SAKARYA UNIVERSITY JOURNAL OF COMPUTER AND INFORMATION SCIENCES
http://saucis.sakarya.edu.tr/
e-ISSN: 2636-8129
Publisher: Sakarya University
Vol. 8, No. 2, 171-183, 2025
DOI: 10.35377/saucis...1592312

RESEARCH ARTICLE

Performance Analysis and Optimization of Enterprise Wireless Networks Based on 802.11ax Technology

Berkay Dağtaş[1,*], İsmail Hakkı Cedimoğlu[2]

[1]Sakarya University, Institute Of Science, Sakarya, Türkiye, ror.org/04ttnw109
[2]Sakarya University, Sakarya, Türkiye, ror.org/04ttnw109

Corresponding author:
Berkay Dağtaş, Sakarya University,
Faculty of Computer and Information Sciences,
Sakarya, Türkiye
berkay.dagtas1@ogr.sakarya.edu.tr

Article History:
Received: 27.11.2024
Revised: 26.02.2025
Accepted: 18.04.2025
Published Online: 13.06.2025

ABSTRACT
This study focuses on performance analysis and optimization of enterprise wireless networks. Fundamental performance parameters of Wi-Fi networks such as signal strength, signal-to-noise ratio (SNR), data rate, and channel interference were evaluated in detail in the study. The analysis process was carried out using Ekahau AI Pro software and Ekahau Sidekick device in a corporate facility, consisting of three main buildings. The obtained data revealed that signal strength dropped to -85 dBm levels in certain areas, negatively affecting the network's coverage area. Particularly in the ground floor of building B-C, secondary signal levels were found to be insufficient for roaming. Across the campus, SNR levels were observed to be 30 dB and above, and these values were found to provide ideal connectivity. During the analysis, it was discovered that in some areas, the number of access points broadcasting signals on the same channel increased up to 6. It has been assessed that this situation may negatively affect network performance in areas where interference is intense. Data rates varied between 1 - 300 Mbps in the 2.4 GHz frequency band and 1 - 585 Mbps in the 5 GHz band. The study provides significant data for performance analysis and optimization of enterprise wireless networks.

Keywords: Wi-Fi performance, Signal strength, SNR, Channel interference, Ekahau AI Pro

1. Introduction

With the rapid development of information and communication technology, the demand for wireless network technology has increased significantly. Wi-Fi is easy to implement in workplaces and educational environments, enabling users to access the internet anytime and anywhere. While this technology provides data communication through radio waves, it typically operates in the 2.4 GHz and 5 GHz radio frequency bands that do not require licensing [1]. These bands are reserved for unlicensed radio services that can be used without obtaining a radio station license.

Wi-Fi is a technology based on the IEEE 802.11 standard that provides wireless data transfer [2]. While Wi-Fi modules were initially used only in tablets, laptops, and smartphones, nowadays, it is possible to find them in many electronic devices, including cameras, printers, 3D printers and multi-cookers. Access points are used to establish wireless network connections. These devices provide remote access to users by broadcasting wireless network signals [3].

Enterprise wireless network systems are typically managed through an access point controller. Different wireless network infrastructures, systems, and services are distributed by this controller and delivered to users through access points[4]. This structure enables effective and secure management of wireless connections in large-scale networks.

This study aims to examine, analyze, and optimize the performance of an enterprise wireless network in a real-world scenario based on the evaluation results. To achieve these goals, tests were conducted using spectrum analysis tools and software that help analyze the results. These tests aim to identify the network's strengths and weaknesses and reveal the main factors affecting user behavior in resource usage. A professional solution including advanced network analysis software and a set of sensors was chosen to analyze wireless network performance. Tests using Ekahau AI Pro Version 2.0 allowed performance measurements and analysis to be performed on various parts of the network.

This software has the capacity to examine many factors affecting network performance and evaluates parameters such as spectrum analysis, signal strength measurements, data transfer rates, and network coverage areas in detail. This analysis process was conducted based on metrics like capacity management, bandwidth usage, signal quality, and channel interference to understand the overall health and performance of the network. Based on the findings, improvement steps were implemented

Cite as: B. Dağtaş and İ. Hakkı Cedimoğlu. (2025). Performance analysis and optimization of enterprise wireless networks based on 802.11ax technology. *Sakarya University Journal of Computer and Information Sciences*. vol. 8, no. 2, pp. 171-183, 2025 doi: 10.35377/saucis...1592312

to increase wireless network performance, and user experience was improved. This study conducts a detailed analysis of wireless network performance in a corporate scenario, comprehensively presents the current state of the network, implements optimization processes based on the findings, and makes a practical contribution to the literature in this field.

2. Literature Review

2.1 Wi-Fi Standards

Wi-Fi is a modern standard for data transmission and reception between devices. These devices must be equipped with radio modules. Wi-Fi standards are defined by the Institute of Electrical and Electronics Engineers (IEEE). The standards differ in terms of frequency bands, data transfer rates, and other features [5]. Wi-Fi standards are presented in Table 1.

Table 1. Wi-Fi Versions and Technical Specifications

Wi-Fi Version	IEEE Standard	Frequency Band	Data Rate	Modulation Technique	Year
Wi-Fi 0	IEEE 802.11	2.4 GHz	2 Mbit/s	FHSS, DSSS	1997
Wi-Fi 1	IEEE 802.11b	2.4 GHz	11 Mbit/s	DSSS, CCK	1999
Wi-Fi 2	IEEE 802.11a	5 GHz	54 Mbit/s	OFDM	1999
Wi-Fi 3	IEEE 802.11g	2.4 GHz	54 Mbit/s	OFDM	2003
Wi-Fi 4	IEEE 802.11n	2.4 GHz, 5 GHz	600 Mbit/s	OFDM, MIMO	2009
Wi-Fi 5	IEEE 802.11ac	5 GHz	3.5 Gbit/s	OFDM, MIMO	2013
Wi-Fi 6	IEEE 802.11ax	2.4 GHz, 5 GHz	9.6 Gbit/s	OFDMA, MU-MIMO, TWT	2021
Wi-Fi 7	IEEE P802.11be	2.4 GHz, 5 GHz, 6 GHz	~40 Gbit/s	OFDMA, MU-MIMO, 320 MHz channels	2024

2.2. Factors Affecting Wireless Network Performance

This section discusses the key factors that affect the performance of wireless networks. Analysis of these factors affecting network performance helps understand existing problems and contributes to improving network efficiency.

2.3. Effects of Obstacles and Building Materials

Penetration loss refers to the reduction in power of a radio signal as it passes through a medium in wireless communication. This loss occurs when the signal weakens while passing through different materials (such as walls, doors, glass, metal surfaces) [6]. Wireless network performance varies significantly depending on how much radio frequency signals are weakened by obstacles and building materials. Table 2 shows how much common building materials weaken Wi-Fi signals, measured in dB [7].

Table 2. Effects of Building Materials on Wi-Fi Signals

Materials	Attenuation (dB)
Drywall	3 dB
Bookshelf	2 dB
Exterior Glass	3 dB
Solid Wood Door	6 dB
Marble	6 dB
Brick	10 dB
Concrete	12 dB
Elevator Shaft	30 dB

When radio signals encounter an obstacle, some of them are absorbed, reflected, or refracted, causing the signal to reach its target with less power. Penetration loss can significantly affect wireless network performance and is a common problem typically encountered in indoor environments.

