International Journal
Information Technology Applications (ITA)
Volume 14, Number 1, July 2025

OPTIMAL DESIGN OF A HOME NETWORK IN A Wi-Fi ENVIRONMENT

Lukáš Horčičák, Erik Chromý

Abstract:

The primary objective of this study is to design an optimal home wireless network based on an in-depth analysis of Wi-Fi signal coverage and interference. The research focuses on applying IEEE 802.11 standards and practical tools to measure, simulate, and improve the wireless environment in a real multi-floor household. Measurement tools such as NetSpot and iPerf were used to analyze signal strength, data throughput, and noise. Predictive simulations were performed using Hamina software to determine the optimal positioning of access points and frequency planning. The redesigned network was deployed and re-measured to compare performance metrics. Results indicate a significant improvement in signal coverage, more stable connectivity, and increased data transfer rates across all floors. The project also demonstrates the importance of proper channel allocation and network segmentation to reduce interference and improve network security. The presented approach provides a practical methodology that can be replicated in similar home or small office environments.

Keywords:

Wi-Fi, network design, signal analysis, performance optimization, wireless tools.

Introduction

Wi-Fi networks are essential for modern households, yet many suffer from poor coverage and interference due to inadequate design. This article focuses on creating an optimal wireless network using IEEE 802.11 standards and practical tools. A real three-floor house was analyzed with NetSpot for signal strength and iPerf for transmission speed, while Hamina was used for predictive design. The redesigned setup improved performance and stability across all floors.

The network upgrade was planned and executed following the Cisco PPDIOO methodology, which ensured a structured process from initial analysis through implementation and optimization. The results demonstrate that applying a lifecycle-based approach, combined with modern diagnostic and simulation tools, can significantly enhance the reliability and performance of home Wi-Fi networks.

1 The IEEE 802.11 Standard

The IEEE 802.11 standard defines a set of protocols for implementing wireless local area networks (WLANs). Since its introduction in 1997, various amendments have significantly improved throughput, range, and efficiency. These enhancements are primarily achieved through advances in modulation and multiplexing techniques. The earlier standard, 802.11b, used *DSSS (Direct Sequence Spread Spectrum)* with a maximum data rate of 11 Mbps in the 2.4 GHz band.

Its successor, 802.11g, introduced *OFDM (Orthogonal Frequency Division Multiplexing)*, raising speeds up to 54 Mbps while maintaining backward compatibility.

802.11n brought *MIMO (Multiple-Input Multiple-Output)* technology, enabling multiple spatial streams for increased capacity. It also supported both 2.4 GHz and 5 GHz bands and introduced *64-QAM* for higher data encoding density.

802.11ac improved upon this by using *256-QAM* and wider channels (up to 160 MHz), offering theoretical speeds over 1 Gbps in the 5 GHz band. The most significant upgrade came with 802.11ax (Wi-Fi 6), which introduced *OFDMA (Orthogonal Frequency Division Multiple Access)*. This method allows multiple devices to share a channel more efficiently, reducing latency and congestion in dense environments. Wi-Fi 6 also added *1024-QAM*, increasing spectral efficiency.

The latest amendment, 802.11be (Wi-Fi 7), further enhances performance with features such as *MLO (Multi-Link Operation)*, 320 MHz-wide channels, and *4096-QAM* modulation. These innovations provide extremely high throughput, ultra-low latency, and improved reliability, particularly for environments with high device density or demanding real-time applications. Though still in early deployment stages, 802.11be is expected to become the new standard for future-proof residential and enterprise wireless networks (Tab.1), [1], [2], [3].

Table 1. Comparison of IEEE 802.11n, 802.11ac, 802.11ax
in terms of speed, frequency bands, technologies used, and typical applications.

Standard	Max Speed	Band(s)	Key Techniques	Use Case
802.11n	600Mbps	2.4/5GHz	MIMO, OFDM, 64-QAM	Older networks
802.11ac	~1.3Gbps	5GHz	MIMO, OFDM, 256-QAM	High-throughput media
802.11ax	>9.6Gbps	2.4/5/6GHz	OFDMA, MU-MIMO, 1024-QAM	Modern homes, IoT
802.11be	>40Gbps	2.4/5/6GHz	MLO, 4096-QAM,	Future-ready

Given today's typical household usage, including video streaming, online gaming, smart home devices, and remote work. The recommended standard is IEEE 802.11ax (Wi-Fi 6) or Wi-Fi 6E, which adds support for the 6 GHz band. These standards offer higher throughput, better spectrum efficiency, and are optimized for environments with many connected devices.

