Wi-Fi 6 and Wi-Fi 6E

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ABSTRACT

The second-largest population in the world is found in India. Thus, as everyone wants to stay connected to modern technology, more bandwidth is needed to access their entertainment, such as video games, music, text, and phoning. The Wi-Fi 6 technology known as 802.11ax was introduced by the IEEE. In comparison to 802.11ac (WiFi5), 802.11ax (WiFi6) has a network bandwidth that is four times higher. It offers several features, including a network without coverage gaps, service with no wait times, no packet loss while roaming, and use in a variety of industries, such as smart governance, smart health care, and digital calculation. WiFi6 is the sixth version of Wi-Fi, which lowers network latency from 30 ms to 20 ms and contains a variety of important 5G technologies as OFDMA, MU-MIMO, and 1024 QAM. The purpose of this essay is to contrast Wi-Fi 5 to Wi-Fi 6.

INTRODUCTION

The demand for WiFi-6 applications is rising as the 5G era approaches. Wi-Fi 6 and Wi-Fi 6E are the latest generations of Wi-Fi technology, offering significant improvements over their predecessors in terms of speed, capacity, efficiency, and performance in high-density environments. Wi-Fi 6, also known as 802.11ax, is the sixth generation of Wi-Fi technology. It introduces several key advancements:

Higher data rates: Wi-Fi 6 supports higher data rates compared to previous generations. It uses more advanced modulation techniques, such as 1024-QAM, which enables higher throughput and better efficiency.

Increased capacity: Wi-Fi 6 uses Orthogonal Frequency Division Multiple Access (OFDMA) to divide a Wi-Fi channel into smaller sub-channels, allowing multiple devices to transmit data simultaneously. This improves the overall network capacity and efficiency, especially in crowded environments.

Reduced latency: With Target Wake Time (TWT) technology, Wi-Fi 6 devices can schedule when and how frequently they wake up to transmit or receive data, reducing latency and power consumption.

Improved power efficiency: Wi-Fi 6 devices support the Target Wake Time feature, which enables devices to enter sleep mode when not in use, conserving battery life and improving overall power efficiency.

Enhanced performance in crowded areas: Wi-Fi 6 includes features like BSS Coloring, which reduces interference in dense environments by distinguishing between neighboring networks, thereby improving performance.

Wi-Fi 6E: Wi-Fi 6E is an extension of Wi-Fi 6 that operates in the newly allocated 6 GHz frequency band. It offers all the benefits of Wi-Fi 6, along with the following additional advantages:

More available spectrum: The 6 GHz band provides a significant amount of additional spectrum for Wi-Fi use. This additional spectrum reduces congestion and allows for faster speeds and higher capacity.

Wider channels: Wi-Fi 6E supports wider channel bandwidths, such as 160 MHz, which enables even higher data rates.

Lower interference: Since the 6 GHz band is less crowded, Wi-Fi 6E networks experience lower interference from other Wi-Fi devices and non-Wi-Fi sources, resulting in improved performance and reliability.

Support for new use cases: The additional spectrum in the 6 GHz band opens up possibilities for new applications and use cases that require higher bandwidth and lower latency, such as virtual reality (VR), augmented reality (AR), 4K/8K video streaming, and other bandwidth-intensive applications. It's worth noting that to take full advantage of Wi-Fi 6E, both the Wi-Fi router or access point and the client devices (such as smartphones, laptops, and IoT devices) need to support the Wi-Fi 6E standard and operate in the 6 GHz band.Wi-Fi 6 and Wi-Fi 6E offer significant improvements in speed, capacity, and performance, making them ideal for environments with a large number of connected devices or high-bandwidth requirements.

Wi-Fi 6 and Wi-Fi 6E offer significant improvements in speed, capacity, efficiency, and performance, making them well-suited for environments with a large number of connected devices or high-bandwidth requirements. They provide faster and more reliable wireless connections, enhancing the overall user experience and enabling the use of advanced applications and services.

