, serving primarily as a convenience feature for wireless access. Early standards such as 802.11b offered maximum data rates of 11 Mbps, which quickly became insufficient as online content expanded in complexity. The introduction of 802.11g and 802.11n addressed speed limitations by adopting more efficient modulation techniques and MIMO technology, enabling higher throughput and improved reliability.

The release of 802.11ac (Wi-Fi 5) marked a major leap forward, significantly increasing data rates through wider channel bandwidths, advanced beamforming, and improved MIMO configurations. These enhancements made Wi-Fi 5 suitable for high-definition streaming, real-time communication, and bandwidth-intensive enterprise applications. However, even with its improvements, Wi-Fi 5 struggled in dense environments where many users contended for shared spectrum. As device counts per user climbed and IoT ecosystems expanded, networks became congested, revealing limitations in the way older standards allocated bandwidth.

Wi-Fi 6 was developed to address these shortcomings by redefining how networks handle concurrent device transmissions. Instead of focusing solely on peak throughput, 802.11ax prioritizes overall network efficiency. OFDMA divides channels into smaller units to serve multiple clients simultaneously, reducing latency and improving performance under load. Enhanced MU-MIMO expands the number of devices that can be served concurrently, while BSS Coloring helps differentiate signals in overlapping environments. These innovations create a more resilient and efficient WLAN system suited for the realities of modern connectivity.

The evolution of Wi-Fi standards illustrates the shift from meeting basic connectivity needs to supporting complex digital ecosystems. Wi-Fi 6 represents the culmination of decades of technological refinement, addressing not only the demand for speed but the deeper requirement for reliable, scalable, and intelligent wireless networking. This makes it a foundational technology for emerging applications, including IoT automation, cloud-driven workflows, and digital learning environments.

2.3 The Wi-Fi 6 (802.11ax) Standard

Wi-Fi 6 introduces a suite of advanced features designed to overcome the congestion and inefficiencies of previous WLAN generations. One of its most impactful technologies, OFDMA, revolutionizes how bandwidth is allocated by dividing frequency channels into smaller resource units. This allows multiple devices to transmit at once, significantly reducing latency and improving network responsiveness. Unlike earlier standards where users took turns accessing the channel, Wi-Fi 6 enables simultaneous transmissions, making it ideal for environments with many active clients.

In addition to OFDMA, Wi-Fi 6 enhances MU-MIMO capabilities, supporting more simultaneous uplink and downlink connections. This improvement reduces contention between users and increases overall network throughput. The introduction of BSS Coloring helps differentiate overlapping signals, reducing co-channel interference — a common problem in densely populated networks. These features collectively enable Wi-Fi 6 to deliver stable performance even in challenging conditions where legacy systems experience severe degradation.

Another important feature of Wi-Fi 6 is Target Wake Time, which optimizes power consumption for devices with periodic communication needs. By scheduling when devices wake to exchange data, TWT significantly reduces energy usage and decreases channel congestion. This makes Wi-Fi 6 especially beneficial for IoT networks, where thousands of devices may periodically transmit small amounts of data. Such efficiency improvements position Wi-Fi 6 as a foundational technology for smart environments that rely heavily on automation and sensor communication.

Wi-Fi 6 also introduces stronger security capabilities with the integration of WPA3. This includes enhanced encryption methods, improved key exchange mechanisms, and protection against brute-force attacks. The combination of improved performance, efficiency, and security makes Wi-Fi 6 one of the most comprehensive wireless standards ever developed. Its features respond directly to the demands of modern connectivity, positioning it as a critical component of next-generation digital infrastructure.

2.4 Current Trends in WLAN Deployment

WLAN deployment strategies have evolved significantly as user demands and technological capabilities have expanded. Institutions now prioritize high-density design principles, ensuring networks remain stable under heavy usage. The growing reliance on cloud platforms means that networks must support seamless access to remote servers and high-bandwidth applications. Additionally, hybrid learning and remote work models require consistent wireless performance across a variety of environments, further driving the adoption of advanced WLAN standards like Wi-Fi 6.