Choosing a router that supports Wi-Fi 6 ensures future-proofing, better coverage, and significantly improved performance, particularly in homes with multiple users and smart devices.

2 Wireless Network Modernization Using PPDIOO Methodology

The modernization of a home wireless network was structured according to the Cisco PPDIOO methodology (Prepare, Plan, Design, Implement, Operate, Optimize). This structured lifecycle approach provided a clear framework for each phase of the project.

In the Prepare phase, the technical requirements of the household were analyzed, including the types of devices, their Wi-Fi standards, and typical usage (e.g. streaming, gaming, remote work). The Plan phase included a thorough site survey using tools like NetSpot for passive measurements and iPerf for throughput testing. In the Design phase, the wireless environment was virtually modeled using Hamina software to predict signal propagation and optimize access point placement. The Implementation phase involved the physical deployment of access points and selection of appropriate frequency channels based on spectrum analysis. During the Operate and Optimize phases, the network's performance was monitored and refined, including segmentation for IoT security and improved channel allocation. The PPDIOO framework ensured a systematic and effective network upgrade tailored to real household needs (Tab.1), (Tab.2).

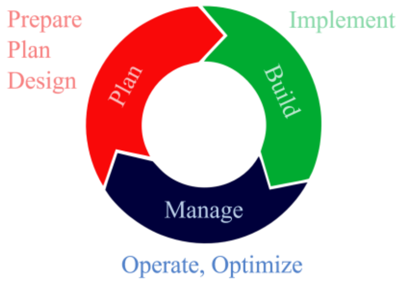

Fig.1: PPDIOO diagram.

2.1 Prepare

In the preparation phase, the wireless needs of the household were identified. The tested environment was a three-story family house equipped with multiple smart devices, including TVs, mobile phones, laptops, and IoT elements such as cameras and smart lighting. Key requirements included full coverage in all rooms, stable performance for 4K streaming, online meetings, and isolated traffic for IoT devices.

2.2 Plan

A detailed survey was conducted using NetSpot for passive signal analysis and iPerf for active hroughput testing. The tested network operated on the IEEE 802.11ac standard, utilizing both 2.4 GHz and 5 GHz frequency bands. Initial RSSI measurements revealed signal drops below –70 dBm in various rooms, especially on the upper floor. The 2.4 GHz band suffered from interference due to overlapping channels, which was confirmed by spectrum analysis (Fig.2-4).

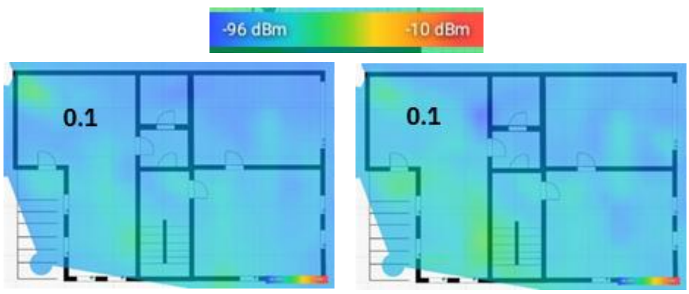

Fig.2: Heatmap - NetSpot RSSI - Basement 2.4 GHz and 5 GHz.

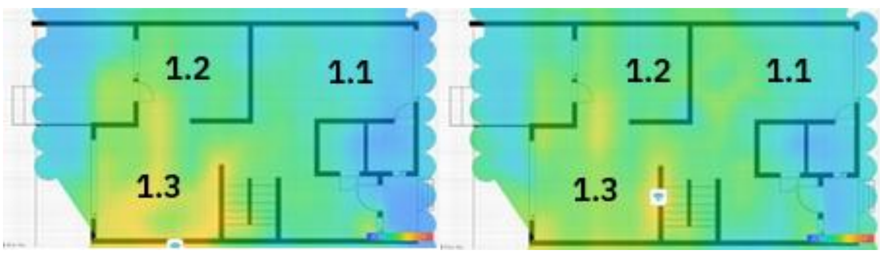

Fig.3: Heatmap - NetSpot RSSI - 1st floor 2.4 GHz and 5 GHz.