HISTORY

Parts of the ISM bands were made available for unauthorized use for communications in accordance with a 1985 Federal Communications Commission decision. These frequency bands are susceptible to interference because they share the same 2.4 GHz channels as devices like microwave ovens. The predecessor to 802.11, known as Wave LAN, was created in 1991 by the NCR Corporation and AT&T Corporation in the Netherlands for use in checkout systems. Vic Hayes of NCR and Bruce Tuch of Bell Labs approached the Institute of Electrical and Electronics Engineers (IEEE) to develop a standard. Vic Hayes served as the chair of IEEE 802.11 for ten years, and both men were engaged in the development of the early 802.11b and 802.11a IEEE standards. Following that, they were both admitted into the Wi-Fi NOW Hall of Fame.

Around the same time, a group of researchers from the Radio Physics Division of the CSIRO (Commonwealth Scientific and Industrial Research Organization) in Australia, led by Dr. John O'Sullivan, developed a prototype test bed for a wireless local area network (WLAN) in 1992. However, this is viewed by some as an instance of patent trolling. The 802.11 protocol's initial introduction in 1997 offered link rates of up to 2 Mbit/s. 802.11b was added in 1999 to allow for 11 Mbit/s communication rates.The Wi-Fi Alliance was established in 1999 as a trade organization to manage the Wi-Fi trademark, which is used to sell the majority of IEEE 802.11 devices. With Apple Inc.'s adoption of Wi-Fi for their iBook line of laptops in 1999, a significant commercial breakthrough was made. It was the first product for the general public to offer Wi-Fi network connectivity, and Apple later branded it as AirPort. The same team from Lucent, including Vic Hayes, Bruce Tuch, Cees Links, Rich McGinn, and others, collaborated on this as well. Wi-Fi makes use of numerous patents that are owned by numerous organizations. Wi-Fi is simultaneously credited to Australia, the US, and the Netherlands. It is a contentious subject on which no global agreement has been established. Following a patent settlement with 14 technology companies in 2009, the Australian CSIRO received $200 million, and a further $220 million was granted in 2012 following legal action with 23 corporations. Australia's contribution to the 2016 National Museum of Australia exhibition A History of the World in 100 Objects was the WLAN prototype test bed from the CSIRO.

STRUCTURE OF WI-FI 6 (802.11AX)

The structure of Wi-Fi 6 (802.11ax) can be divided into different components that work together to provide enhanced wireless connectivity. Let's explore the key elements of Wi-Fi 6:

Orthogonal Frequency Division Multiple Accesses (OFDMA): OFDMA is a fundamental feature of Wi-Fi 6 that enables more efficient spectrum utilization. It divides the available frequency spectrum into smaller sub-channels called Resource Units (RUs). Each RU can be allocated to a different device or used for specific purposes. This allows multiple devices to transmit data simultaneously within a single channel, significantly increasing the network's capacity and reducing latency. In the previous version, a lot of little management and control frames would fill the entire channel whenever a STA sent data, regardless of the size of the data packet. This compares to a large bus with just one passenger inside. This is totally unrealistic. In order to create resource units (RUs), the OFDMA technology splits a radio channel into several subcarriers in the frequency domain. Since just user data is transmitted through RUs and does not take up the entire channel, it is possible to perform simultaneous data transmission from numerous STAs during each time segment. STAs are no longer required to stand in line. This technology boosts productivity and decreases queuing time. Wi-Fi 6 supports OFDMA in both the downlink and uplink directions. 802.11ac has 52 data carrying sub carriers in a 20 MHz RF channel, while 802.11ax has 234 sub carriers. When using downlink OFDMA, an AP allocates RUs depending on the downlink packets and user priorities. An AP observes STAs of the resources that can be distributed via trigger frames in uplink OFDMA.