These losses vary depending on the frequency used, the material of the medium, and the distance the signal needs to travel through. For example, high-frequency signals (like 5 GHz) usually experience more penetration loss compared to low-frequency signals (like 2.4 GHz) [8]. Therefore, penetration loss is a critical parameter in terms of Wi-Fi coverage planning and performance optimization.

2.4. Signal Strength (RSSI - Received Signal Strength Indicator)

The Received Signal Strength Indicator (RSSI) is a critical measurement in Wi-Fi networks that represents the power level of the signal a wireless device receives from an access point or router. The RSSI value is measured in decibels (dBm) and provides an indication of the signal strength at the receiver. The closer an end device is to the network, the higher the measured RSSI value will be [9]. RSSI values are presented in Table 3.

Table 3. RSSI Values

Signal Strength (dBm)	Category
-30 dBm	Excellent
-67 dBm	Very Good
-70 dBm	Acceptable
-80 dBm	Weak
-90 dBm	Insufficient

2.5. Signal to Noise Ratio (SNR)

Signal-to-Noise Ratio (SNR) is a parameter that measures the strength of a data signal relative to the background noise level. This ratio is critically important for evaluating signal quality, and the SNR calculation method is shown in Equation 1.

$$\boldsymbol{SNR(dB) = 10.log_{10}\left(\frac{P_{signal}}{P_{noise}}\right)} \quad (1)$$

Here;

P_{Signal} : Signal power (in Watts)

P_{noise} : Noise power (in Watts)

SNR is measured in dB instead of dBm. In cases where the measurements are already in decibels (dB), the difference between the signal power and the noise power directly gives the signal-to-noise ratio (SNR). This is shown in Equation 2.

$$\boldsymbol{SNR = S - N} \quad (2)$$

Here;
S : Signal level (in dB)

N : Noise level (in dB)

Even if a client receives an excellent signal in close proximity to an access point, strong signals originating from neighboring wireless networks or radio frequency (RF) devices may disrupt connection continuity. Such signals are interpreted as noise by the client device [10]. The relationship between SNR levels and signal quality is presented in Table 4 [11].

Table 4. Relationship between SNR Levels and Signal Quality

SNR Level	Description
> 40 dB	Excellent quality
25-40 dB	Very Good quality
15-25 dB	Good quality
10-15 dB	Moderate quality
0-10 dB	Low or no signal

2.6. Channel Interference

Channel interference in wireless communication is one of the most important factors affecting wireless network performance. This situation, which is frequently encountered especially in enterprise wireless networks, is examined under two headings.

2.6.1. Co-Channel Interference

Co-Channel Interference (CCI) occurs when two or more Access Points (APs) configured on the same channel are physically positioned close to each other, regardless of the frequency band (2.4GHz / 5GHz). This situation causes signals to interfere with each other and creates interference [12]. The 802.11 standard is based on "Carrier Sense Multiple Access" (CSMA) technique [13]. This requires a device to transmit data only when the channel is free. CCI can confuse the carrier sensing mechanism by giving the impression that the channel is busy, which may prevent the channel from being used.

2.6.2. Adjacent Channel Interference

Adjacent Channel Interference (ACI) is a type of interference where signals from transmitters on adjacent frequency channels "leak" and cause interference on another channel [14]. Adjacent channel interference is caused by overlapping channels in the 2.4 GHz band. In this band, there are only three non-overlapping channels 1, 6 and 11 [15]. Figure 1 shows the channel planning in 2.4 GHz and 5 GHz frequency bands respectively [16].

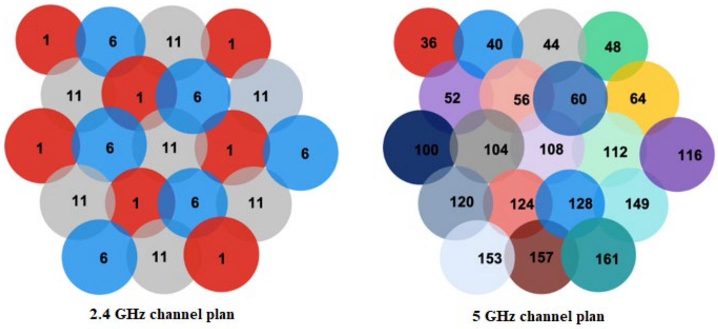

Figure 1. Channel allocation scheme for 2.4 GHz and 5 GHz Wi-Fi bands

3. Materials and Methods

Figure 2. Wi-Fi Performance Analysis and Optimization Process

3.1 Using Ekahau and Alternative Tools in Wireless Network Performance Analysis

Evaluating wireless network performance is critically important for reliable data communication and user experience. Therefore, various software tools are used to optimize the performance of wireless networks during and after installation. These tools aim to improve network efficiency by analyzing network capacity, signal strength, signal-to-noise ratio (SNR), data rates, and other performance metrics. The comparative features of Wi-Fi performance testing tools are presented in Table 5 [17], [18], [19], [20].

Table 5. Wi-Fi Features and Comparisons of Wi-Fi Performance Testing Tools

Feature	Ekahau AI Pro	Acrylic Wi-Fi	AirMagnet Survey Pro	NetSpot
Number of Heatmaps	26	14	11	15
Supported Frequencies	2.4 GHz, 5 GHz, 6 GHz	2.4 GHz, 5 GHz, 6 GHz	2.4 GHz, 5 GHz, 6 GHz	2.4 GHz, 5 GHz, 6 GHz
Wi-Fi Standards	802.11a/b/g/n/ac/ax	802.11a/b/g/n/ac/ax	802.11a/b/g/n/ac/ax	802.11a/b/g/n/ac/ax
User Level	Professional IT experts	From beginners to professionals	Professional IT experts	From beginners to professionals
Reporting Formats	PDF, CSV, DOCX	PDF, CSV, DOCX	PDF, CSV, XML	PDF, CSV
Spectrum Analysis	Yes	Yes	Yes	Yes

3.2. Wireless Network Performance Testing

In this section, it is explained how enterprise Wi-Fi network design and performance tests were conducted using Ekahau AI Pro software and Sidekick device. The study was carried out in a facility consisting of blocks A, B, and C. The area information of these blocks included in the study is presented in Table 6, and the architectural plans are shown in Figure 3.

Table 6. Building Floor Areas and Measurements

Building	Floor	Area (Square Meters)
A	Ground Floor	16695
B-C	First Floor	5110
	Ground Floor	6199

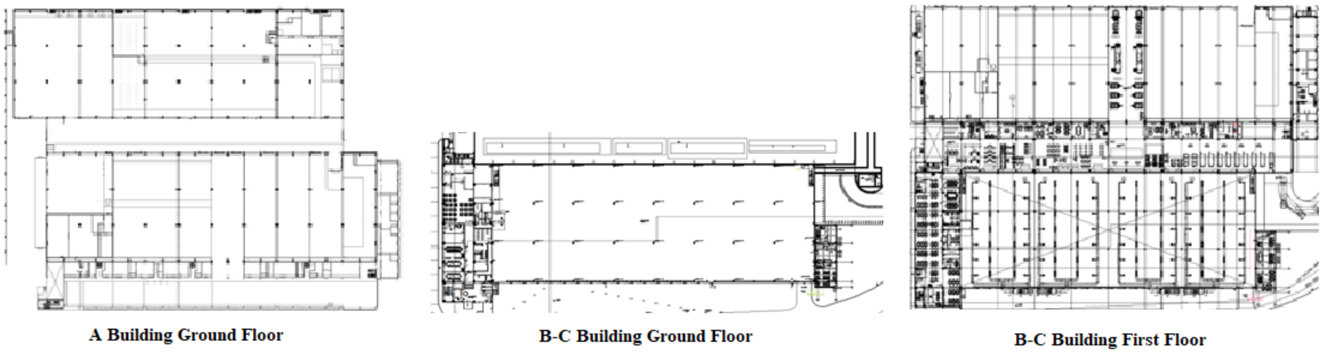

Figure 3. Floor Plans of A, B, and C Buildings

Measurements were first carried out in an office environment using the automatic planner feature of Ekahau AI Pro software, then conducted on-site using Ekahau AI Pro software installed on an iPad and the Ekahau Sidekick 2 device.