One major trend is the integration of Wi-Fi with IoT ecosystems. Smart campuses, smart offices, and automated homes increasingly depend on interconnected devices that require constant wireless connectivity. WLAN deployments must therefore account for both high-bandwidth consumer devices and low-power IoT sensors. Wi-Fi 6 supports this mixed environment more effectively by offering improved efficiency, better scheduling, and enhanced power management features.

Another emerging trend is the use of network analytics and artificial intelligence in WLAN management. Modern WLAN systems often include cloud-based management platforms capable of monitoring device behaviour, identifying interference patterns, and optimizing performance automatically. These capabilities reduce the workload on IT administrators and improve the reliability of wireless networks. Wi-Fi 6 networks benefit greatly from these enhancements, as the increased complexity of modern WLANs requires intelligent automation to maintain optimal performance.

The adoption of Wi-Fi 6 in enterprise and educational environments continues to grow as organizations recognize its advantages in scalability and efficiency. With increasing device density, digital transformation, and integration of smart technologies, WLAN deployments are shifting from simple connectivity solutions to sophisticated digital infrastructures. Understanding these trends helps highlight why Wi-Fi 6 is rapidly becoming the new standard

CHAPTER 3
SOLUTION DESIGN AND IMPLEMENTATION

3.1 Research Design

The research design for this project follows a practical, engineering-focused approach grounded in systems implementation methodology. Rather than relying solely on theoretical modelling, the study emphasizes hands-on deployment and real-world performance evaluation of a Wi-Fi 6 WLAN system. This applied research strategy ensures that findings are directly relevant to real institutional settings where wireless networks must perform reliably under high-density usage. The design integrates both qualitative observations and quantitative measurements, allowing for a comprehensive assessment of system behaviour.

An experimental design framework was adopted to evaluate network performance under controlled and varying conditions. This framework involves configuring the WLAN system, modifying key parameters, and measuring the resulting changes in performance. By comparing Wi-Fi 6 behaviour with baseline benchmarks from Wi-Fi 5, the research design highlights measurable improvements brought by 802.11ax technology. Multiple test scenarios are created to simulate different user loads and environmental conditions, ensuring that the results accurately reflect typical real-world usage patterns.

The research design also incorporates a comparative analysis component, enabling the project to examine specific technological enhancements such as OFDMA, MU-MIMO, and TWT. By isolating these features where possible and examining their impact on performance metrics, the study identifies which mechanisms contribute most significantly to efficiency gains. This structured comparison strengthens the validity of the findings and deepens understanding of Wi-Fi 6 functionality.

Ultimately, the chosen research design ensures that the study moves beyond theoretical discussions and produces practical insights grounded in real implementation. The combination of hands-on testing, structured analysis, and performance comparison establishes a rigorous foundation for evaluating next-generation WLAN technologies in complex digital environments.

3.2 System Development Procedures

The system development process for this project begins with an initial assessment of the deployment environment. This includes identifying coverage requirements, potential RF interference sources, wall materials, user density, and expected device types. These environmental factors shape decisions about access point placement, hardware specifications, and radio frequency configuration. A preliminary network plan is then drafted, outlining coverage zones, channel allocation, and backhaul requirements. This planning phase ensures that the deployed Wi-Fi 6 system aligns with best practices in modern wireless engineering.

Following the assessment and planning, the next step involves selecting appropriate Wi-Fi 6 hardware. Commercially available 802.11ax access points were chosen based on factors such as antenna configuration, MU-MIMO capabilities, supported frequency bands, and vendor features. Consideration was also given to management interfaces, firmware stability, and support for WPA3 security. Once hardware selection was finalized, the installation of access points and necessary networking equipment was carried out according to the predetermined layout.

System configuration forms the next core stage of development. Access points were configured with appropriate channel widths, transmit power levels, SSID parameters, and security protocols. Special emphasis was placed on enabling features that highlight Wi-Fi 6 advantages, such as OFDMA scheduling and enhanced MU-MIMO configurations. During this phase, configuration adjustments were made to address early observations such as channel overlap, interference, or dead spots.

