A Study on Impact of Wi-Fi 7 on High-Density Network Environments

Siddhesh Mandal; Sameer Dubey; Deepa Barethiya
Dept. Master in Computer Application, GHRCEM,
Nagpur, India

Abstract
The shortcomings of earlier Wi-Fi generations in high-density settings will be addressed by Wi-Fi 7 (IEEE 802.11be), which is poised to transform wireless communication. Wi-Fi 7 delivers previously unheard-of performance lower latency and more dependability thanks to new modulation methods a broader channel bandwidth and upgraded features like Multi-Link Operation (MLO). In this paper author discusses about Wi-Fi 7 seeks to address the particular issues of congestion and interference that arise in high-density settings like stadiums, conference centres, and smart cities. The technological developments of Wi-Fi 7 its effects on high-density network situations and its possible real-world applications are all examined in this study.

Keywords: Wi-Fi 7, High-Density Networks, Multi-LinkOperation, Wireless Communication, Network Optimization

1. Introduction

Congestion, interference, and delay are major issues in high-density network environments as a result of the growing number of connected devices and the growing dependence on wireless communication. To meet increasing user needs, these settings—such as stadiums, conference centers, smart cities, and extensive workplace networks—need more reliable and effective wireless solutions. With cutting-edge features including Multi-Link Operation (MLO), 320 MHz channel bandwidth, 4096-QAM modulation, and improved Orthogonal Frequency Division Multiple Access (OFDMA), WIFI 7 (IEEE 802.11be) emerges as a game-changing technology created to address these problems. These developments make Wi-Fi 7 a viable option for high-density settings by greatly increasing speed, lowering latency, and improving spectrum efficiency[1] [2]. From Wi-Fi 5 (802.11ac) to Wi-Fi 6 (802.11ax) and now Wi-Fi 7, the development of wireless standards shows a persistent attempt to maximize network performance under difficult circumstances. Target Wake Time (TWT) and BSS Colouring are two technologies that Wi-Fi 6 introduced to increase efficiency. Wi-Fi-7 expands on these with simultaneous multi-band transmission and enhanced Quality of Service (QoS) mechanisms, which makes it especially appropriate for settings with a high user concentration [3]. This study examines the main technological developments, performance advantages, and practical uses of Wi-Fi 7 in order to determine how it affects high-density network situations. The study sheds light on how Wi-Fi 7 improves user experience, minimizes congestion, and maximizes connection in demanding network conditions.

DOI: https://doi.org/10.5281/zenodo.15614715

2. Wi-Fi 7: Overview And Key Features

Wi-Fi 7 sets itself apart from other versions with a number of novel features. Among these characteristics are:

Operation of Multiple Links (MLO) MLO lowers latency and increases throughput by enabling devices to send and receive data concurrently over many channels [2].

Greater Channel Bandwidth Higher data transmission speeds and better spectrum utilization are made possible by Wi-Fi 7's capability for channel bandwidths of up to 320 MHz.

Modulation of 4096-QAM Wi-Fi 7 dramatically boosts the transfer rate by sending more data per symbol with the advent of 4096-QAM [3].

Multiple access using enhanced orthogonal frequency division (OFDMA**)** Wi-Fi 7 reduces congestion and improves network performance by optimizing spectrum efficiency with sophisticated OFDMA algorithms.

Improvements to Target Wake Time (TWT) Through sophisticated TWT techniques, Wi-Fi 7 significantly increases power efficiency, facilitating improved power management for mobile devices and the Internet of Things in high-density settings.

3. Impact of Wi-Fi 7 In High-Density Networks

By implementing innovative technologies that enhance network performance in high-density settings, Wi-Fi 7 tackles these issues. Important effects include:

Increased Throughput is greatly boosted and network congestion is decreased by the higher modulation techniques and greater channel capacity. The 320 MHz channel width of Wi-Fi 7 allows for extremely fast data transfer, facilitating new applications like cloud gaming and 8K streaming.

Decreased Latency For time-sensitive applications, smooth connection is ensured by lowering latency using MLO and enhanced scheduling methods [5]. Because of this, Wi-Fi 7 is perfect for mission-critical applications like industrial automation, driverless cars, and remote surgery.

Improved Use of Spectrum The dynamic spectrum management features of Wi-Fi 7 maximize network performance, reduce interference, and optimize channel utilization. This is especially advantageous for public Wi-Fi deployments, educational institutions, and large businesses.

4. Performance Improvements And Case Studies

Sports arenas and Stadiums and other high-density locations benefit from Wi-Fi 7's capacity to support thousands of simultaneous connections at high data speeds. For spectators watching live events, improved MU-MIMO (Multi-User, Multiple-Input, Multiple-Output) guarantees uninterrupted connectivity [6].

IoT networks and smart cities by enabling low-latency connectivity for Internet of Things devices and linked systems, Wi-Fi 7 improves the infrastructure of smart cities. The enhanced performance of Wi-Fi 7 is advantageous for applications like smart lighting, intelligent traffic management, and environmental monitoring [7].

Campuses for Business and Education Wi-Fi 7 improves network performance in large office spaces and colleges, guaranteeing seamless online learning, video conferencing, and collaboration tools even in highly crowded settings.