The Ekahau AI Automatic Planner was used to provide a fast and effective simulation of the wireless network design. After uploading the facility's architectural plans in DWG format into the Ekahau AI Pro software, user-dense areas were identified, and the Huawei 5776-26 access points, which support the 802.11ax standard, were automatically positioned throughout the facility. The AI Automatic Planner placed the access points based on the coverage requirements defined by Ekahau Best Practices, aiming to maximize signal coverage for both the 2.4 GHz and 5 GHz frequency bands while minimizing the risk of channel overlap. The Ekahau automatic planner results are presented in Figure 4.

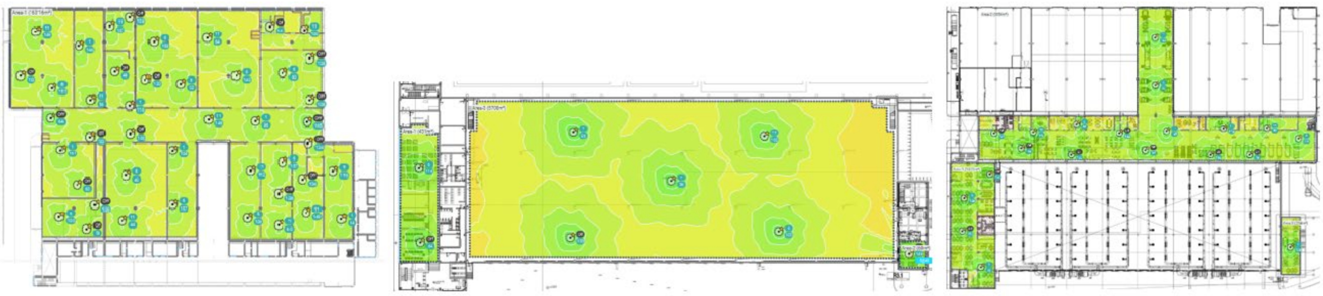

Figure 4. Ekahau Automatic Planner Result for A, B, and C Buildings

A comprehensive on-site test was conducted using the Ekahau Sidekick device to evaluate the performance of the wireless network designed using the automatic planner under real field conditions. On-site tests were planned and carried out to cover personnel-intensive areas where the wireless network would be actively used.

Ekahau Sidekick 2 is one of the fastest and most precise measuring devices used for analyzing wireless network performance. The device can perform highly accurate measurements in 2.4 GHz, 5 GHz, and 6 GHz frequency bands, and with its 9 integrated broadband 3D antennas, it ensures accurate capture of signals from all directions. Additionally, environmental interference was quickly detected with its spectrum analysis feature that can perform 50 scans per second. This allowed parameters such as signal strengths, SNR (Signal-to-Noise Ratio), and channel interference to be analyzed accurately and reliably. The routes followed during measurements in blocks A, B, and C are shown in Figure 5.

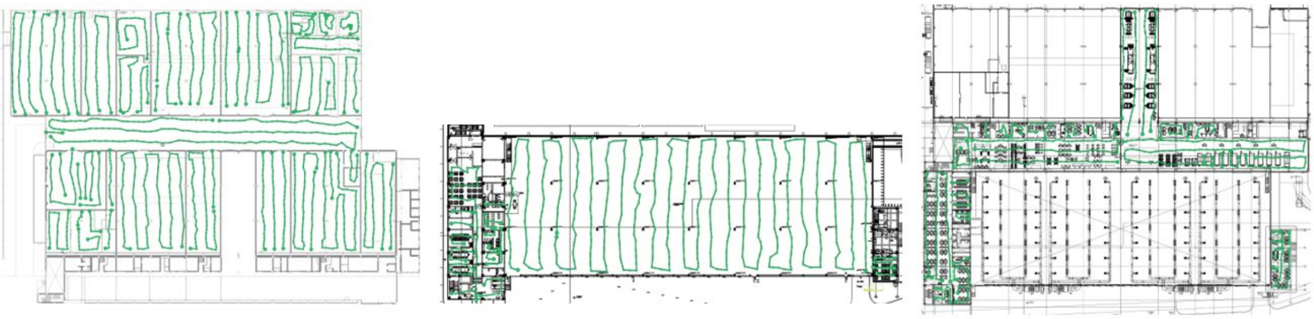

Figure 5. Measurement Routes Conducted with Sidekick in A, B, and C Buildings

On-site tests followed Ekahau Best Practices guidelines, and performance data for both 2.4 GHz and 5 GHz frequency bands were analyzed in detail. These are presented in Table 7.

Table 7. Ekahau Best Practices

Criteria	2.4GHz	5GHz
Signal Strength Min	-67 dBm	-67 dBm
Secondary Signal Strength Min	-67 dBm	-67 dBm
Tertiary Signal Strength	OFF	OFF
Signal-to-Noise Ratio Min	20 dB	25 dB
Data Rate Min	24 Mbps	24 Mbps
Channel Interference Max	2 at min. -85.0 dBm	1 at min. -85.0 dBm

4. Results

In this study, wireless network performance was assessed based on key parameters including signal strength, signal-to-noise ratio (SNR), throughput, and channel interference. Additionally, the effectiveness of applied optimization strategies was analyzed. Signal strength measurements were conducted across blocks A, B, and C in both 2.4 GHz and 5 GHz frequency bands. The results, illustrated in Figures 6 and 7, demonstrate the signal distribution in the evaluated areas. Green regions correspond to optimal signal levels, yellow indicates areas near threshold limits, while gray represents locations with insufficient or no coverage.