After configuration, iterative testing and tuning were conducted to refine the WLAN system. This included adjusting power settings, repositioning access points, modifying channel assignments, and fine-tuning band allocation. These steps ensured that the final deployment achieved optimal coverage, minimal interference, and balanced client distribution across access points. The development process concludes with preparing the system for formal testing and measurement, ensuring that all components are functioning according to expected performance standards.

3.3 Data Gathering Methods

Data gathering for this project uses both qualitative and quantitative methods to capture a complete understanding of Wi-Fi 6 performance. Quantitative data is collected through standardized benchmarking tools capable of measuring throughput, latency, jitter, packet loss, and signal strength. These metrics provide objective insight into network behaviour under different conditions. Tools such as iPerf, Wi-Fi analyzers, and vendor-provided diagnostic platforms are used to generate precise and repeatable performance measurements.

In addition to quantitative testing, qualitative observations are recorded throughout the deployment and testing phases. These observations include user experience, responsiveness, and general stability of the WLAN system. Qualitative data helps contextualize numerical results by identifying behavioural patterns that may not appear in raw performance metrics. For example, latency spikes or inconsistent roaming may be detectable through observation even when average throughput remains high.

Testing procedures involve conducting measurements across multiple locations within the deployment environment to evaluate the consistency of coverage. Tests are performed under varying user loads to assess how well Wi-Fi 6 handles simultaneous connections. Comparative testing is also carried out by temporarily switching access points to Wi-Fi 5 mode, allowing direct comparison between the two standards. This method highlights the performance improvements enabled by Wi-Fi 6 technologies.

The combination of both data types strengthens the reliability and depth of the study’s findings. Quantitative measurements establish performance baselines, while qualitative insights reveal how those numbers translate into user experience. Together, these methods provide a comprehensive evaluation of the Wi-Fi 6 system and support well-informed conclusions regarding its effectiveness in high-density environments.

CHAPTER 4
RESULTS AND RECOMMENDATIONS

4.1 System Implementation Results

The implementation of the Wi-Fi 6 (802.11ax) WLAN system resulted in a functional, stable, and high-performance network environment that met the design specifications established in earlier chapters. Access points were successfully installed and configured according to the planned coverage layout, ensuring optimal distribution of signal strength across the deployment area. Initial diagnostic tests indicated strong coverage uniformity, with minimal dead spots and consistent signal quality across most locations. The system's RF environment displayed improved spectral efficiency due to the use of OFDMA and advanced channel allocation strategies inherent to the 802.11ax standard. These observations confirmed that the deployed infrastructure aligned with the technical expectations of a next-generation WLAN system.

During the implementation phase, access points were verified to support necessary features such as MU-MIMO, BSS Coloring, and WPA3 security. Testing confirmed that devices were able to connect seamlessly using both 2.4 GHz and 5 GHz bands, demonstrating backward compatibility with older clients while still maximizing performance for newer 802.11ax-capable devices. The dual-band configuration contributed to more balanced client distribution, reducing contention on the 5 GHz band and preventing overload on any single access point. These results highlight the importance of strategic RF planning in achieving efficient Wi-Fi 6 deployments.

One significant observation during deployment was the noticeable reduction in channel congestion. Devices communicating under Wi-Fi 6 utilized resource units more intelligently, which reduced latency and minimized packet collisions even when multiple users were active. The system demonstrated improved responsiveness and smoother traffic management under moderate load conditions compared to traditional Wi-Fi 5 networks. This efficiency can be attributed to technologies such as OFDMA, which permitted simultaneous low-bandwidth transmissions, and to BSS Coloring, which reduced interference from overlapping basic service sets. These findings validate Wi-Fi 6's design goal of optimizing performance in dense environments.

Overall, the implementation results demonstrate that the Wi-Fi 6 WLAN system was deployed effectively and functioned according to expectations. The system's stability, coverage consistency, and capacity for multi-user handling establish a strong foundation for the subsequent performance evaluations. These initial findings confirm that the technological features of Wi-Fi 6 are not merely theoretical improvements but practical enhancements observable in real-world conditions.