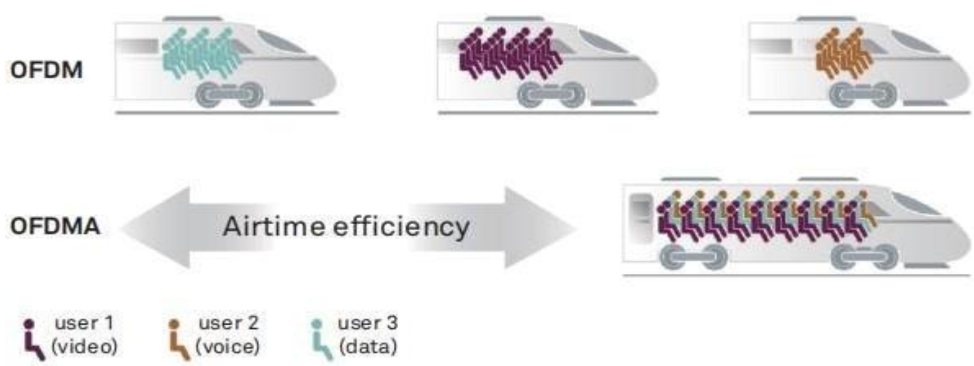

Figure 1. Channel Mode of OFDMA [4]

Multi-User Multiple Input Multiple Output (MU-MIMO): MU-MIMO is an essential feature in Wi-Fi 6 that has been improved compared to previous Wi-Fi generations. It allows multiple devices to simultaneously communicate with the access point (AP) using multiple antennas. In Wi-Fi 6, MU-MIMO supports both uplink and downlink transmissions, enabling more efficient communication with multiple devices and improving overall network performance. . It was developed to handle the technology and setting where several users are simultaneously attempting to join to a wireless network. With the use of this technology, numerous users can access router functionalities without any disruption. The downlink MU-MIMO of 802.11ac Wave 2 is used. When a STA supports MU-MIMO, an AP can send data packets to several of those STAs at once. In Wi-Fi 5, an AP could only send data to one STA at a time, but Wi-Fi 6 has taken over this technology and can send data to eight STAs simultaneously. Wi-Fi 6 also supports uplink MU-MIMO and permits a maximum of eight 1x1 STAs to be transmitted simultaneously uplink. The two most important technologies of Wi-Fi 6 are OFDMA and MU-MIMO; these enable the transmission of many simultaneous functions in the frequency and physical domains, respectively. These two benefits significantly increase the network's overall performance and speed and maximize user happiness. [7 - 10]

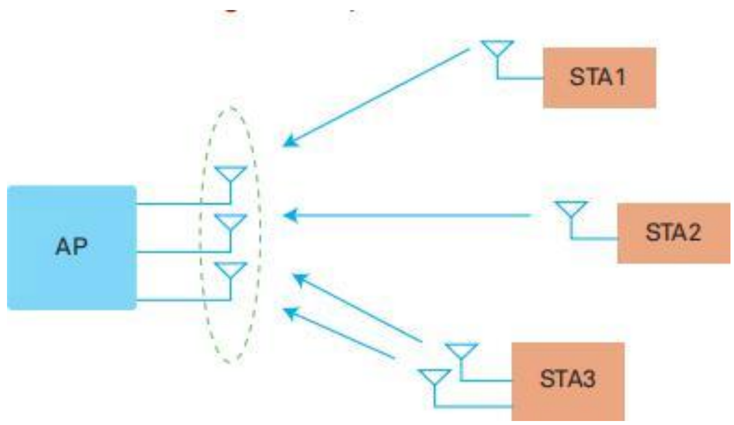

Figure 2. Co-working of MU-MIMO

Target Wake Time (TWT): TWT is a power-saving feature introduced in Wi-Fi 6. It allows devices to schedule when and how frequently they wake up to transmit or receive data. By synchronizing communication schedules between the AP and devices, TWT reduces unnecessary device wake-ups, resulting in power savings and improved battery life for connected devices. It is a technique that enables an AP to monitor activity in the Wi-Fi network in order to lessen conflict between stations (STAs) and shorten the necessary processing time. The TWT function prolongs device sleep times and preserves battery life. For instance, if several smart home gadgets are linked to your home's Wi-Fi network, the AP can establish a wake-up protocol with each device separately. In this way, the devices only switch to the working mode after receiving the wakeup messages, and they remain in the sleep mode at all other times. Another example is that one of the gadgets within the Wi-Fi 6 AP's range might be an IoT proximity sensor, which doesn't need to be in constant radio contact with the network. The IoT sensor can be regularly activated using the TWT capability. The TWT function can extend battery life in portable/mobile devices and increase network efficiency by operating in this manner. This technology enables simultaneous connection for several services, such as video, voice, and data services, across numerous devices. [8]