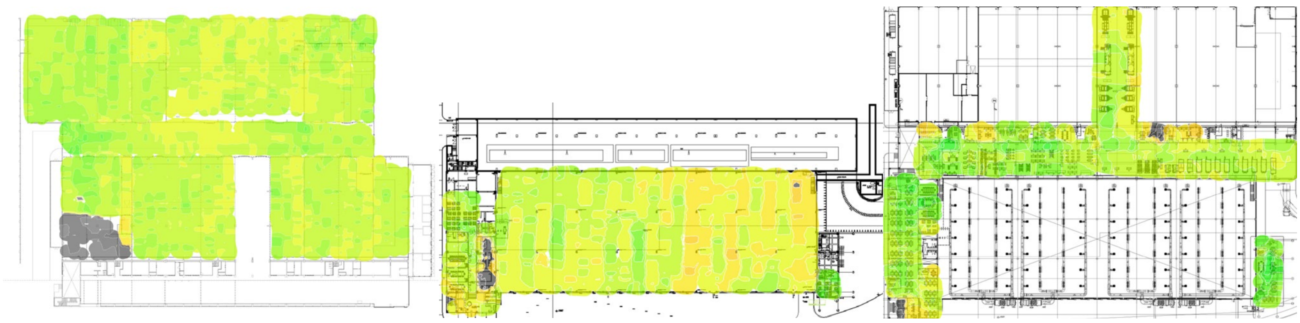

Figure 6. 2.4 GHz Signal Strength Heatmaps

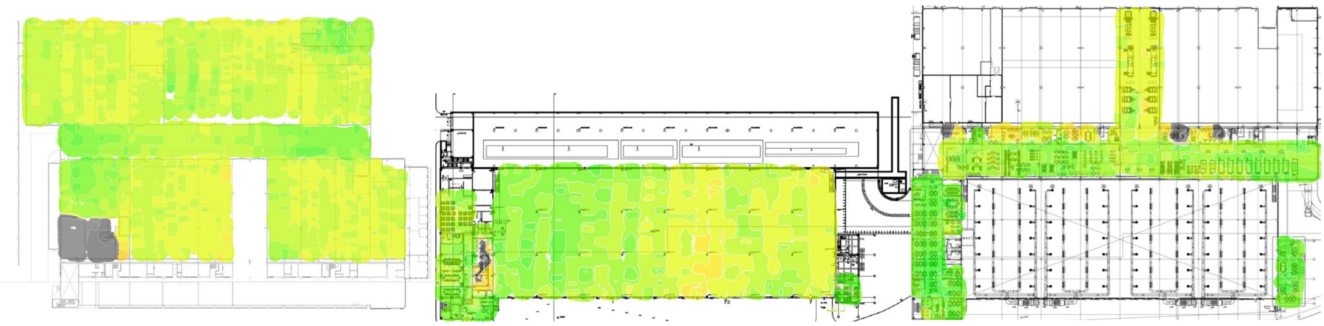

Figure 7. 5 GHz Signal Strength Heatmaps

Secondary signal strength is a critical metric in evaluating wireless network performance, particularly in maintaining seamless handover between access points (APs) and ensuring redundancy in the event of AP failures. Analysis results indicate that in areas where secondary signal strength is equal to or greater than -67 dBm in both the 2.4 GHz and 5 GHz frequency bands, these performance criteria are successfully met. Conversely, gray zones with signal levels equal to or below -85 dBm reveal insufficient support for client roaming, as illustrated in Figures 8 and 9.

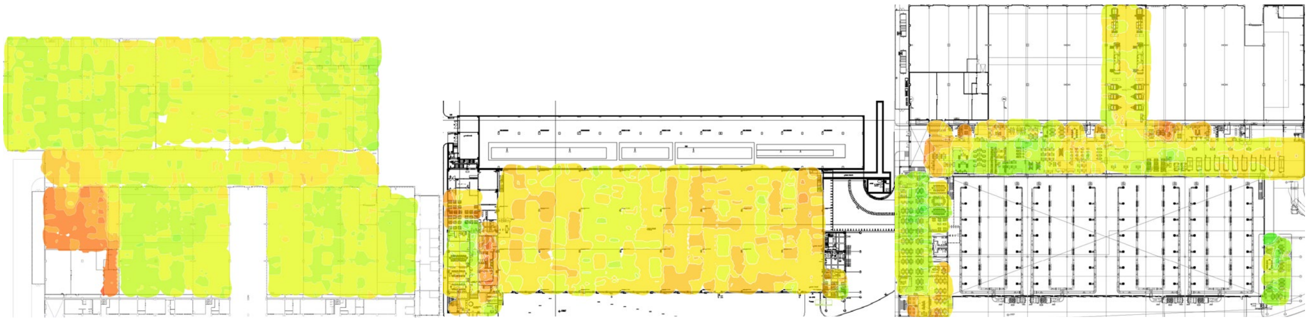

Figure 8. 2.4 GHz Secondary Signal Strength Heatmaps

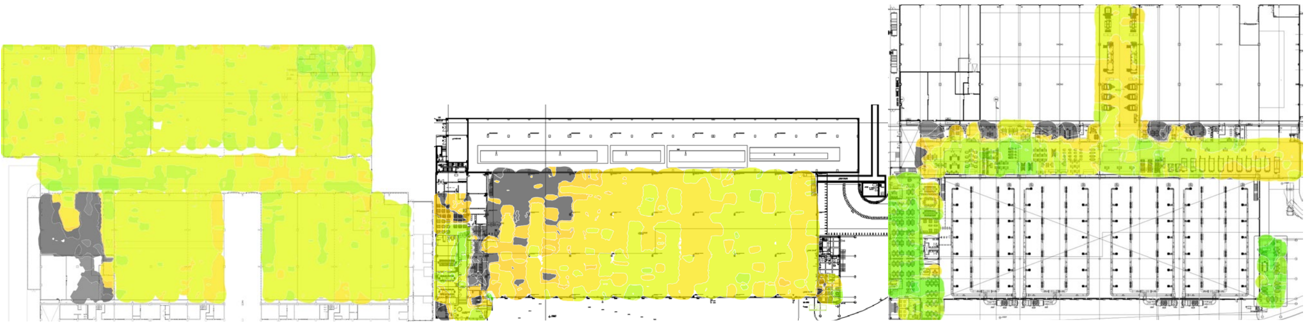

Figure 9. 5 GHz Secondary Signal Strength Heatmaps

For successful data transmission, the signal strength must exceed the level of background noise. Figures 10 and 11 present the SNR (Signal-to-Noise Ratio) heatmaps obtained for the ground floor and first floor of blocks A and B-C. In these maps, green areas indicate high SNR values (≥ 30 dB), which are associated with excellent signal quality and reliable communication. Conversely, yellow and gray areas represent zones with lower SNR levels, potentially leading to degraded performance or connection instability.