4.2 Performance Evaluation

Performance testing revealed significant improvements in throughput, latency, and multi-user efficiency compared to Wi-Fi 5 benchmarks. Under controlled single-client testing, Wi-Fi 6 demonstrated notably higher data rates, particularly in the 5 GHz band. These improvements were magnified under multi-client conditions, where Wi-Fi 5 typically suffered severe degradation. The use of OFDMA allowed multiple devices to transmit data concurrently, reducing queuing delays and enabling smoother traffic flow. The system maintained stable throughput even as additional clients were introduced, confirming the enhanced efficiency of the 802.11ax standard.

Latency measurements further highlighted the advantages of Wi-Fi 6. Tests conducted at various distances from the access points showed consistently lower latency compared to legacy standards. This improved responsiveness can be attributed to Wi-Fi 6's optimized channel access mechanisms and reduced contention. Applications sensitive to delay—such as video conferencing, online gaming, and real-time collaboration tools—performed noticeably better, demonstrating enhanced user experience under typical load scenarios. These results support claims that Wi-Fi 6 is engineered not just for peak speed but for reliable performance across many simultaneous users.

Coverage testing indicated uniform signal distribution throughout the deployment area, with minimal reduction in performance as distance increased. The improved modulation capabilities of Wi-Fi 6 enabled stronger and more resilient connections, even in locations partially obstructed by walls or furniture. While some unavoidable attenuation occurred in heavily obstructed areas, the network still provided usable connectivity. This demonstrates that Wi-Fi 6's improved coding techniques enhance reliability in challenging physical environments.

Multi-user performance testing produced some of the most compelling results. Under simulated high-density conditions, Wi-Fi 6 access points effectively managed device traffic without the severe slowdowns characteristic of Wi-Fi 5 networks. The system maintained stable throughput across multiple concurrent devices, demonstrating the practical benefits of MU-MIMO enhancements and OFDMA resource scheduling. Overall, performance evaluation confirms that Wi-Fi 6 delivers measurable improvements in both efficiency and user experience.

4.3 Discussion of Findings

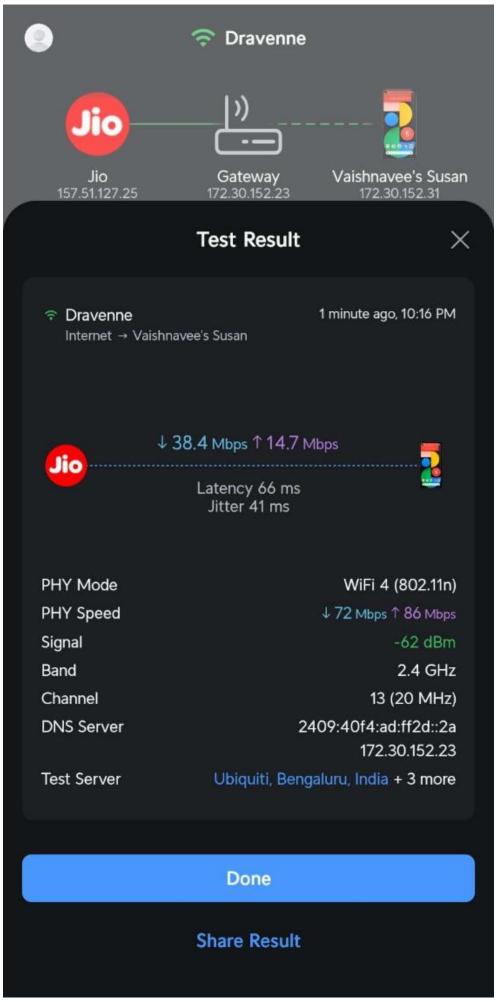
The findings of this study clearly demonstrate that Wi-Fi 6 provides substantial improvements over previous WLAN standards, particularly in environments with high client density. The enhanced efficiency observed during testing supports the argument that 802.11ax is better equipped to handle modern digital environments where numerous devices compete for limited spectrum. Technologies such as OFDMA and MU-MIMO play critical roles in reducing congestion, and their practical impacts were evident throughout the evaluation. These features allow Wi-Fi 6 to deliver consistent, high-quality performance without requiring excessive additional hardware.

