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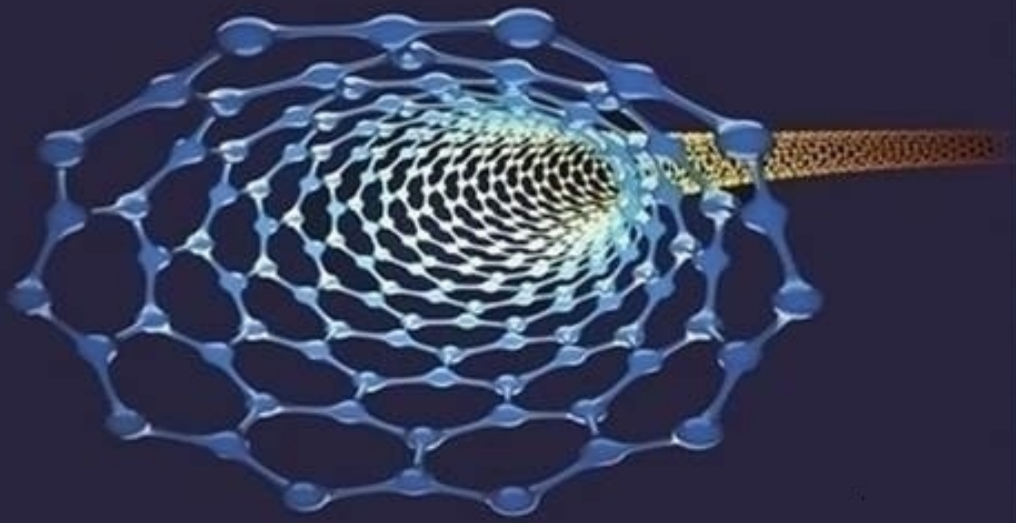

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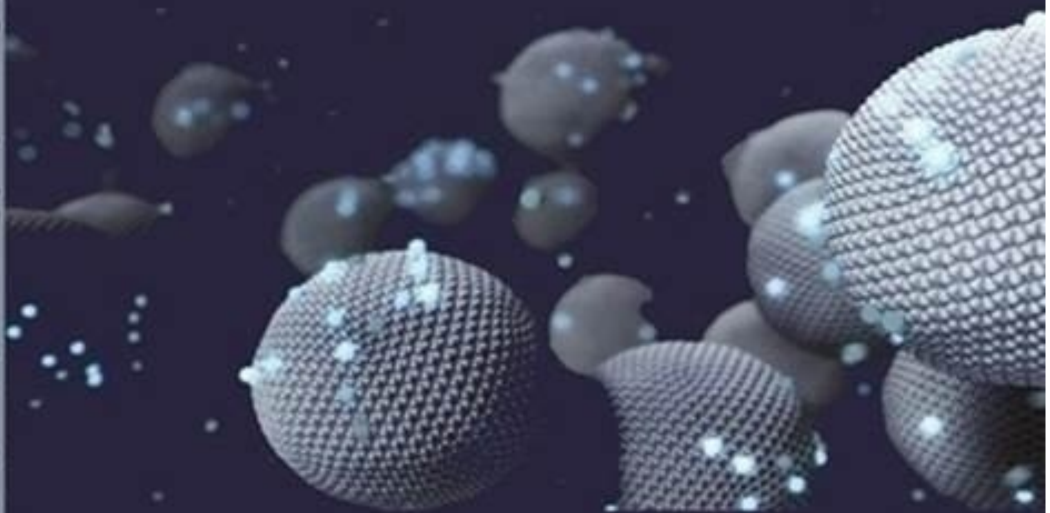

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RESEARCH PAPER

Practical Analysis of IEEE 802.11ax Wireless Protocol in Wi-Fi Boosters Environments

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A B S T R A C T:
All the world now is depending on networks to share information between the users, where different data types are transferred wirelessly from network to network. Using wireless LANs are important to connect the users and share the data, these Wireless LANs have different types of obstacles that affect the data sharing or the wireless signal, such as, compatibility wireless protocol types, range coverage, walls penetration, moving devices, different routing protocols, data transferred types, weak signal, and many more. In this paper a practical analysis will be made to the latest IEEE 802.11ax wireless protocol to be compared with two types of Wi-Fi booster's networks, Mesh and Extender Wi-Fi, while transferring 4k video size data rate, inside a room and on different rooms for wall penetration analysis, while measuring the throughput, delay, and signal strength metrics. The main importance of this paper is to give a more practical understanding and avoid the main problems of using the wireless protocol 802.11ax in different network types.