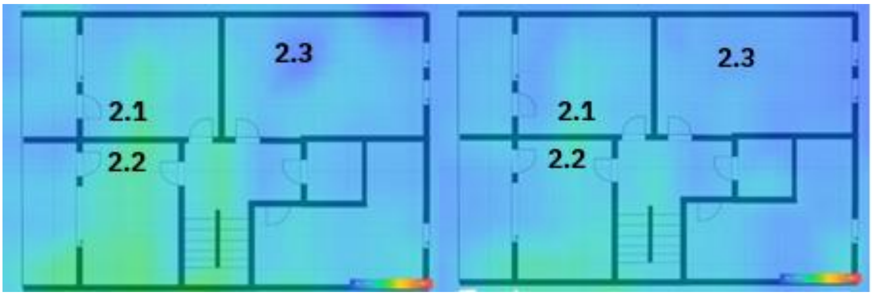

Fig.4: Heatmap - NetSpot RSSI - 2nd floor 2.4 GHz and 5 GHz.

Transmission speed measured using iPerf was:

Table 2: Transmission speed - Before upgrade.

	Frequency band	
Room:	2,4 GHz	5 GHz
1.1	81 Mbit/s	135 Mbit/s
	76 Mbit/s	145 Mbit/s
	94 Mbit/s	145 Mbit/s
1.2	98 Mbit/s	304 Mbit/s
	96 Mbit/s	389 Mbit/s
	97 Mbit/s	349 Mbit/s
1.3	91 Mbit/s	409 Mbit/s
	79 Mbit/s	424 Mbit/s
	92 Mbit/s	477 Mbit/s
2.1	79 Mbit/s	20 Mbit/s
	76 Mbit/s	21 Mbit/s
	90 Mbit/s	13 Mbit/s
2.2	89 Mbit/s	136 Mbit/s
	76 Mbit/s	144 Mbit/s
	94 Mbit/s	122 Mbit/s
2.3	28 Mbit/s	1 Mbit/s
	32 Mbit/s	2 Mbit/s
	31 Mbit/s	1 Mbit/s
0.1	88 Mbit/s	210 Mbit/s
	73 Mbit/s	233 Mbit/s
	87 Mbit/s	192 Mbit/s

2.3 Design

The network was virtually redesigned using Hamina Wireless software (Fig.5-7). Two access points (APs) were strategically placed on each floor to ensure seamless coverage. Non-overlapping channels (1, 6, 11) were selected for the 2.4 GHz band. In the 5 GHz spectrum, DFS channels were used to avoid neighboring network interference.

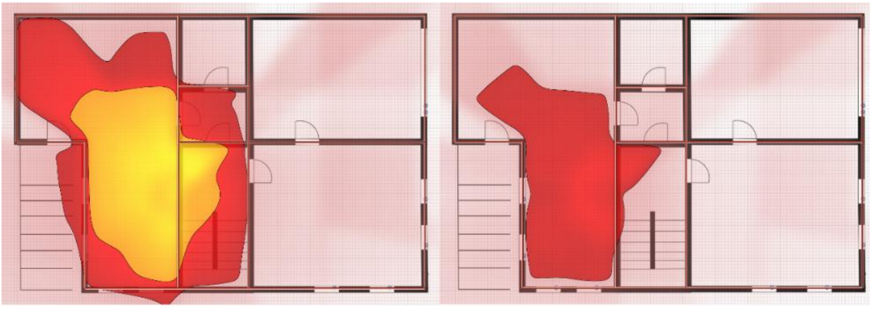

Fig.5: Simulation of Hamina coverage - Basement 2.4 GHz and 5 GHz.

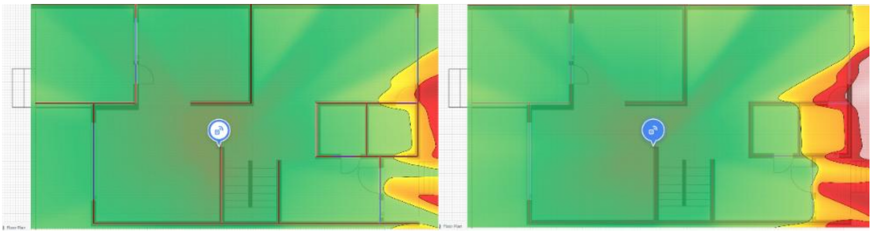

Fig.6: Simulation of Hamina coverage - 1st floor 2.4 GHz and 5 GHz.