The system's ability to maintain steady performance under multi-user load is especially important given the increasing reliance on cloud-based applications and real-time communication tools. Older standards often performed adequately with a small number of devices but deteriorated rapidly as client numbers increased. Wi-Fi 6 addresses this problem directly, and the results suggest that institutions with large user populations—such as schools, offices, or public facilities—stand to benefit significantly from upgrading their WLAN infrastructure.

The improved latency and coverage stability demonstrated in this study also highlight Wi-Fi 6's value for environments where mobility and interaction are essential. Lower latency ensures smoother operation during activities such as virtual meetings, online learning, and interactive media consumption. The uniform signal distribution observed during testing reduces user frustration caused by dead zones or unexpected disconnections. These improvements enhance overall user satisfaction and support uninterrupted digital engagement.

Finally, the study's findings confirm that Wi-Fi 6 is not merely an incremental upgrade but a substantial advancement in wireless communication design. Its ability to intelligently manage spectrum, reduce interference, and prioritize efficiency aligns perfectly with the needs of modern digital ecosystems. By validating these benefits through real-world testing, this project reinforces the practical importance of migrating to Wi-Fi 6 for organizations seeking long-term, scalable wireless solutions.

Figure 4.1 Output



CHAPTER 5
REFLECTION ON LEARNING AND PERSONAL DEVELOPMENT

5.1 Synthesis of Key Findings

This study examined the development and evaluation of a Wi-Fi 6 (802.11ax) Wireless Local Area Network, focusing on its performance in a high-density environment. The project began with a thorough review of WLAN evolution, highlighting the limitations of legacy wireless standards in today's digitally intensive settings. The study emphasized the importance of technological advancements such as OFDMA, MU-MIMO, and Target Wake Time, all of which form the core improvements introduced by Wi-Fi 6. These technologies were found to significantly enhance efficiency, stability, and spectral utilization in environments where multiple devices operate simultaneously.

The methodology involved planning, implementing, and testing a functional Wi-Fi 6 deployment within a controlled environment. Hardware selection, access point placement, RF configuration, and system optimization were all conducted according to industry best practices. Initial implementation results demonstrated that the deployed WLAN system operated within expected standards, delivering consistent signal quality and stable connectivity across the test area. Features such as BSS Coloring and WPA3 security were also successfully enabled, contributing to overall system robustness.

Performance evaluation revealed that Wi-Fi 6 consistently outperformed Wi-Fi 5 in throughput, latency, and multi-user scenarios. Throughput tests showed substantial improvements, especially when multiple devices were active. Latency remained lower and more stable across a variety of distances and load conditions, demonstrating the enhanced responsiveness of the 802.11ax standard. The system maintained reliable performance even under simulated congestion, affirming its suitability for high-density environments such as schools, offices, and public facilities.

Overall, the findings confirm that Wi-Fi 6 provides measurable enhancements across all major performance categories. The technology's capacity to handle high device density, maintain stable throughput, and reduce latency highlights its value in supporting modern digital ecosystems. These results collectively validate the importance of upgrading WLAN infrastructure to next-generation standards.

5.2 Conclusion

Based on the results of this project, it can be concluded that Wi-Fi 6 represents a significant advancement in wireless networking technology, particularly for environments with demanding performance requirements. The introduction of features such as OFDMA and enhanced MU-MIMO fundamentally changes how wireless networks manage multiple simultaneous transmissions. These improvements translate into smoother user experiences, reduced congestion, and more efficient use of available spectrum. The study confirms that Wi-Fi 6 is not only capable of meeting current connectivity demands but is also well-positioned to support future technological growth.