KEY WORDS: IEEE 802.11ax, Wi-Fi Boosters, Signal Strength, Mesh Network, Extender Network.

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1. I NTRODUCTION:

When the WLAN signal is not performing at best due to dropped connections, slow speeds, dead Wi-Fi spots, etc. [1]. A solution must be done to enhance the network connection for the WLAN users with the best Wi-Fi wireless protocol. The IEEE 802.11 wireless protocols became very popular in recent wireless devices as they give the standards of data transmission speed rate and coverage distance [2]. These standards made it possible to share large amounts of data between the users in the same network or through different networks with different rooms. The upgrades in IEEE wireless protocols of 802.11 made it possible to enhance the mobility, flexibility, increasing data rates, penetrating walls, reducing the time of maintenance and installation, and the ease of use between networks, as it results in large scale WLAN deployment enhancement for different areas, interior, and exterior with different types of applications [3].

These deployments can be used for Wi-Fi booster networks such as in both mesh and Wi-Fi extenders. In mesh, all devices can work as one system connected through the entire area, the main device called a mesh router, while other devices are called nodes that are connected through different areas with a triple or double connection between all devices. While in Wi-Fi extenders, is a device that extends the Wi-Fi signal through different areas to help far devices to connect to the main device, as shown in figure (1) [4].

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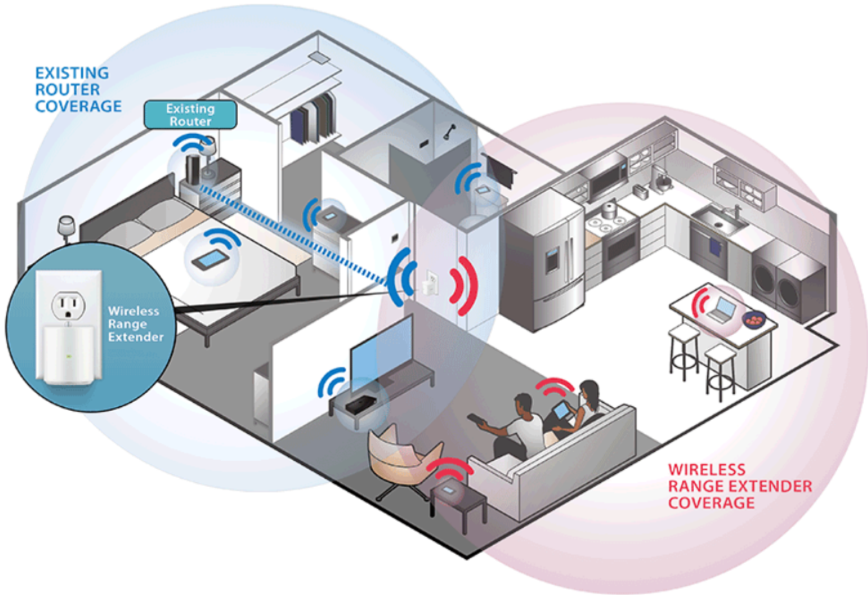

Figure (1): Wi-Fi Boosters in Home Wireless Networks [4].

These new Wi-Fi Boosters use the new IEEE 802.11ax wireless protocol, as it gives huge improvements from the old IEEE 802.11 wireless standards as shown in table 1 [5].

Table 1: IEEE 802.11 Wireless Protocols Standards [5].

IEEE 802.11 Wireless Standards	Frequency	Maximum Data Rate
802.11a	5GHz	54 Mbps
802.11b	2.4GHz	11 Mbps
802.11g	2.4GHz	54 Mbps
802.11n	2.4GHz, 5GHz	600 Mbps
802.11ac	2.4GHz, 5GHz	1.3 Gbps
802.11ax	2.4GHz, 5GHz, 6GHz	10-12 Gbps

The increase in data rate was done using different and faster coding schemes and modulation with wider channels and the implementation of (MIMO) Multiple Input Multiple Output technique [6].

Still, further data rate upgrades need newer channel access techniques rather than giving wider channels, therefore it's more difficult to upgrade the wireless protocols frequently [6].