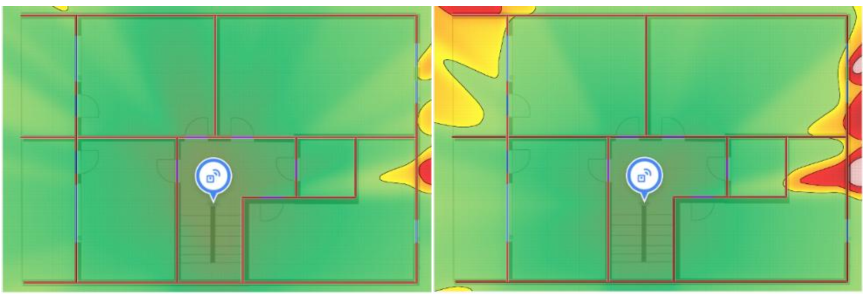

Fig.7: Simulation of Hamina coverage - 2nd floor 2.4 GHz and 5 GHz.

2.4 Implementation

The implementation phase involved physical installation of access points based on the design. Ceiling-mounted APs with Power over Ethernet (PoE) were used to allow flexible placement. Transmission power was adjusted to prevent signal bleeding between floors. Channel allocation and minimum RSSI thresholds were configured to support stable roaming.

2.5 Operate

After deployment, the network was monitored using FortiOS tools to track client distribution, signal strength, and performance. Adjustments included fine-tuning roaming parameters and verifying signal balance across the house.

Tab.3: Transmission speed - After upgrade

	Frequency band	
Room:	2,4 GHz	5 GHz
1.1	116 Mbit/s	426 Mbit/s
	115 Mbit/s	415 Mbit/s
	96 Mbit/s	411 Mbit/s
1.2	138 Mbit/s	865 Mbit/s
	142 Mbit/s	796 Mbit/s
	139 Mbit/s	824 Mbit/s
1.3	182 Mbit/s	932 Mbit/s
	184 Mbit/s	907 Mbit/s
	185 Mbit/s	901 Mbit/s
2.1	90 Mbit/s	753 Mbit/s
	100 Mbit/s	715 Mbit/s
	85 Mbit/s	718 Mbit/s
2.2	89 Mbit/s	909 Mbit/s
	95 Mbit/s	855 Mbit/s
	97 Mbit/s	910 Mbit/s
2.3	57 Mbit/s	492 Mbit/s
	58 Mbit/s	468 Mbit/s
	61 Mbit/s	492 Mbit/s
0.1	80 Mbit/s	209 Mbit/s
	86 Mbit/s	198 Mbit/s
	82 Mbit/s	200 Mbit/s

2.6 Optimize

In the proposed solution, the wireless network was segmented into three separate VLANs to enhance security and manage traffic more efficiently. One segment was dedicated to primary household users, another to guest devices with limited access, and a third isolated VLAN was used exclusively for IoT and smart home appliances. This segmentation helped prevent unauthorized access between device groups and reduced potential interference and network load.

Performance analysis based on iPerf measurements revealed a substantial increase in throughput. As shown in (Fig.9), the most significant improvements were observed in the 5 GHz band, where some locations (e.g., 1.3, 2.3) exceeded 900 Mbps, compared to values below 200 Mbps before optimization. In the 2.4 GHz band, improvements were also evident, with transmission speed nearly doubling in several areas.

This visual comparison confirms the effectiveness of deploying multiple access points with optimized placement and transitioning to the IEEE 802.11ax standard. The redesigned network consistently delivered high throughput and reliable coverage across all tested zones (Fig.8), (Fig.9).