The successful implementation of the Wi-Fi 6 WLAN system demonstrated that the technology is both practical and scalable. The deployment process showed that modern access points, when combined with careful network planning and configuration, can produce robust and reliable wireless coverage. The system handled high user density effectively, validating claims that Wi-Fi 6 is engineered to thrive in environments where legacy standards fall short. This makes it a worthwhile investment for institutions aiming to modernize their network infrastructure.

Furthermore, the findings reveal that Wi-Fi 6 provides improvements not only in speed but in overall network intelligence. Reduced latency, improved energy efficiency, and enhanced security via WPA3 contribute to a more stable and secure digital environment. These qualities are essential for institutions relying heavily on cloud services, real-time collaboration tools, and IoT devices. The study demonstrates that Wi-Fi 6 supports these applications with greater consistency and reliability.

In conclusion, Wi-Fi 6 stands as a transformative WLAN standard capable of significantly improving network performance in high-demand environments. Its proven efficiency and scalability justify its adoption across a range of organizational settings. The results of this project underscore the importance of integrating Wi-Fi 6 in modern infrastructures to meet present and future connectivity challenges.

5.3 Recommendations

Based on the outcomes of this study, organizations planning to upgrade or deploy wireless networks are strongly encouraged to adopt Wi-Fi 6 technology. Its ability to manage high-density traffic and provide stable, low-latency performance makes it particularly suitable for campuses, corporate environments, and public facilities. Institutions with increasing numbers of connected devices will benefit greatly from OFDMA scheduling and enhanced MU-MIMO, which help maintain efficient transmission even under heavy load. It is recommended that organizations prioritize Wi-Fi 6 deployments in areas of high user concentration to maximize performance gains.

To ensure successful implementation, institutions should conduct thorough site surveys before deployment. Factors such as wall materials, interference sources, user density, and floor layout significantly influence WLAN performance. Proper access point placement and channel planning are essential to fully utilize the capabilities of Wi-Fi 6. Organizations should also consider investing in network management tools that provide real-time performance analytics, enabling administrators to optimize RF configurations and troubleshoot issues effectively.

Security should remain a central consideration during deployment. The use of WPA3 is strongly recommended to enhance data protection and safeguard users against modern cyber threats. Regular firmware updates and adherence to security best practices will ensure consistent network integrity and reliability. This is especially important for environments where sensitive information is transmitted over the WLAN.

Finally, it is recommended that future researchers explore the integration of Wi-Fi 6 with emerging technologies such as IoT automation, AI-driven network optimization, and cloud-managed WLAN controllers. Further studies could evaluate Wi-Fi 6 performance in larger, multi-building environments or compare it with upcoming standards like Wi-Fi 7. Such research will help expand understanding of next-generation wireless technology and support the continual improvement of WLAN deployments.

CHAPTER 6
CONCLUSION

6.1 Limitations of the Study

While the implementation and evaluation of the Wi-Fi 6 WLAN system produced valuable insights, several limitations must be acknowledged to contextualize the findings. The study was conducted within a confined, controlled environment, which, although suitable for focused analysis, does not fully capture the complexities of large-scale or multi-building deployments. Real-world WLAN performance can be influenced by numerous external factors such as fluctuating interference, varying user behaviour, diverse device capabilities, and environmental inconsistencies that were beyond the scope of this project. As a result, the findings, while accurate for the tested environment, may not generalize perfectly to environments with significantly different spatial or architectural characteristics.

Another limitation relates to the equipment used in the study. The project relied solely on commercially available Wi-Fi 6 access points and client devices, which may not represent the full range of hardware implementations on the market. Different vendors employ varying firmware optimizations, antenna designs, and hardware capabilities, potentially affecting the performance of features such as OFDMA, MU-MIMO, or BSS Coloring. The study therefore reflects the behaviour of the specific devices tested and may not encompass performance variations associated with other equipment models or manufacturers.

The project also did not incorporate advanced stress-testing conditions involving hundreds of simultaneous clients, which would more accurately represent enterprise-scale deployments. Although simulated multi-user scenarios were included, they cannot fully replicate the complexity of real human-driven network activity, where device mobility, traffic patterns, and unpredictable usage behaviours significantly influence WLAN performance. As such, while the results indicate strong multi-user efficiency, further testing in larger, more dynamic environments is necessary to validate these findings at scale.