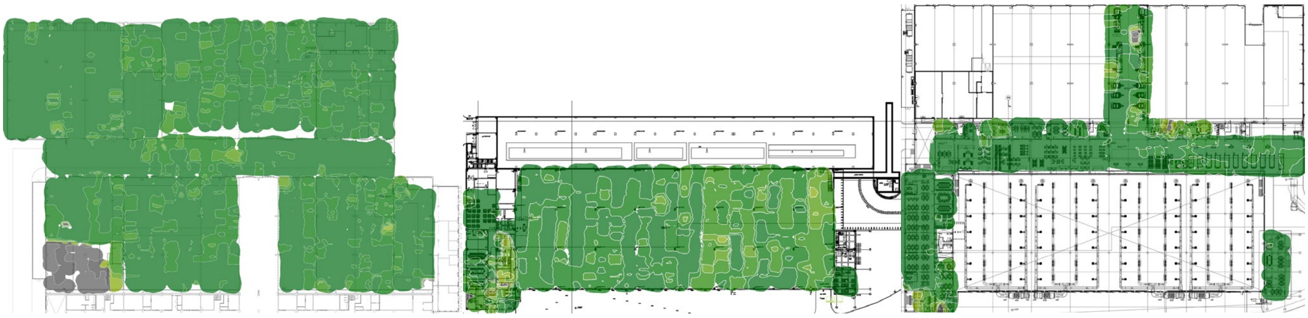

Figure 10. 2.4 GHz SNR Heatmaps

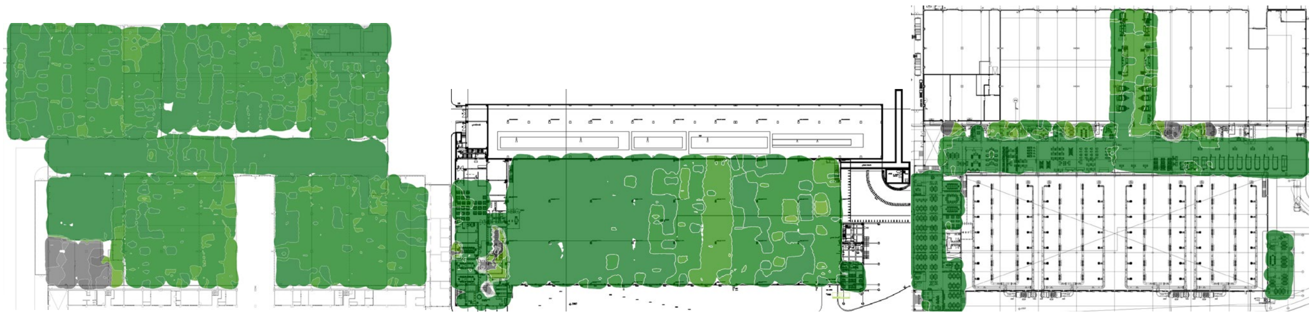

Figure 11. 5 GHz SNR Heatmaps

The data rate analyses conducted in the 2.4 GHz and 5 GHz frequency bands for blocks A and B-C are presented in Figures 12 and 13. The data rate refers to the maximum speed at which wireless devices can transmit or receive data, typically expressed in megabits per second (Mbps). In the 2.4 GHz frequency band, data rates ranged between 1 Mbps and 300 Mbps, whereas in the 5 GHz band, they varied between 1 Mbps and 585 Mbps. In the heatmaps, green-colored areas denote regions with higher data rates, indicating efficient data transmission capabilities, while yellow and orange areas represent locations where the data transmission rates are relatively lower.

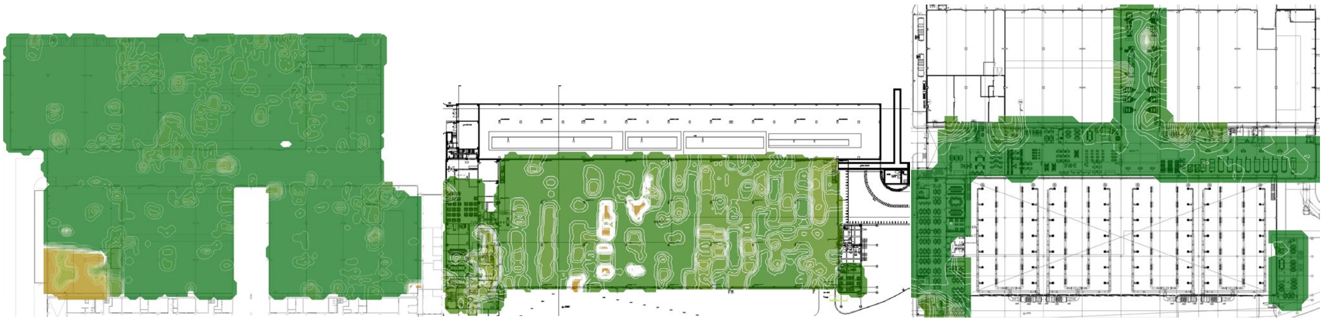

Figure 12. 2.4 GHz Data Rate Heatmaps

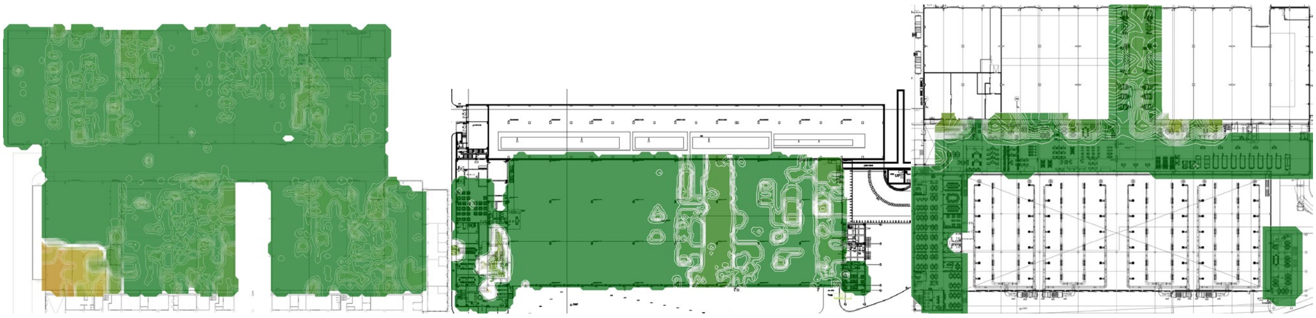

Figure 13. 5 GHz Data Rate Heatmaps

The throughput analyses for the 2.4 GHz and 5 GHz frequency bands in blocks A and B-C are illustrated in Figures 14 and 15. Throughput refers to the actual rate at which data is successfully transmitted over a network channel and is a critical metric that reflects end-user experience. While the data rate provides insight into the theoretical capacity of the network, throughput represents the practical, real-world performance. In the 2.4 GHz band, throughput values ranged from 1 Mbps to 240 Mbps, whereas in the 5 GHz band, values varied between 1 Mbps and 420 Mbps. As shown in the heatmaps, green areas correspond to zones with higher throughput performance, while yellow and orange areas indicate relatively lower throughput levels.

