Wi-Fi CERTIFIED 7™

Technology Overview

January 2024

Executive Summary

Wi-Fi CERTIFIED 7™ is a generational program to enhance wireless local-area network (WLAN) performance and experience in the 2.4 GHz, 5 GHz, and 6 GHz bands. The deployment of Wi-Fi 7 is expected to cater to all market segments supported by past Wi-Fi CERTIFIED® programs and to extend support for emerging segments that require a high level of user interactivity, immersion, and reliability, such as augmented reality (AR), virtual reality (VR), and extended reality (XR).

The principal target markets for the program are environments that demand high performance in terms of peak throughput, high network and link efficiency, increased reliability, and low latency in both commercial and consumer market segments represented by a variety of use cases, including:

- Streaming ultra-high definition video
- Multi-user AR/VR/XR
- Automotive
- Hybrid work and rich telepresence
- Immersive gaming and entertainment
- Emergency Preparedness Communication Services
- Industrial Internet of Things
- Immersive 3-D training

Wi-Fi 7 currently provides certification for regular access points (APs) and stations (STAs), and future updates will provide certification for Mobile APs, and 20 MHz-only STAs.

Wi-Fi 7 features are based on the 802.11be draft amendment from IEEE 802.11. The key features of Wi-Fi 7 are:

- **320 MHz channels:** Superwide channels enable multigigabit Wi-Fi device speeds
- **Multi-link operation (MLO):** Enables devices to combine different channels across frequency bands together, allowing concurrent transmission and reception of data over multiple links
- **4K quadrature amplitude modulation (QAM):** Increased transmission rates and efficiency enable next-generation use cases
- **512 compressed Block Ack:** Allows the transmitter to aggregate up to 512 MAC protocol data units (MPDUs) in a single frame and allows the receiver to acknowledge up to 512 MPDUs in a single Block Ack (BA) frame
- **Multiple resource units (M-RU) to a single STA:** Allows multiple RUs to be assigned to a single user and can combine RUs for increased transmission efficiency
- **Triggered uplink access:** Satisfies uplink streams' quality of service (QoS) requirements and significantly improves uplink efficiency
- **Emergency Preparedness Communication Services (EPCS):** Provides a seamless National Security & Emergency Preparedness (NSEP) service experience to the users while maintaining the priority and quality of service in Wi-Fi access networks

Wi-Fi CERTIFIED 7™: Advanced performance for next generation Wi-Fi®

Features	Benefits
320 MHz channels	2X higher throughput
Multi-link Operation (MLO)	Deterministic latency, increased efficiency, greater reliability
4K QAM	20% higher transmission rates
512 Compressed Block Ack	Reduced transmission overhead
Multiple RUs to a single STA	Enhanced spectral efficiency

The benefits of the Wi-Fi 7 program can be classified into the following categories:

- Higher aggregate throughput (network and link level)
- Improved support for low latency
- Higher efficiency in dense networks
- Increased robustness and reliability
- Reduced power consumption

Introduction

WLAN continues its phenomenal growth and has become critical for providing wireless data services at home, in dense environments (shopping malls, stadiums, conventions centers, etc.), and in enterprise environments.

Wi-Fi 7 is driven by the needs of the market as illustrated in Figure 1. There is extensive industry interest in enhanced Wi-Fi capabilities in the 2.4 GHz, 5 GHz, and 6 GHz bands to ensure high throughput and reduce worst-case latency and jitter in a more efficient and robust manner in both home and industrial settings, supporting time-sensitive applications such as AR, VR, mobile gaming, etc. Wi-Fi 7 delivers on these goals of extremely high throughputs, low latency, and low jitter by leveraging new features that support wideband, high-speed communication with more nimble and robust use of spectrum in the presence of interference.