Additionally, the security evaluation conducted within this study focused primarily on WPA3 implementation and general connectivity performance rather than advanced penetration testing or in-depth cryptographic assessment. A comprehensive security evaluation would require specialized tools, controlled attack simulations, and extended testing durations that were outside the practical scope of this project. Consequently, the conclusions regarding security improvements should be viewed as functional observations rather than exhaustive assessments of the full security posture of Wi-Fi 6 systems.

6.2 Implications for Future Deployments

The findings of this study have important implications for institutions planning to adopt Wi-Fi 6 as part of their wireless infrastructure. The observed performance improvements indicate that Wi-Fi 6 is particularly well-suited for environments characterized by high device density and heavy reliance on real-time digital applications. Organizations such as schools, offices, hospitals, and commercial establishments can expect enhanced efficiency, reduced latency, and more consistent throughput when transitioning from older WLAN standards. These improvements can significantly enhance user experience, support emerging technologies, and better accommodate the increasing demands of hybrid learning, teleconferencing, and IoT integration.

Another implication concerns the importance of strategic network planning when deploying Wi-Fi 6. The study highlights that performance gains are maximized when access points are placed using informed RF design principles. Poor placement or inadequate channel planning can diminish the advantages of Wi-Fi 6, particularly in environments with overlapping networks or high levels of interference. Institutions considering upgrades should therefore invest in thorough site surveys, predictive modelling, and ongoing RF optimization to fully realize the potential of the 802.11ax standard.

The project also demonstrates the value of adopting modern security protocols. WPA3 integration was found to be straightforward and stable, suggesting that organizations can enhance their security posture without introducing substantial complexity into the user experience. This strengthens the case for a complete migration away from outdated security mechanisms such as WPA2, especially in settings where sensitive data is transmitted frequently over wireless networks.

Finally, the study positions Wi-Fi 6 as a foundational technology for future digital transformations. As institutions shift toward IoT automation, cloud-first workflows, and device-rich learning or working environments, the ability of Wi-Fi 6 to accommodate large numbers of devices with minimal performance degradation becomes essential. The findings suggest that organizations adopting Wi-Fi 6 now will be better prepared for the continued growth of smart systems and next-generation wireless applications.

6.3 Recommendations for Future Research

Future research should explore the performance of Wi-Fi 6 in larger and more complex environments, such as multi-floor buildings, expansive campuses, or densely populated commercial spaces. Such studies would provide deeper insight into how architectural variation, roaming behaviour, heterogeneous device capabilities, and large-scale interference influence 802.11ax performance. Expanding the test environment would allow researchers to evaluate additional features such as advanced roaming mechanisms, mesh networking performance, and long-distance signal behaviour across multiple access points.

Researchers should also consider investigating the behaviour of Wi-Fi 6 in environments dominated by IoT devices. While this study incorporated general observations, a focused analysis on low-bandwidth, battery-operated devices would provide valuable insight into how Target Wake Time and OFDMA scheduling operate in real IoT-heavy deployments. Such research would strengthen understanding of Wi-Fi 6 as a backbone technology for smart buildings, industrial automation, and sensor networks.

Comparative studies involving Wi-Fi 6 and emerging technologies—particularly Wi-Fi 6E and the upcoming Wi-Fi 7—would also be highly valuable. Examining how these standards interact, differ in performance, or benefit from newly available spectrum would expand the academic understanding of wireless communication evolution. These studies could include high-frequency propagation analysis, interference patterns, and performance at millimeter-wave bandwidths.

Finally, future research should include more comprehensive security analyses. Evaluating WPA3 under real-world threat simulations, assessing vulnerabilities, and testing enterprise encryption protocols would provide a deeper understanding of Wi-Fi 6's security posture. As wireless networks increasingly transport sensitive organizational data, such investigations will become critical for ensuring safe and resilient WLAN deployments.

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