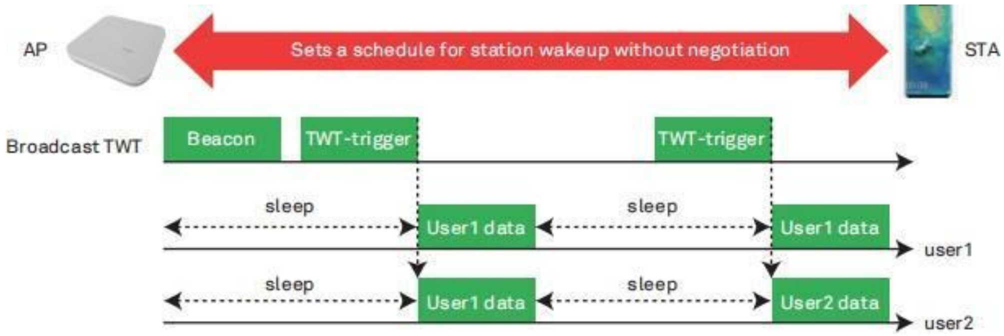

Figure 3. Broadcast Operation of TWT

BSS Coloring: BSS Coloring is a mechanism that helps alleviate congestion and interference in environments with multiple overlapping Wi-Fi networks. Each network is assigned a unique "color" that is embedded in the Wi-Fi frames. Devices can then differentiate between frames from their own network and frames from neighboring networks, reducing interference and improving overall network performance.

*1024-QAM***:** Wi-Fi 6 introduces a more advanced modulation scheme known as 1024-QAM. It allows for more efficient encoding of data and provides higher throughput compared to the 256-QAM used in previous Wi-Fi standards. This higher modulation scheme enables Wi-Fi 6 devices to achieve higher data rates, improving overall network speed and capacity.

Channel Utilization and Spectrum Efficiency: Wi-Fi 6 incorporates various mechanisms to enhance spectrum efficiency and reduce interference. These include improved channel access methods, more efficient use of available channels, and better management of transmission collisions. These enhancements result in higher network throughput and improved performance, particularly in high-density environments.

By combining these features, Wi-Fi 6 (802.11ax) provides higher data rates, increased network capacity, reduced latency, improved power efficiency, and better performance in crowded areas. These advancements enable Wi-Fi 6 to meet the growing demands of modern wireless communication and support a wide range of applications and devices.

How Wi-Fi 6 (802.11ax) uses Orthogonal Frequency Division Multiple Access (OFDMA)?

Wi-Fi 6 (802.11ax) utilizes Orthogonal Frequency Division Multiple Access (OFDMA) as a key feature to improve the efficiency and capacity of wireless communication. Here's a detailed explanation of how Wi-Fi 6 utilizes OFDMA:

Division of Frequency Spectrum: OFDMA divides the available frequency spectrum into smaller sub-channels called Resource Units (RUs). These RUs can vary in size depending on the specific implementation, typically ranging from 26 sub-carriers to 242 sub-carriers.

Allocation of Resource Units: In Wi-Fi 6, the access point (AP) allocates different RUs to different devices within a given channel. Each RU can be allocated to a specific device, a group of devices, or a specific purpose. This allocation is managed by the AP using advanced scheduling algorithms.

Simultaneous Data Transmission: With OFDMA, multiple devices can transmit data simultaneously within the same channel by utilizing their assigned RUs. Each device can use its allocated RU to send or receive data independently of other devices. This parallel transmission capability increases the network's capacity and efficiency, allowing more devices to communicate simultaneously.