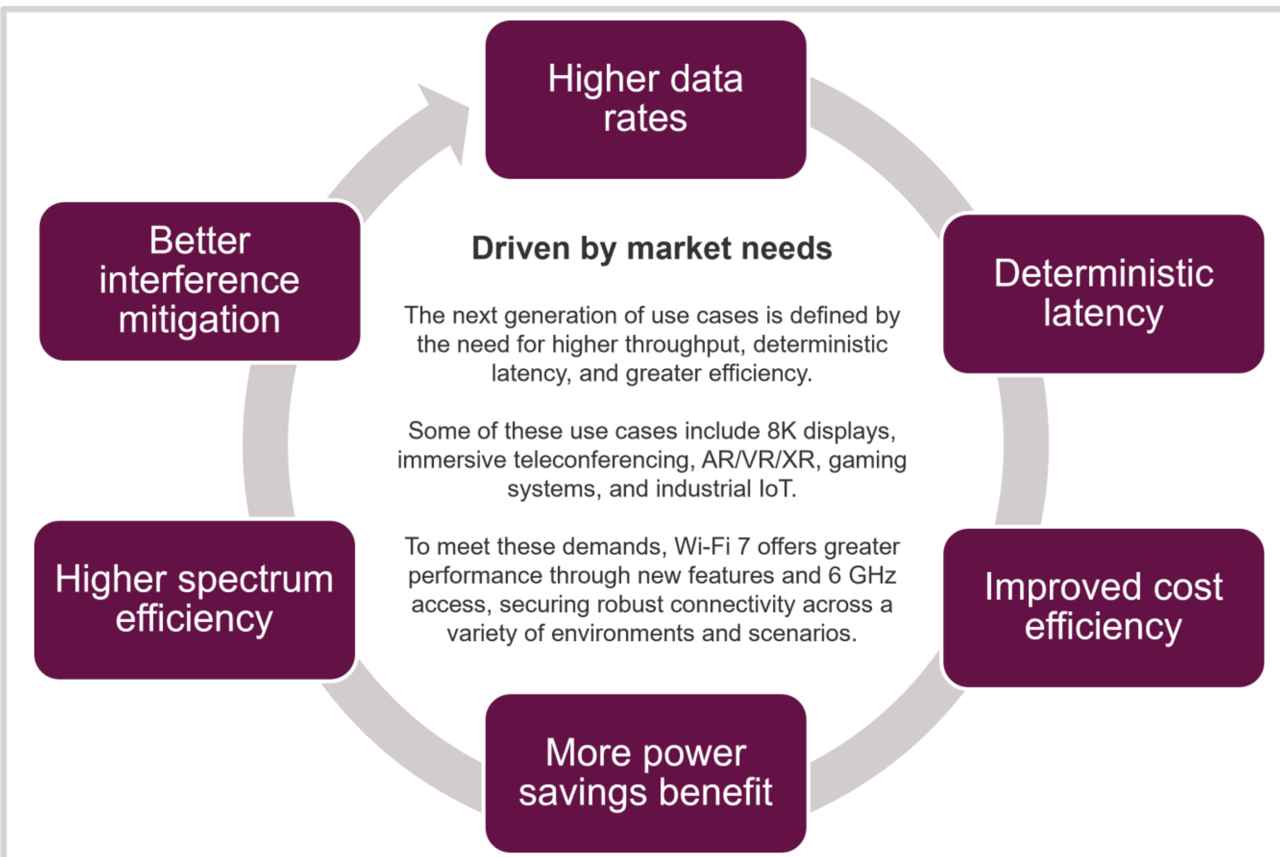


Figure 1: Wi-Fi 7 addresses various contemporary market needs

Video traffic is projected to be the dominant type of traffic in many WLAN deployments and is expected to grow at 29% CAGR through 2030[1] with the proliferation of cloud-based applications and an increased emphasis on upload capacity as users create and share more content. The throughput requirements of video-based applications are

[1] McKinsey, February 2020

increasing due to the higher resolutions required by many services. New high-throughput, low-latency applications are popping up in the areas of immersive gaming, remote office work, cloud computing, and AR/VR/XR. Along with the high-throughput and stringent real-time delay requirements needed by these emerging applications, users expect guaranteed reliability, reduced latency and jitter, and improved power efficiency over a Wi-Fi connection. Users also expect reliable performance, even in the presence of a high level of interference from overlapping wireless networks.

To serve the market needs mentioned above and the use cases discussed below, Wi-Fi 7 introduces several new features. These are tabulated in Table 1 along with the benefits that the feature offers.