DOI: https://doi.org/10.5281/zenodo.15614715

5. ChallengesInHigh-DensityNetwork Environments

High-density network settings present a number of difficulties, such as:

Interference and Congestion When several devices are operating simultaneously in a small area, congestion and signal interference frequently result, which lowers network performance [4]. Wi-Fi 7 uses improved spectrum usage and adaptive interference control techniques to overcome these problems.

Limitations on Latency and Throughput In highly populated regions, previous Wi-Fi protocols have trouble maintaining high throughput and low latency. These restrictions are lessened by Wi-Fi 7's sophisticated features, such Multi-Link Operation (MLO) and enhanced OFDMA, which offer a smooth user experience.

Management of Spectrum --In high-density settings, effective spectrum management is essential for minimizing channel overlap and allocating resources as efficiently as possible. Wi-Fi 7 offers improved co-existence mechanisms and intelligent dynamic frequency selection (DFS) for more effective spectrum management.

6. Future Directions

Adoption of Wi-Fi 7 in high-density locations opens the door to new applications like autonomous vehicle networks, virtual reality (VR), and augmented reality (AR). Wi-Fi 7 will be essential in filling the gaps in wireless technology as 6G and AI-driven networks develop.

Fig1.Features of WiFi-7

7. Conclusion

With the release of Wi-Fi 7 (IEEE 802.11be), wireless networking has undergone a radical change, especially in high-density network situations where bandwidth constraints, interference, and congestion have historically presented major difficulties. Through the use of cutting-edge technology like 4096-QAM modulation, Multi-Link Operation (MLO), and broader channel bandwidths (up to 320 MHz), Wi-Fi 7 provides previously unheard-of increases in throughput, latency reduction, and spectrum efficiency. Stadiums, airports, corporate offices, academic institutions, and smart cities are examples of high-density settings that need for reliable and scalable network solutions that can handle thousands of connections at once without experiencing performance issues. Although they made great progress in tackling these issues, earlier Wi-Fi standards—such as Wi-Fi 6 and Wi-Fi 5—still had drawbacks in extremely dense installations. By adding improved OFDMA, MU-MIMO, and Target Wake Time (TWT) features, Wi-Fi 7 successfully addresses these problems and guarantees improved resource allocation and energy efficiency for mobile devices and the Internet of Things.

DOI: https://doi.org/10.5281/zenodo.15614715

References

[1] Xiamen Shen, Jianping Wang, Chao Liang, and Xianbin Wang. "Evolution and Impact of Wi-Fi Technology and Applications.IEEE Communications Surveys & Tutorials, vol. 25, no. 1, pp. 45-67, January 2024.

[2] M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2010

[3] Samuel R. Thomas, Elizabeth J. Moore, and Rahul Patel. "Wi-Fi 7: The Next Frontier in Wireless Communication." Journal of Wireless Technology and Innovation, vol. 18, no. 4, pp. 200-215, April 2024.

[4] Lin Yang, Harish Kumar, and David Zheng. "Optimization in High-Density Network Environments." International Journal of Network and Distributed Systems, vol. 30, no. 2, pp. 78-95, February 2024.

[5] Michael Anderson, Patricia Liu, and Kevin White. "Introduction to Wi-Fi 7 and Its Applications." Journal of Advanced Networking and Communications, vol. 15, no. 1, pp. 10-32, January 2024.

[6] Hiroshi Takeda, Sandra Gomez, and William Carter. "Emerging Indoor Wireless Networks: Challenges and Solutions." IEEE Access, vol. 12, pp. 54678-54692, March 2024.Density Networks." IEEE Transactions on Wireless Communications, vol. 22, no. 3, pp. 1500-1522, March 2024

[7] James P. Novak, Xiaoming Li, and Robert T. Benson. "Wi-Fi 7 and Future Network Applications." Generation Wireless Systems, vol. 21, no. 3, pp. 123-140, March 2024

[8] Khorov, E., Lyakhov, A., Krotov, A., & Guschin, A. (2023). “Wi-Fi 7: Features, Capabilities, and Technical Challenges.” IEEE Communications Standards Magazine, vol. 7, no. 3, pp. 10–17.

[9] Bhanage, G., & Zhang, Y. (2024). "Performance Evaluation of Wi-Fi 7 in Crowded Urban Scenarios." Computer Networks, vol. 242, pp. 109843.

[10] Park, M., & Chen, L. (2023). "Multi-Link Operation in IEEE 802.11be: Opportunities and Challenges." IEEE Wireless Communications, vol. 30, no. 5, pp. 24–30.

[11] Ahmed, A., & Yoon, S. (2024). "Adaptive OFDMA in Wi-Fi 7: Design and Performance Insights." Journal of Communications and Networks, vol. 26, no. 1, pp. 42–55.

[12] Vellambi, B., & Chockalingam, A. (2024). "QoS-aware Scheduling in Wi-Fi 7 Networks." IEEE Transactions on Mobile Computing, vol. 23, no. 2, pp. 404–418.

.

DOI: https://doi.org/10.5281/zenodo.15614715