Dynamic RU Allocation: The AP dynamically adjusts the RU allocation based on the real-time communication needs of connected devices. It can allocate more RUs to devices that require higher bandwidth or prioritize specific devices or applications. This dynamic allocation helps optimize resource utilization and maximize network performance.

Efficient Handling of Small Data Frames: OFDMA in Wi-Fi 6 also addresses the issue of small data frames. Traditional Wi-Fi standards, such as Wi-Fi 5 (802.11ac), often experience inefficiency when handling small packets, leading to increased overhead. With OFDMA, Wi-Fi 6 can group several small data frames from different devices together in a single RU, reducing overhead and improving overall efficiency.

Support for Uplink OFDMA: Wi-Fi 6 extends the benefits of OFDMA to uplink transmissions as well. Previously, uplink transmissions were limited to Single User Multiple Input Multiple Output (SU-MIMO) or Single User Single Input Single Output (SU-SISO) techniques. With Wi-Fi 6's uplink OFDMA, multiple devices can transmit data to the AP simultaneously, further enhancing capacity and reducing latency.

By employing OFDMA, Wi-Fi 6 enables more efficient utilization of the frequency spectrum, supports simultaneous transmissions from multiple devices, improves network capacity, and enhances overall performance. These enhancements make Wi-Fi 6 particularly well-suited for high-density environments with numerous connected devices and diverse traffic requirements.

WI-FI 5 VS WI-FI 6

802.11 Standards Physical							
802.11 Protocol	**Release Date**	**Frequency (GHz)**	**Minimum Sub-Carrier Bandwidth**	**No. of Valid Sub-Carrier**	**Stream Data Rate Min-Max (Mbit/s)**	**Allowable MIMO Streams**	**Modulation Antenna Tech.**
802.11 ac	Dec 2013	5	312.5 KHz	234	433	8	256-QAM
802.11 ax	Sep 2019	2.4 & 5	78.5 KHz	980	600	10	1024-QAM

Table 1. IEEE802.11 ac (Wi-Fi 5) vs. IEEE802.11 ax (Wi-Fi 6)

A. *IEEE802.11ac*: Wi-Fi 5 is a product of 802.11ac technology. Released in December 2013, it is the fifth generation of Wi-Fi networking standards. This 5GHz working frequency has sectors of 20, 40, 80, and 160 MHz These bandwidth sectors' stream rates are 7.2-96.3 Mbps for 20 MHz, 15-20 Mbps for 40 MHz, 32.5 Mbps - 433.3 Mbps for 80 MHz, and 65 Mbps - 866.7 Mbps for 160 MHz These standards demonstrate improved performance and coverage over earlier Wi-Fi standards. It can be reached using OFDM technology [9]. In the downlink, 802.11ac devices offer

MU-MIMO (4*4). The modulation method used by the 802.11ac standard is 256 QAM. With the help of this method, a group of users, wireless terminals, and other devices with many inputs and outputs can communicate with one another. It is challenging to use Wi-Fi 5 in settings that call for several overlapping cells with disputed ambient interference. [10]

B. *IEEE802.11ax:* Wi-Fi 6 is a product of 802.11ax technology. The way we support applications on today's Wi-Fi networks will change thanks to Wi-Fi 6. Compared to preceding Wi-Fi generations, its implementation enables a new and increased level of user satisfaction in dense deployment settings. Wi-Fi 6 is more concerned with upping the user experience's difficulty. The following modifications will be made to the Wi-Fi market during the next five years in order to increase customer satisfaction [10, 12]. Highest possible bandwidth: 9.6 Gbit/s. More STAs may access the network simultaneously thanks to a 4-times improvement over 11ac in network access capacity. This also results in a more than 30% reduction in terminal power consumption. It uses a small amount of power.