Feature	Benefit
320 MHz channels	• Two times higher throughput than Wi-Fi CERTIFIED 6® by doubling the widest channel size • Multigigabit Wi-Fi device speeds • Enables a higher number of simultaneous transmissions at the fastest possible speeds
Multi-link operation	• Prior to Wi-Fi 7, devices used a single link to transmit data or support multiple bands, but in an inefficient manner. MLO enables devices to combine different channels across frequency bands together, allowing concurrent transmission and reception of data over multiple links • MLO allows more efficient load balancing of traffic among links to meet user needs, such as utilizing 5 GHz or 6 GHz for higher throughput and 2.4 GHz for range and selecting the most robust link in the presence of interference, resulting in increased throughput, lower latency, and improved reliability for applications like VR/AR, online gaming, cloud computing, and remote offices • MLO manageability features are also available
4K QAM	• 20 percent higher transmission rates than Wi-Fi 6's 1024-QAM • Higher transmission rate enables higher transmission efficiency. Supports flawless streaming of 4K or 8K videos, playing massive online games without lag, or live streaming from a home computer
512 compressed Block Ack	• Acknowledging the frames in a single BA with up to 512 MPDUs improves the efficiency and reduces the overhead of transmitting individual acknowledgements, compared to up to 256 MPDUs in Wi-Fi 6.
Multiple RUs to a single STA	• Allows multiple RUs to be assigned to a single user and can combine RUs for increased transmission efficiency • Significantly improves flexibility for spectrum resource scheduling and further enhances spectral efficiency
Triggered uplink access	• Optimizes Wi-Fi 6-defined triggered uplink access scheduling to accommodate uplink latency-sensitive streams • Satisfies uplink streams' QoS requirements and significantly improves uplink efficiency
Emergency Preparedness Communication Services	• Provides a seamless NSEP service experience to users while maintaining the priority and quality of service in Wi-Fi access networks • Support for 5G offload to Wi-Fi access

Table 1: Key Wi-Fi 7 features and benefits

Each of these key features and the underlying foundational technology is further elaborated on in the next section.

Table 2 below compares the key performance indicators (KPIs) of Wi-Fi 7 with the previous generations of Wi-Fi.

Parameter	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6	Wi-Fi 7	Benefits of Wi-Fi 7
Bands	2.4 GHz & 5 GHz	5 GHz	2.4 GHz, 5 GHz, & 6 GHz	2.4 GHz, 5 GHz, & 6 GHz	Designed for 6 GHz from the ground up, increasing capacity and supporting next-generation use cases
Channel Widths	40 MHz & 20 MHz	160 MHz, 80 MHz, 40 MHz, & 20 MHz	160 MHz, 80 MHz, 40 MHz, & 20 MHz	320 MHz, 160 MHz, 80 MHz, 40 MHz, & 20 MHz	Doubles the size of the widest Wi-Fi 6 channel and makes 160 MHz mandatory to support high-speed use cases
Highest Modulation	64-QAM	256-QAM	1024-QAM	4096-QAM	20% higher transmission rate than Wi-Fi 6's 1024-QAM, enabling higher transmission efficiency for better streaming and low gaming lag
Multi-Link Operation	N	N	N	Y	Increased throughput, lower latency, reduced interference, reduced intra-AP roaming disruption
Max Data Rate	600 Mbps	3.5 Gbps	9.6 Gbps	36 Gbps (tri-link MLO, see note 2) 23 Gbps (single link)	Over three times higher throughput than Wi-Fi 6
Max Spatial Streams	4	4	8	8	Service devices simultaneously and achieve general efficiency
Uplink Channel Access	Enhanced distributed channel access (EDCA)	EDCA	EDCA Triggered access	EDCA Optimized triggered access	More predictable latency with lower overheads

Table 2: Comparison of Wi-Fi 7 with previous generations of Wi-Fi

Note 1: Max Parameter Values are based on IEEE 802.11be

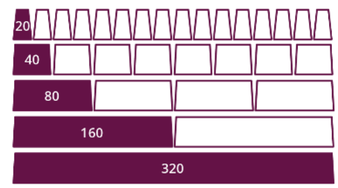
Note 2: For 320 MHz in 6 GHz, 160 MHz in 5 GHz, and 20 MHz in 2.4 GHz

Underlying and foundational technology

Wi-Fi 7 contains numerous features that set it apart as a game-changing technology, making it equipped to handle the connectivity needs of the next generation of devices thanks to wider channels, the 6 GHz band, multi-link operation, and more.