The latest IEEE 802.11 wireless protocol used recently is the 802.11ax protocol, this protocol is the successor of the IEEE 802.11ac, also known as WIFI 6E that operates in 6 GHz frequency as it operates from 1 and 7.125 GHz, including the 2.4 and 5 GHz bands, this protocol was created mainly to enhance the throughput of the data transmission between the devices for small and medium areas and offices [7].

The main contribution of this paper is to measure the practical performance of the latest IEEE 802.11ax wireless protocol with real-life scenarios for the best user environment to see the best usage with the highest throughput and lowest delay.

In this paper the performance of IEEE 802.11ax wireless protocol will be measured with real devices and simulated with two types of Wi-Fi boosted networks, mesh and Wi-Fi extenders, with a 4k video transmission to capture the highest throughput between the devices, end to end delay, and signal strength of the transmitted video.

The rest of the paper will be organized as follows, section 2 will give short-related work information, while section 3 will provide a deep background of the IEEE 802.11ax with related network design, and section 4 will give the scenario simulations parameters and the final result will be discussed, finally, in section 5 the conclusion and future work of the paper will be presented.

2. Related work:

As IEEE 802.11ax is the latest wireless protocol in the market many researchers tried to analyze, simulate and enhance these protocols. In [8] the important techniques of IEEE 802.11ax such as OFDMA random access, spatial reuse, UL MU-MIMO, and OFDMA PHY were discussed and overview, highlighting the main principal design to give smart environmental opportunities. In [9], the author explains briefly the different breakthroughs of the 802.11ax protocol with the new orthogonal FDM technique, with newer frequency reuse method. The results show an enhancement in the protocol of more than 20% than the default one. In [10] the research paper surveys the evaluation of 802.11ax performance and by using technology SLISP platform, as the result shows that the 802.11ax highly improves large scale networks end-user experience and achieving higher throughput for data rates transmission. Also, in [11] the author gives an overview of the 802.11ax key features such as MU-MIMO, OFDMA PHY, UL, OFDMA random access, spatial reuse, and power-saving, also the paper highlights the principal design to give better scenarios to be used. Finally, in [12] the author shows the 802.11ax and 802.11ac comparison while using 5GHz frequency with NS3 simulator with measuring the throughput and delay for both protocols, the result shows that 802.11ax gives better throughput with a large number of uses but with a higher delay that the 802.11ac wireless protocol.

3. IEEE 802.11ax Wireless Protocol and Network Boosters:

As Wi-Fi upgrading, more devices are created to support the latest IEEE 802.11 wireless protocols, and with more connected devices to the same routers, they need a huge bandwidth for heavy traffic applications, therefore future networks will demand more bandwidth reliability and capacity to support and maintains reliability for all connected users [13].

4. IEEE 802.11ax Wireless Protocol:

Upgrading Wi-Fi standards gives more improvement in both performance and stability, therefore the latest 802.11ax gives a significant boost to the performance of Wi-Fi with a maximum data rate of 10-12 Gbps and longer coverage distance. This wireless protocol is the new enhanced version of the previews 802.11ac wireless protocol, with newer features that support scalability and flexibility with less power consumption for more traffic demanding applications.

The new IEEE 802.11ax gives a higher level of service to the new and old applications, which makes it very desirable to be used and replace the old IEEE 802.11 wireless protocols. The IEEE 802.11ax can support more users in a large environment with enhanced user experience in different wireless networks, with more reliable performance for highly advanced applications such as UHD, IoT, 4K videos, gaming, transferring large files, and many more.

It can achieve better performance by maximizing the main dimensions, firstly, with denser modulation using 1024 QAM (Quadrature Amplitude Modulation) that can give more than 35% of speed data rate, secondly, by using OFDMA based scheduling to decrease the latency and overhead as shown in figure (2), and finally, very powerful and highly efficient signal broadcasting for minimum received signal strength indication (RSSI) [14].

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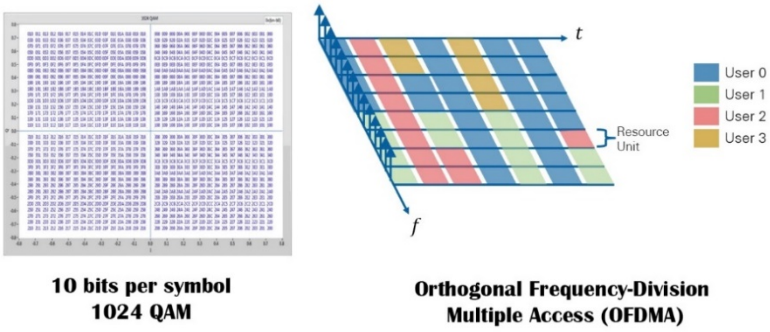

Figure (2): 1024 QAM / OFDMA enhancement Techniques for 802.11ax [14].