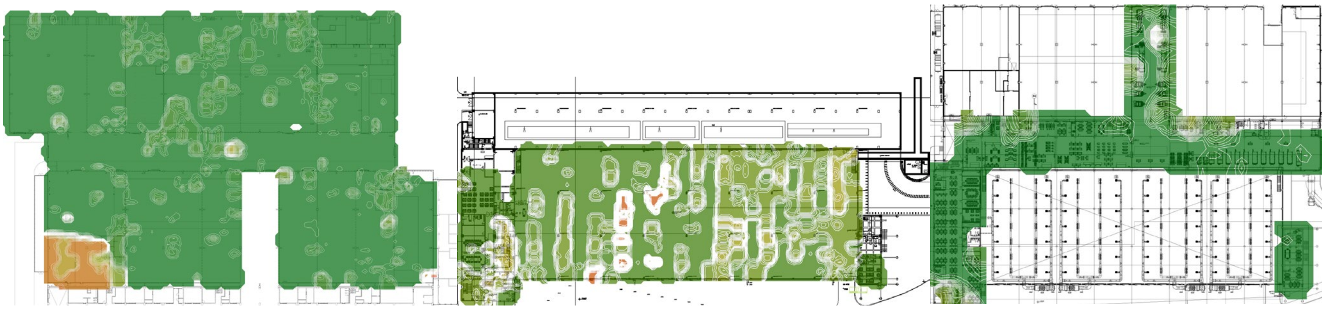

Figure 14. 2.4 GHz Throughput Heatmaps

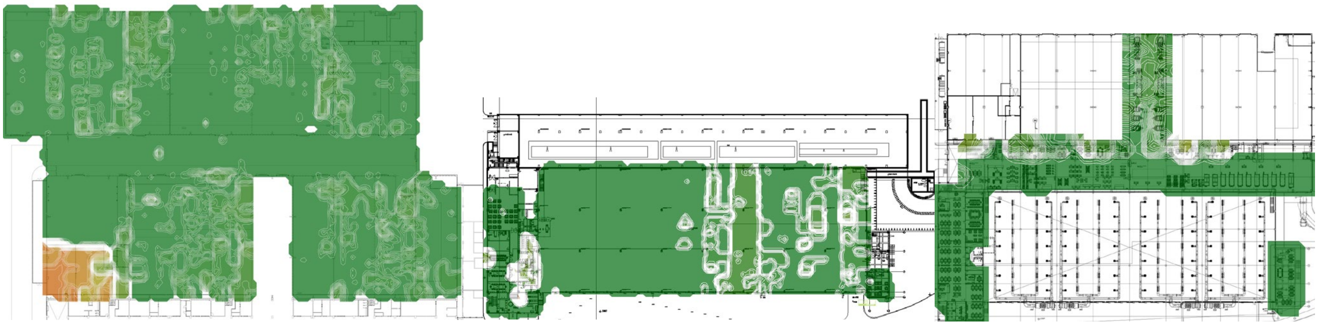

Figure 15. 5 GHz Throughput Heatmaps

The channel interference analysis is presented in Figures 16 and 17. In the heatmaps, green areas represent zones where interference is minimal or entirely absent, indicating optimal conditions for network performance. Conversely, the gray-shaded regions denote areas where multiple access points operate on the same channel, leading to co-channel interference. Such interference can significantly degrade wireless network efficiency and stability.

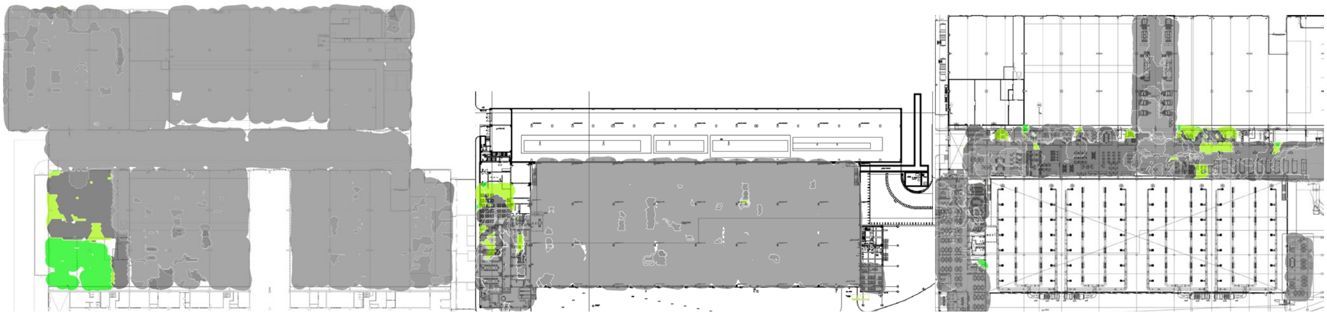

Figure 16. 2.4 GHz Channel Interference Heatmaps

Figure 17. 5 GHz Channel Interference Heatmaps

The overall network performance heatmaps for the 5 GHz frequency band are presented in Figure 18. The 5 GHz band is commonly preferred in enterprise networks due to its lower channel congestion and greater bandwidth capacity. Accordingly, the analysis and optimization efforts in this study primarily focused on this band, where more effective improvements could be implemented. These heatmaps provide a comprehensive visual representation of performance bottlenecks and areas with optimization potential. In the performance maps, red and yellow tones indicate weak signal strength, whereas purple regions denote high levels of channel congestion.

The optimization efforts aimed at enhancing network performance in the 5 GHz frequency band and their results have been thoroughly presented. Based on the analyses obtained from performance tests, various optimization measures were implemented, and subsequent on-site assessments were carried out within the facility. The overall impact of these optimizations on network performance was comprehensively evaluated.

As illustrated in Figures 19 to 21, the improper placement of access points was identified as one of the main causes of weak Wi-Fi signal strength. In addition, signal degradation due to distance and the attenuating effect of interior building materials also contributed to reduced performance. To address these issues, the positions and orientations of access points were restructured, and additional access points were deployed in signal-poor areas. Moreover, transmit power levels were adjusted to improve signal coverage and distribution. These improvements not only resolved signal degradation but also significantly enhanced low signal-to-noise ratios (SNR) and secondary signal strength, ultimately contributing to overall network performance.

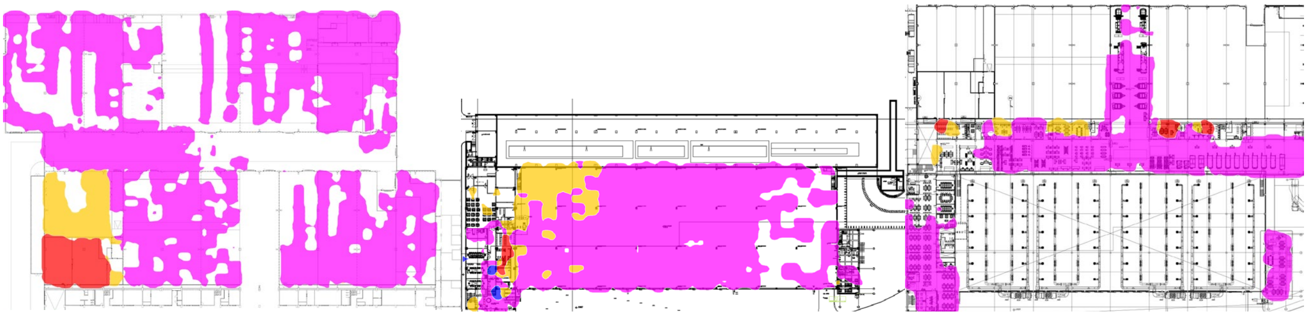

Figure 18. 5 GHz Network Performance Heatmaps

Figure 19. Access Point Orientation and Placement Optimization.

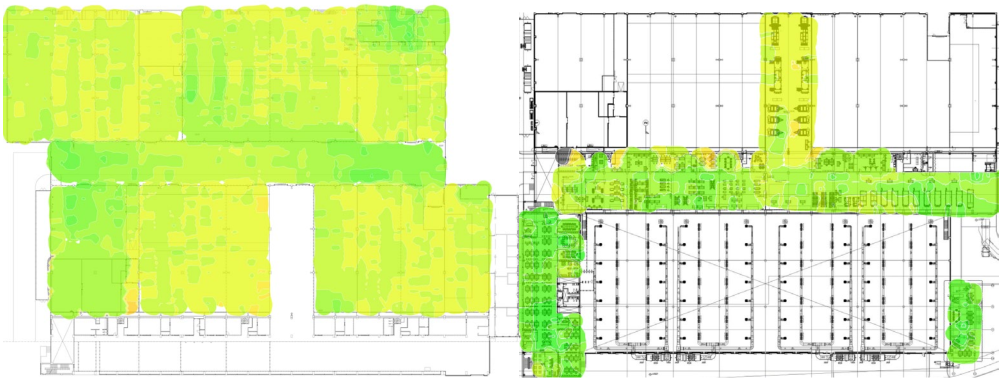

Figure 20. Optimized Signal Strength Heatmaps

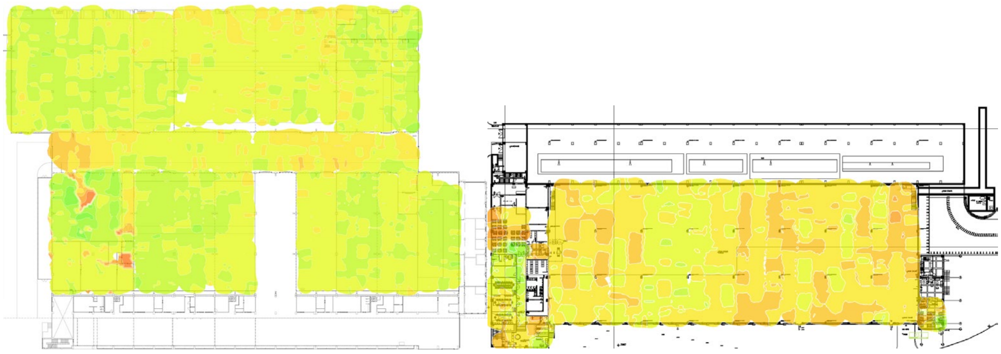

Figure 21. Optimized Secondary Signal Strength Heatmaps

To minimize channel interference and improve overall network performance, frequency and channel configurations of the access points were carefully optimized. In regions where interference was identified in the 2.4 GHz frequency band, the 2.4 GHz transmission was disabled due to the limited number of non-overlapping channels in this band, thereby preventing further signal congestion.