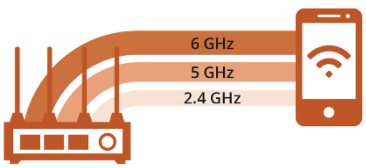
320 MHz channel operations

In many regulatory domains, 320 MHz channel operation is allowed within the 6 GHz unlicensed band. Wi-Fi 7 enables the operation of 320 MHz according to the protocols defined in IEEE 802.11be Draft 3.0. This increases the peak modulation coding scheme (MCS) data rate from 2.409 Gbps in Wi-Fi 6 to 5.7648 Gbps, providing higher multigigabit Wi-Fi device speeds for two spatial streams. It also doubles the maximum number of RUs that are available to an AP for allocation, thus improving the orthogonal frequency-division multiple access (OFDMA) efficiency in both uplinks and downlinks, enabling a higher number of simultaneous transmissions at the fastest possible speeds.



Multi-link operation (MLO)

Multi-link operation in Wi-Fi 7 allows devices to have connectivity on multiple links, enabling a STA multi-link device to discover, authenticate, associate, and set up multiple links with an AP multi-link device. Each link enables channel access and frame exchanges between the STA multi-link device and the AP multi-link device based on the supported capabilities exchanged during setup. Wi-Fi 7 through MLO provides throughput improvements, better reliability, lower latency, and flexibility to STAs in terms of co-existence with other technologies, thus providing exceptional performance and user experience.



Wi-Fi 7 supports multiple modes of operation: Simultaneous Transmit and Receive, Multi Link Single Radio and Enhanced Multi Link Single Radio, and single link multi-link device operation. In Simultaneous Transmit and Receive operation, the devices are expected to be able to transmit and receive on each of the links independently and would attain the maximum performance.

Since multiple links are established between an AP multi-link device and a STA multi-link device, throughput can be increased by a factor of two or more. For example, an AP multi-link device could support three radios and establish three links with a STA multi-link device, one in 2.4 GHz with a bandwidth of 40 MHz and two spatial streams, one in 5 GHz with a bandwidth of 160 MHz and two spatial streams, and another one in 6 GHz with a bandwidth of 320 MHz and two spatial streams. This would lead to an aggregate maximum data rate of 2 X (344.1 Mbps + 1441.2 Mbps + 2882.4 Mbps) = 9.335 Gbps.

MLO also allows each of the links in an AP multi-link device or STA multi-link device to access the medium simultaneously and this means the amount of time a packet would spend in the transmit queue at the STA can be reduced to as much of as half or even less. This in turn will reduce the latency and jitter in the system, especially shortening the tail of the distribution.

QoS can also be improved by using different links for different traffic and also by directing traffic to each of the links based on metrics such as received signal strength indicator and signal-to-noise ratio to use the links efficiently.

Simultaneous Transmit and Receive provides dramatic improvements in throughput and latency. In many modern applications (such as AR/VR), however, latency is critical even at lower throughputs. Wi-Fi 7 provides an alternative that gives preference to the latency improvements through the Enhanced Multi Link Single Radio mode of operation. Enhanced Multi Link Single Radio is a mode that is used by the STA multi-link device through an AP multi-link device assistance. The STA multi-link device has support for two radiofrequency (RF) links with only one spatial stream (i.e., RF chain) support on each of the links, but can be switched to one RF link with two spatial streams support. When in Enhanced Multi Link Single Radio mode, the STA multi-link device will be in a listening mode on both the links awaiting a trigger from AP multi-link device through a Multi User Request to Send frame on any link and when it does receive the Multi User Request to Send, the STA multi-link device will switch both RF chains onto that link.

Wi-Fi 7 MLO also supports Multi Link Single Radio and single link mode devices. Multi Link Single Radio allows devices to operate on multiple links — but not simultaneously — and allows the device to hop from one link onto another. This allows the device to be able to operate on multiple technologies. For example, the device may support both 5 GHz and 6 GHz, but not both simultaneously. The device may set up links on both bands, signal to the AP to put the STA on one of the links in power save mode and use the other for data transfer, but be ready to switch to the other channel should the load conditions change. The AP may need to do load balancing by switching the device to operate the other channel for data transfer.