The OFDMA technology in IEEE 802.11ax supports eight spatial streams and gives approximately up to 10-12 Gbps data rate at the physical layer. Therefore, all users will achieve higher data transmission at the MAC layer, with the best user experience. Also, with the support of dual-band frequency of 2.4GHz and 5GHz different devices can connect for a longer range and faster data rate [15].

The new IEEE 802.11ax works by using a higher number of QAM modulations that achieve a faster data rate by permitting more data packets to be sent over the channel. Also, it can give higher spectrum utilization efficiently by creating broader channels and splitting them into sub narrow channels, which increase the available number of total channels, which make it easier for the users to find and connect to a clear channel to the router, as shown in figure (3) [16].

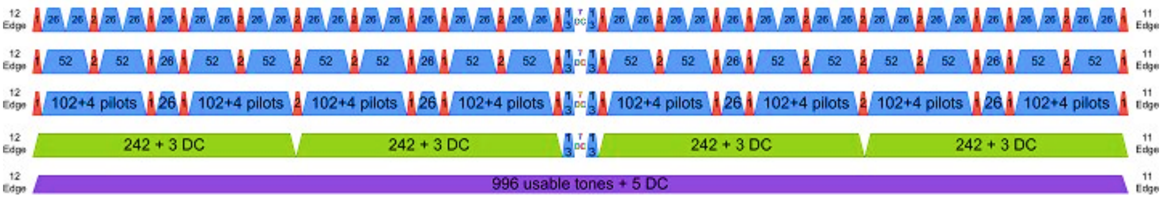

Figure (3): Sub-Channels of Different Resource Unit sizes [16].

The other basic IEEE 802.11 standard wireless protocols allow only one transmission per time between the user and the access point router, while the new standards such as 802.11ac with the integration of Multi-Input, Multiple Output (MU-MIMO), allows the wireless access point router to connect up to four connections simultaneously, while the 802.11ax can give up to eight connections in the same time while using an explicit beamforming technique, also to aim those connections more accurately at the receiver's antenna, as shown in figure (4) [17].

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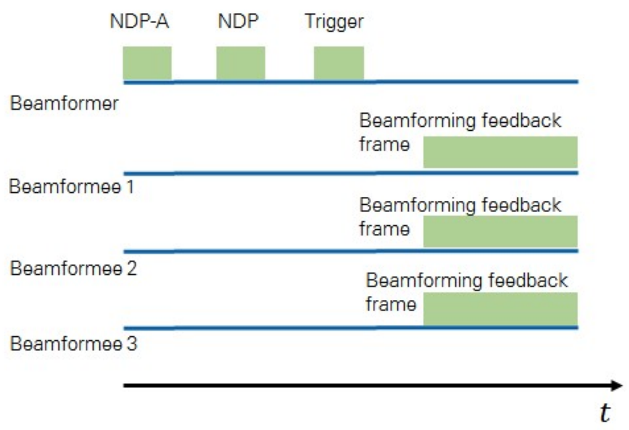

Figure (4): MU-MIMO operation requesting channel information using a beamformer router [17].

Furthermore, to increase the speed of 802.11ax four times the existing speed, the OFDMA technology was piggybacked on MU-MIMO channels, which allows each MU-MIMO connection to be divided into four additional connections, thus boosting the data transfer rates, as shown in figure (5) [17].

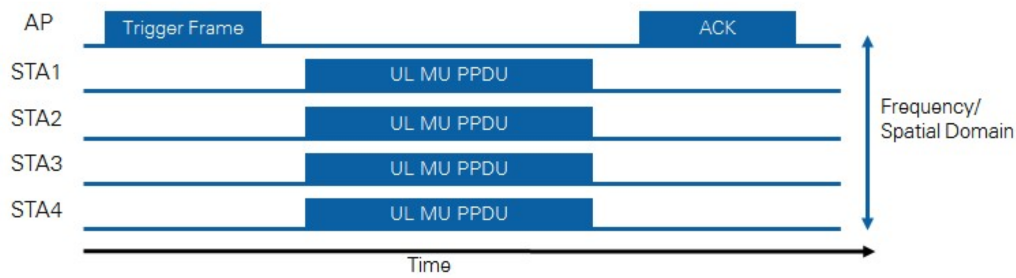

Figure (4): Acknowledge Message in MU-MIMO channels [17].