Primary VLAN: Users and trusted devices.
Guest VLAN: Temporary devices
IoT VLAN: Smart home appliances

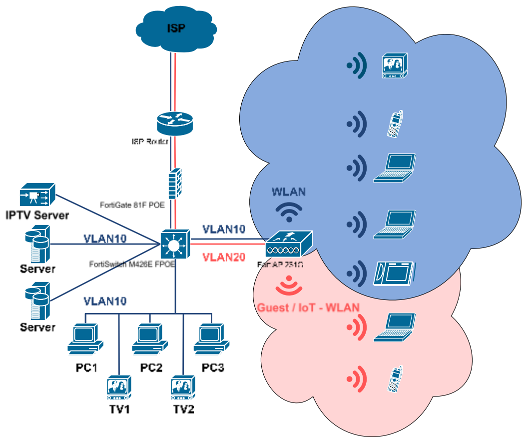

Fig.8: Network segmentation.

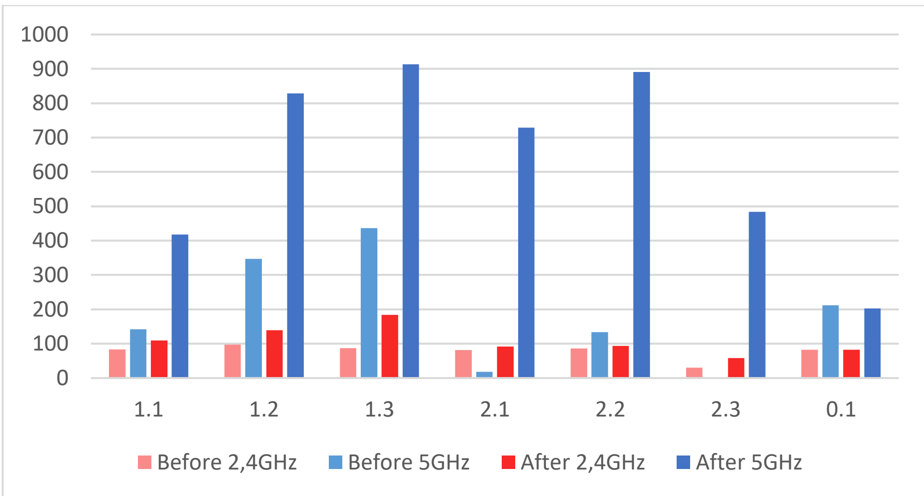

Fig.9: Transmission speed comparison.

Conclusion

This paper presents a practical approach to designing and optimizing a home Wi-Fi network using real-world measurements, predictive simulation, and structured planning based on the PPDIOO methodology. The original network, based on the IEEE 802.11ac standard and a single access point, was upgraded to a multi-access point infrastructure using the IEEE 802.11ax (Wi-Fi 6) standard. This upgrade, combined with optimal placement and network segmentation, significantly improved coverage, throughput, and overall reliability across all floors of the household. The results confirm that applying modern Wi-Fi standards and design tools can greatly enhance wireless performance in residential environments.

Acknowledgement

The author would like to thank to Ing. Erik Chromý, PhD., for his expert guidance and support during the development of this work. Appreciation is also extended to Pan-European University, Faculty of Informatics, for providing the academic environment and resources necessary to complete the project. This work was conducted as part of the bachelor thesis titled Optimal Design of a Home Network in a Wi-Fi Environment.

References

[1] Hucaby, D. (2014). CCNA Wireless 640-722 Official Cert Guide. Cisco Press. ISBN 978-1-58720-561-3.

[2] Edgeworth, B., Henry, J., Ransome, J. (2020). CCNP and CCIE Enterprise Core ENCOR 350-401 Official Cert Guide. Cisco Press. ISBN 978-0-13-678632-0.

[3] Henry, J., Dougherty, D. (2024). CCNP Enterprise Wireless Design ENWLSD 300-425 and Implementation ENWLSI 300-430. Cisco Press. ISBN 978-0-13-745962-9.

Authors

Lukáš Horčičák
Pan-European University, Faculty of Informatics, Bratislava, Slovakia
xhorcicak@paneurouni.com

Lukáš Horčičák is a student of Applied Informatics at the Faculty of Informatics, Paneuropean University in Bratislava.

Ing. Erik Chromý, PhD.
Pan-European University, Faculty of Informatics, Bratislava, Slovakia
erik.chromy@paneurouni.com

Erik Chromý is a specialist in computer networks and telecommunications. At the Faculty of Informatics, he focuses on network quality, modern communication systems, and simulation tools. He has contributed to several applied research projects and regularly publishes in international journals and conferences.