For the 5 GHz frequency band, which offers a broader spectrum, potential interference caused by wide channel usage was mitigated by restricting the channel width to 20 MHz. Furthermore, each access point was statically assigned to independent and non-overlapping channels. These configurations effectively reduced channel interference to ≤ 1 at the minimum signal strength threshold, thereby significantly improving the stability and performance of the wireless network across the entire facility, as illustrated in Figure 22.

The findings obtained from this study demonstrate the significant impact of the applied optimization strategies on wireless network performance. Prior to the implementation of these strategies, notable weaknesses in signal strength and severe interference issues were recorded, especially in zones with high user density. Following the repositioning of access points, reconfiguration of channels, and adjustment of power levels, a marked improvement in both network stability and performance was achieved. A comparative evaluation of performance metrics before and after the optimization efforts is presented in Table 8.

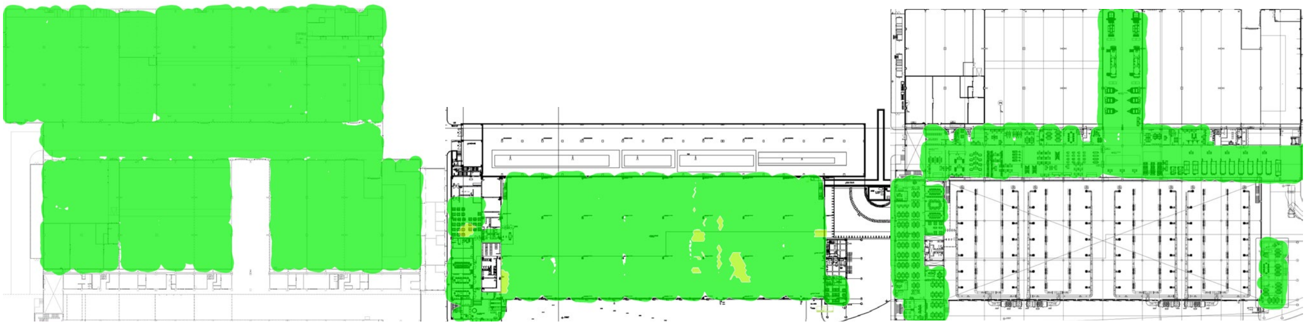

Figure 22. Optimized Channel Interference Heatmaps

Table 8. Comparison of Wireless Network Performance Metrics Before and After Optimization

Measurement Criteria	Before Optimization	After Optimization
Signal Strength	≤ -85 dBm	≥ -67 dBm
Secondary Signal Strength	≤ -67 dBm	≥ -67 dBm
Signal-to-Noise Ratio (SNR)	≤ 5 dB	≥ 30 dB
Data Rate	1 Mbps - 585 Mbps	1 Mbps - 585 Mbps
Throughput	1 Mbps - 420 Mbps	1 Mbps - 420 Mbps
Channel Interference at Minimum Signal Strength	-85 dBm ≥ 6	-85 dBm ≤ 1

5. Discussion

In the evaluation of wireless network performance, theoretical planning and software-based simulations alone are often insufficient. In this context, the importance of field tests and professional analysis tools becomes even more evident. Professional Wi-Fi analysis tools such as Ekahau AI Pro and Sidekick 2 not only enable signal strength measurements, but also allow for highly precise analysis of critical metrics such as spectrum activity, channel overlap, and signal-to-noise ratio (SNR). The results obtained in this study clearly demonstrate how effective and reliable these tools are in enterprise network environments.

In particular, the automatic planner feature offered by Ekahau AI Pro provides a significant advantage in optimizing access point (AP) placements by taking into account the internal building architecture. However, measurements conducted in the field have shown that relying solely on simulation results is insufficient. Real-time tests revealed significant differences between the planned AP placements and the actual signal distribution, especially with regard to secondary signal strength and roaming continuity. The success achieved through reorienting access points to enhance secondary signal strength contributes new insights to the literature. The findings indicate that secondary signal strength can be significantly improved not only by increasing the number of APs but also through proper orientation and strategic placement. Given the limited number of studies in the literature that demonstrate field-based improvements in secondary signal coverage through directional AP optimization, this contribution is particularly valuable.

In parallel with similar studies in the literature, this study also employed common mitigation strategies for channel interference. Specifically, the 2.4 GHz band was disabled due to its limited channel structure, and the 5 GHz band was constrained to 20 MHz channels to minimize overlap. Additionally, the assignment of static and non-overlapping channels to each AP positively impacted network stability. As a result of these optimizations, measurable improvements were observed in signal strength, SNR, and client handover continuity.

In conclusion, the use of advanced analysis tools is of great importance in the performance analysis of enterprise wireless networks. Especially in corporate environments, issues such as signal leakage, increased interference, or roaming failures are considered unacceptable. The findings presented in this study prove that comprehensive, field-supported optimization strategies are essential for building a high-performance and secure Wi-Fi infrastructure.

6. Conclusions

The aim of this study was to conduct performance tests of a corporate company's wireless network and implement optimizations based on the results. Performance analysis methods were carried out through measurements. Throughout the study, Ekahau AI Pro software and Ekahau Sidekick 2 device were used on all building floors. During the measurements, areas where access points (APs) were located were examined, and parameters such as signal strength, SNR (Signal-to-Noise Ratio), data rate, network capacity, and channel interference were accurately and reliably analyzed. These measurements and analyses revealed that the network was not implemented as initially designed. Placing APs in locations other than those determined by the automatic planner caused AP insufficiency in some areas, while many APs broadcast signals beyond the targeted coverage zones. The best signal strength was measured as -30 dBm in targeted areas with high personnel density, whereas in more distant regions, signal strength dropped between -67 dBm and -85 dBm. At signal levels around -85 dBm, connection continuity issues and disconnections were likely to occur. SNR levels were observed to be around 30 dB and above, indicating ideal connectivity. Channel interference emerged as the most significant issue in the existing network. This situation was particularly common in the 2.4 GHz band due to its limited number of channels, causing channel overlaps that negatively affected network performance. Despite the use of wide channels in the 5 GHz frequency band, heavy channel interference was also detected. In areas with channel interference, performance problems such as decreased network capacity, reduced SNR, packet loss, and increased latency were identified.