As the 802.11ax wireless protocol supports 2.4GHz, 5GHz, and 6GHz frequencies, it can determine frequency ranges of 20MHz, 40MHz, 80MHz, and 160MHz channels, which means it can give more channels that are not interfering with each other, hence giving more data rates speed and longer-range coverage without interference.

5. Wi-Fi Boosters Networks:

WLANs are a form of networks that transfer data without using any cables, but still, it cannot transmit for longer distance, therefore wireless devices will be used to strengthen the signal for longer distances [18], these devices called Wi-Fi boosters.

These boosters can extend the network wireless coverage over a specific area, they can be used as signal extenders, by rebroadcasting the weak Wi-Fi signal to other areas with the same name or with different names. Unfortunately, rebroadcasting the same signal more than one time weakens the signal strengths and quality [19]. Also, Wi-Fi boosters can use a newer technology called mesh Wi-Fi networks, these networks consist of several nodes that are connected, while all the users will connect to any node directly, the main advantage is that the signal does not weaken during rebroadcasting as each node is connected directly with other nodes while all nodes are connected in a mesh topology.

Mesh networks can be suited best for high-performance networks, while Wi-Fi extenders are suited best for local and small range networks, figure (5) shows the Wi-Fi boosters types [20].

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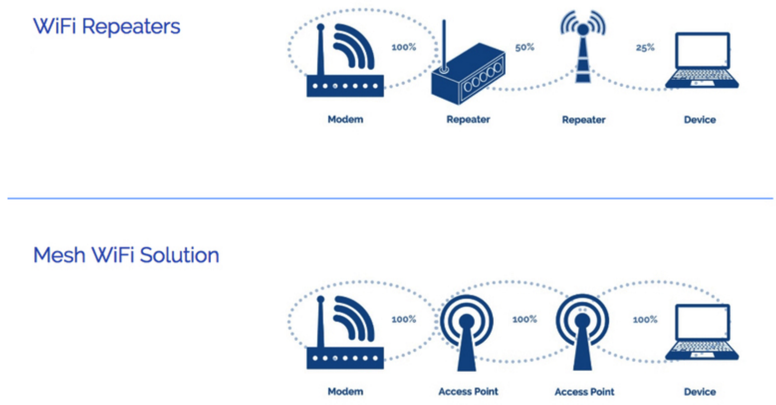

Figure (5): Wi-Fi Boosters Types [20].

6. Practical Scenarios Analysis and Results:

To analyze the IEEE 802.11ax wireless protocol performance in real-life scenarios, two practical scenarios were designed and implemented, the first scenario with a group of 6 wireless routers that support the 802.11ax wireless protocol are connected in a mesh topology with 2 802.11ax supported laptops that transferring a 4k 10 min video with a total size of (8.35 GB), while the second scenario connects 6 wireless routers in an extender signal design while connecting the 2 two laptops while transferring the 4k video. Both scenarios were implemented inside one room (10x10) m^2 and between rooms (20x20) m^2 to measure the wall penetration effect on the performance of the network, as shown in table (2).

Table (2): Practical Simulation Parameters.

Parameters	Metrics
IEEE Wireless Protocol	802.11ax
Network Topologies	Wi-Fi Mesh, Extender
Area size (No Walls, Walls)	10x10 m^2, 20x20 m^2
No. of wireless devices connected	6 routers, 2 laptops
Video format, Size, Duration	4K, 8.35 GB, 5 Min
No. of Walls used	1, 2 Walls
Wi-Fi Frequencies measured	2.4GHz, 5GHz

Figure (6) shows the practical throughput (Gbps) performance of both network boosters, mesh, and extender. The best performance was found in mesh 5GHz frequency with no walls as it gives the highest throughput compared to others, unfortunate with walls the performance drops down heavy as the 5GHz frequency as its path loss is much higher than the 2.4GHz which fades the signal faster through walls [21].

Mesh networks give better performance in throughput as the nodes communicate together in different channels than transmitted data channels, which gives the best performance through walls also.