Parameters	**Wi-Fi 5 (802.11ac)**	**Wi-Fi 6 (802.11ax)**
Bandwidth (Channels)	20,40,80+80,160 MHz	20,40,80+80,160 MHz
Access Mode	OFDM	OFDMA
Connection Speed	Less	40% Higher
Maximum User/Access Point	4	8
Antennas	MU-MIMO (4*4)	MU-MIMO (8*8)
Interference	High	Low
Power Consumption	High	Low
Feature	N/A	TWT, BSS Coloring

Table 2. IEEE802.11 ac (Wi-Fi 5) vs. IEEE802.11 ax (Wi-Fi 6)- Additional Features [14]

WI-FI 6 VS WI-FI 6E

	Wi-Fi 6	**Wi-Fi 6E**
Data Delivery Rate At 15 Feet	1.146 Gbps	1.788 Gbps
Data Bands	2.4 & 5 GHz	2.4, 5 & 6 GHz
Number of 160-MHz-Wide Channels Available	1 (in 5-GHz band)	8 (1 in 5-GHz, 7 in 6-GHz bands)
Mesh Capability	Yes	Yes

Table 3. Wi-Fi 6 vs Wi-Fi 6E [20,23]

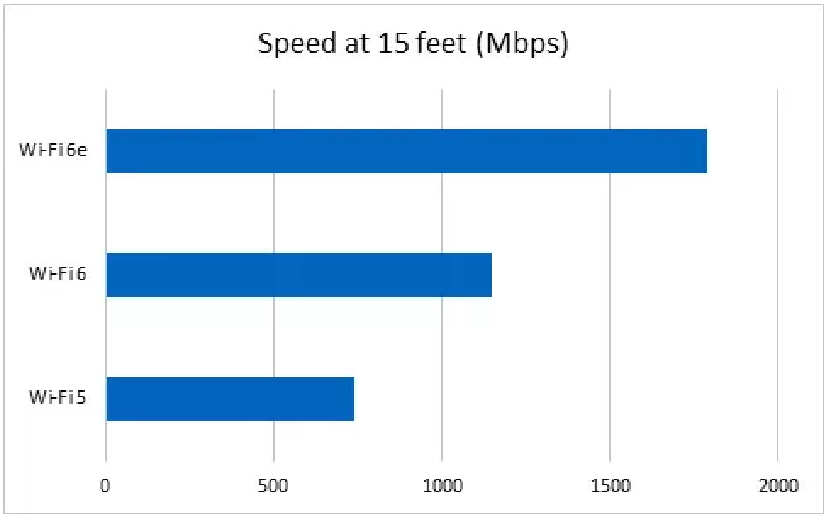

Figure 4. Speed Comparison of Wi-Fi Technologies [42]

CONCLUSION

In comparison to IEEE802.11ac, this paper explains how IEEE802.11ax improves quality and performance. The new IEEE 802.11ax standard was introduced in September 2019 and aims to achieve throughput and high data stream rates in the Gigabit per second level. Enterprise Wi-Fi has developed into a foundation that enables digital evolution and boosts output and productivity across a range of industries. A pleasant Wi-Fi network can significantly increase user happiness and company operating efficiency while also supporting more digital and intelligent services. You must deploy or upgrade to the most recent WiFi as soon as possible if you have not already done so in order to satisfy the requirements of your digital service development. Our analysis demonstrates how the futures of 5G and Wi-Fi 6 must be understood in the broader context of how prior generations of cellular and Wi-Fi technologies have influenced the growth of wireless networking and what this may signify going forward. In terms of broad demand-side trends, it is anticipated that data traffic will continue to increase rapidly, with a growing proportion of devices using wireless connectivity as their initial point of connection. Increased digital connectivity is crucial to facilitate remote employment, education, and social involvement throughout the global crisis, as the COVID-19 pandemic of 2019–2021 has shown. However, new trends may also be able to emerge as a result of the pandemic's altered social and work patterns. The spatial and temporal use of wireless broadband connectivity as well as the related economics of each technology may be impacted by such developments. Consumer data demand will also be significantly influenced by the continuous consumption of video content that is both greater and of higher quality, while enterprise use will be reflected by the increasing use of cloud-based platforms and apps.

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