Based on the results, AP placements were reorganized, and access points were added to regions with signal strength between -67 dBm and -85 dBm. This arrangement brought the signal strength to the desired levels across all building floors and significantly reduced connection interruptions. Signal strength optimizations not only resolved weak signal issues but also improved low SNR and secondary signal strength values, enhancing overall network performance. In regions with severe channel interference, the 2.4 GHz band was disabled due to its limited channel structure to eliminate interference. In the 5 GHz band, the channel width was limited to 20 MHz to prevent potential interference caused by wide channel usage, and channel assignments for each access point were statically configured to be independent and non-overlapping. Each floor was upgraded to serve an average capacity of 200 end users.

Future studies may focus on the advantages of the 320 MHz wide channel structure offered by Wi-Fi 7 technology and the 6 GHz band in high-density environments. Additionally, AI-powered network management systems could be explored in areas such as channel optimization and dynamic resource allocation. The findings of this study demonstrate that proper AP placement and channel configuration have a direct impact on network performance. Strategies aimed at optimizing weak signal areas and reducing interference have increased network stability and ensured continuous connectivity. From a security perspective, a stable network design minimizes risks such as unauthorized access and data loss, contributing to the establishment of secure communication environments.

References

[1] H. Soy et al., "Kablosuz yerel alan ağlarında güncel gelişmeler: IEEE 802.11ac ile yeni nesil gigabit Wi-Fi," *J. Faculty Eng. Archit. Gazi Univ.*, vol. 28, no. 4, pp. 675-687, 2013.

[2] K. Pahlavan and P. Krishnamurthy, "Evolution and impact of Wi-Fi technology and applications: A historical perspective," *Int. J. Wirel. Inf. Netw.*, vol. 28, no. 1, pp. 3–19, Mar. 2021, doi: 10.1007/s10776-020-00501-8.

[3] R. Nazir, A. A. Laghari, K. Kumar, S. David, and M. Ali, "Survey on Wireless Network Security," *Arch. Comput. Methods Eng.*, vol. 29, no. 3, pp. 1591–1610, May 2022, doi: 10.1007/s11831-021-09631-5.

[4] A. Yılmaz and Z. Aslan, "802.11ax teknolojisinin kablosuz ağ altyapılarındaki rolü ve geleceği: Performans, güvenlik ve yenilik," *J. Anadolu Bil Vocat. School Higher Educ.*, vol. 19, no. 69, pp. 1–29, Jul. 2024, doi: 10.17932/IAU.ABMYOD.2006.005/abmyod_v19i69001.

[5] IEEE, "The evolution of Wi-Fi technology and standards," IEEE Standards Association, [Online]. Available: https://standards.ieee.org/beyond-standards/the-evolution-of-wi-fi-technology-and-standards/. Accessed: Oct. 23, 2024.

[6] S. Bytyqi and B. Jashari, "Experimental assessment of the effects of building materials on Wi-Fi signal 2.4 GHz and 5 GHz," *J. Comput. Commun.*, vol. 12, no. 05, pp. 1–10, 2024, doi: 10.4236/JCC.2024.125001.

[7] Ekahau, "How to accurately measure wall attenuation for the best Wi-Fi designs," [Online]. Available: https://www.ekahau.com/blog/how-to-measure-wall-attenuation-for-spotless-wi-fi-network-designs/#Why-You-Should-Measure-Wall-Attenuation. Accessed: Oct. 13, 2024.

[8] C. M. Own, J. Hou, and W. Tao, "Signal fuse learning method with dual bands WiFi signal measurements in indoor Positioning," *IEEE Access*, vol. 7, pp. 131805–131817, 2019, doi: 10.1109/ACCESS.2019.2940054.

[9] C. Aneke, H. Akpan Jacob, K. Constance, and A. Chikezie Samuel, "Application of Ekahau real time location software for the calibration of test beds for wireless network-base asset location management system," *J. Multidiscip. Eng. Sci. Stud.*, vol. 5, no. 8, pp. 2769-2776, Aug. 2019.

[10] N. E. Kaljahi, "Performance evaluation of Wi-Fi networks," M.S. thesis, Dept. Inf. Security Commun. Technol., Norwegian Univ. Sci. Technol., Trondheim, Norway, 2021.

[11] Ekahau, "Ekahau Site Survey & Heatmap Visualizations," Ekahau, Helsinki, Finland, Tech. Rep., 2016. [Online]. Available: https://www.ekahau.com/wp-content/uploads/2020/06/Ekahau-Site-Survey-Heatmap-Visualizations.pdf

[12] A. A. Rabbany et al., "Analisis pengaruh co-channel interference terhadap kualitas Wi-Fi pada frekuensi 2,4 GHz," *J. Komputer, Inf. Teknologi, dan Elektro*, vol. 6, no. 2, pp. 31–35, Aug. 2021.

[13] D. H. Kang, K. W. Sung, and J. Zander, "Attainable user throughput by dense Wi-Fi deployment at 5 GHz," in *Proc. IEEE Int. Symp. Personal, Indoor and Mobile Radio Commun. (PIMRC)*, London, UK, 2013, pp. 3418–3422, doi: 10.1109/PIMRC.2013.6666739.

[14] A. Zubow and R. Sombrutzki, "Adjacent channel interference in IEEE 802.11n," in *Proc. IEEE Wireless Commun. Netw. Conf. (WCNC)*, Paris, France, 2012, pp. 1163–1168, doi: 10.1109/WCNC.2012.6213952.

[15] I. Dolinska, M. Jakubowski, and A. Masiukiewicz, "Interference comparison in Wi-Fi 2.4 GHz and 5 GHz bands," in *Proc. Int. Conf. Inf. Digital Technol. (IDT)*, Zilina, Slovakia, Jul. 2017, pp. 106–112, doi: 10.1109/DT.2017.8024280.

[16] Fortinet, "Channels and channel planning," Fortinet Document Library, [Online]. Available: https://docs.fortinet.com/document/fortilan-cloud/24.2.0/fortilan-cloud-wi-fi-concept-guide/15862/channels-and-channel-planning. Accessed: Oct. 16, 2024.

[17] NetAlly, "AirMagnet® Survey Pro wireless design & site survey analysis software," NetAlly, Colorado Springs, CO, USA, Tech. Rep., 2023. [Online]. Available: https://www.netally.com/wp-content/uploads/AirMagnet-Survey-Pro-Datasheet.pdf

[18] Ekahau, "Ekahau AI Pro: The most trusted solution for business-critical Wi-Fi design create fast and reliable networks with powerful AI tools and expert-level customization options," Ekahau, Helsinki, Finland, Tech. Rep., 2024. [Online]. Available: www.ekahau.com

[19] NetSpot, "Plan, survey, visualize & improve WiFi network with NetSpot," [Online]. Available: https://www.netspotapp.com/features.html. Accessed: Oct. 30, 2024.

[20] Acrylic WiFi, "Wi-Fi site survey tool site survey," Tarlogic Security, Tech. Rep., 2024. [Online]. Available: www.acrylicwifi.com

Article Information Form

Author Contributions: The article was prepared by İsmail Hakkı Cedimoğlu and Berkay Dağtaş. İsmail Hakkı Cedimoğlu contributed to the literature review and provided guidance particularly in the methodology and results sections. Berkay Dağtaş was responsible for field studies, data collection, analysis, and the drafting of the manuscript.

Artificial Intelligence Statement: ChatGPT was used solely for grammar and spelling corrections during the preparation of the article. The scientific content, analysis, and interpretation were produced entirely by the authors.

Plagiarism Statement: This article has been scanned by iThenticate.