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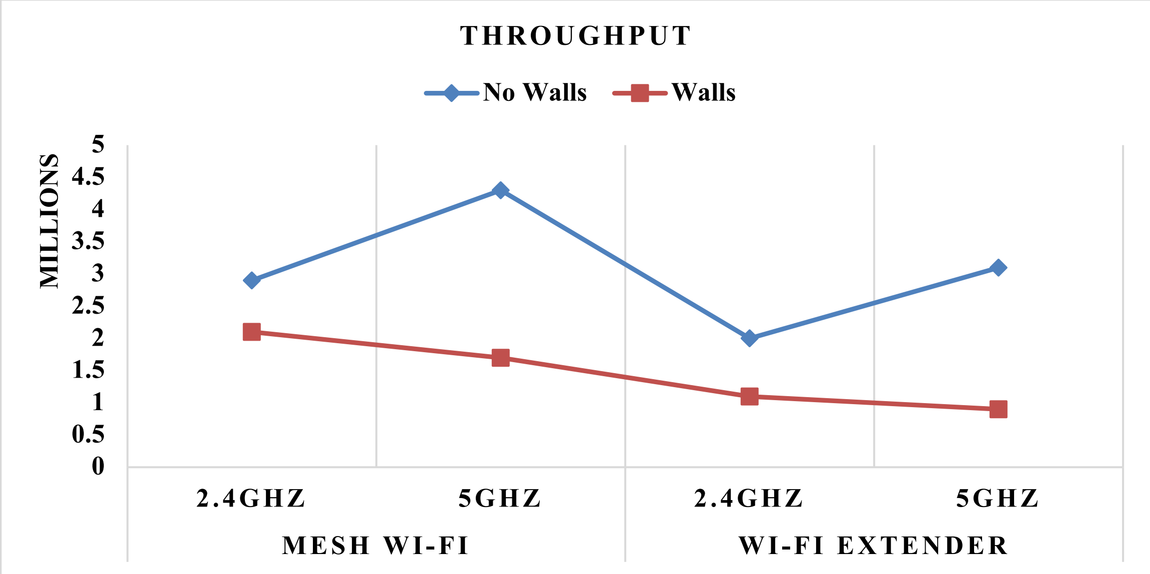

Figure (6): Throughput (Gbps) of Both Mesh and Extender network with and without walls

Figure (7) demonstrates the highest delay (seconds) in 5GHz extender Wi-Fi networks as its signal fades through walls with also rebroadcasting fading, which gives a very high delay in receiving the packets. The lowest delay can also be seen in the 5GHz no walls scenario as it's connected directly to the user with maximum transmission rate.

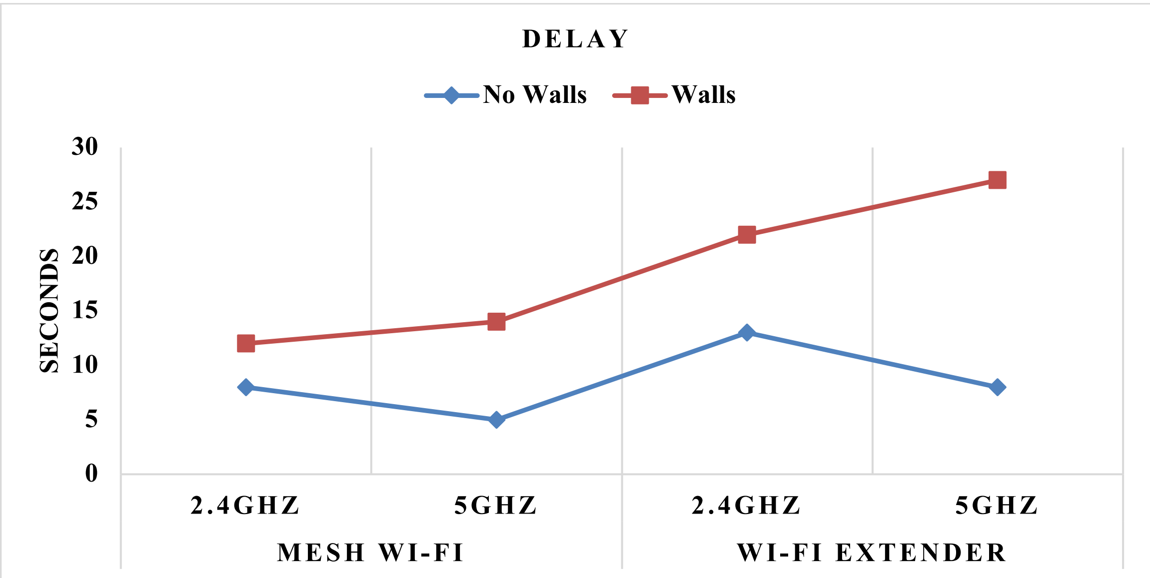

Figure (7): Delay (seconds) of Both Mesh and Extender network with and without walls

Finally, figure (8) shows the signal strength of the two networks, where the 2.4GHz shows the best result for both with and without walls, as it has lower path loss which gives more distance coverage. Unfortunately, 5GHz gives the lowest signal strength as it has short-range coverage.

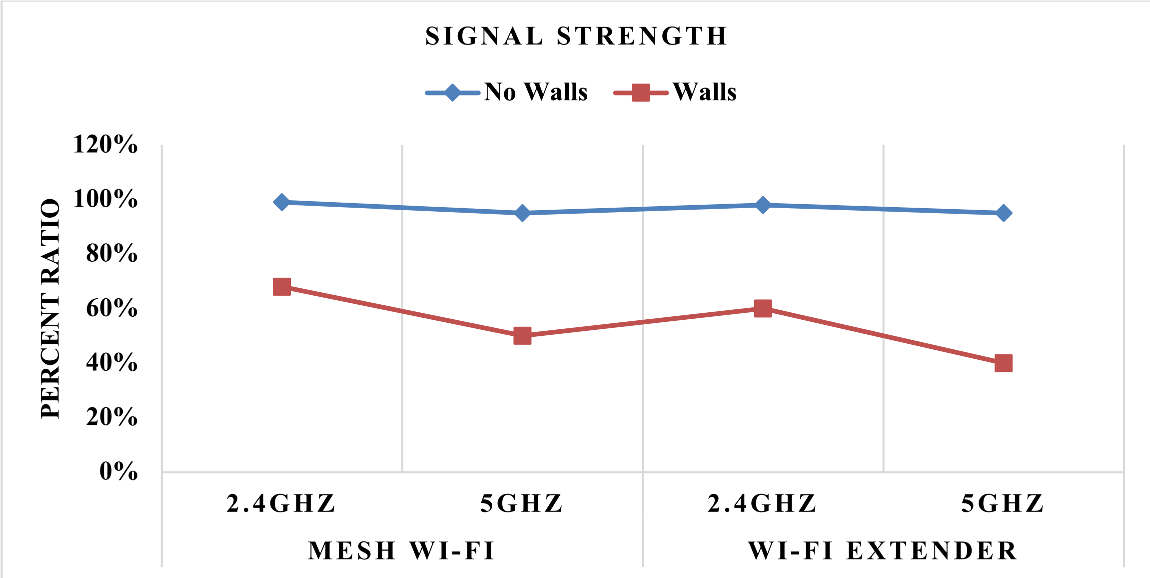

Figure (6): Signal Strength of Both Mesh and Extender network with and without walls

7. CONCLUSIONS

The IEEE 802.11ax wireless protocol gives remarkable improvement to the old wireless protocols in data transmission performance for different user environments, as it is implemented with advanced mechanisms to support more users and higher data transmission with reliable data transfer nowadays.

In this paper, a comprehensive practical analysis was done using real IEEE 802.11ax wireless routers connected with two scenarios Wi-Fi mesh and Wi-Fi extenders that broadcast two types of frequencies 2.4GHz and 5GHz in one room and two rooms separated with walls, to measures the throughput, delay and signal strength of the received signal.

The result shows that the best Wi-Fi booster for IEEE 802.11ax is Wi-Fi mesh connection as it keeps the signal strength as high as possible in both 5GHz and 2.4GHz, while 5GHz gives the lowest performance through walls. For Wi-Fi extenders, it gives lower performance compared to Wi-Fi mesh networks as it's suited for very short coverage with lower walls as possible.

For future work, it's recommended to test more result and metrics for the IEEE 802.11ax and comparing it with the older version in the different user environment, also its recommended to use more advance varying technology such as MANET, VANET, and FANET to measure the fast-changing topology impact of the IEEE 802.11ax performance.

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