MLO manageability features

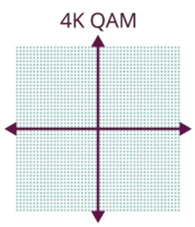
One attribute of MLO is that STAs associate on multiple links but are oftentimes awake on just one link in order to maximize battery life. Accordingly, they do not have optimal information about traffic levels across the links. The same situation arises in previous Wi-Fi generations where enterprise AP devices used available mechanisms such as Wi-Fi CERTIFIED Agile Multiband™ to help STAs identify the best link for their traffic, especially in high density and congested environments.

With Wi-Fi 7, AP devices are provided with modernized mechanisms to deliver this same service via the Basic Load Balancing protocol. Basic Load Balancing provides more predictability and assurance and is a major improvement over previous Wi-Fi generations in terms of responsiveness and the seamlessness of the link management since no (Re)Association is required.

MLO can also provide the STA with sustained undisturbed connectivity even as the AP device performs disruptive operations on an individual link or band (such as a software upgrade or when changing roles to a sniffer to help troubleshoot a connectivity issue). Wi-Fi 7 offers the AP device two mechanisms for this purpose: AP multi-link device reconfiguration for stateless operations and Advertised TID-to-Link Mapping for stateful operations.

4K QAM

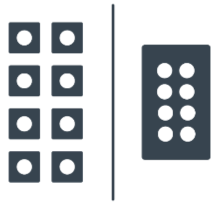
Wi-Fi 7 introduces 4K QAM, raising the transmission rates by 20 percent at shorter ranges over Wi-Fi 6's 1K QAM without any increase in bandwidth or number of antennas. 4K QAM achieves the higher transmission rate by packing four times more constellation points than 1K QAM.



A higher transmission rate enables higher transmission efficiency and improves spectral efficiency, making better use of available bandwidth. 4K QAM helps support flawless streaming of 4K/8K videos, playing massive online games without lags, or live streaming from a home computer. The enhanced spectral efficiency is particularly beneficial in densely populated areas, where bandwidth is often at a premium. The higher data rate allows devices to finish transmissions more quickly, allowing more devices to efficiently share and operate in the same spectrum in the densely populated areas.

512 compressed Block Ack

Wi-Fi 7 introduces 512 compressed Block Ack, which allows the transmitter to aggregate up to 512 MAC Protocol Data Units (MPDUs) in a single frame and allows the receiver to acknowledge up to 512 MPDUs in a single BA frame, as opposed to up to 256 MPDUs in a single aggregation in Wi-Fi 6. 512 compressed Block Ack reduces the protocol overhead and can improve the transmitter's performance when transmitting Wi-Fi 7 high throughput PHY rates using 320 MHz and MCS13.

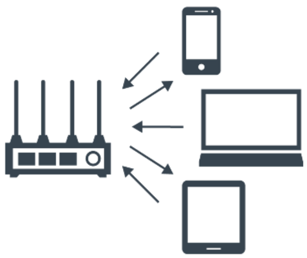


Multiple RUs to a single STA (M-RU)

Wi-Fi 6 APs allocate only in contiguous RUs, which means that even though there are resources available for transmission, if the RUs can not be in a contiguous block, part of the bandwidth will be left unused, resulting in loss of some efficiency. Wi-Fi 7 allows multiple RUs to be assigned to a single user facilitating combined RUs for increased transmission efficiency. This in turn provides flexibility to fit the data, avoid interference, and further enhance spectral efficiency.

Triggered uplink access optimization

Wi-Fi 6 added triggered access to improve the reliability and performance of the channel access, especially in congested environments. The Wi-Fi 6 triggered access was targeted for all applications, from best-effort data transmissions to real-time video and audio applications. Wi-Fi 7 APs are further improved to support low latency applications using stream classification service (SCS) procedure with QoS Characteristic element, as defined in IEEE 802.11be D3.0.



For uplink latency-sensitive flows, SCS procedure allows client devices to inform APs via QoS Characteristics element of their desired triggered uplink access interval, minimum data rate, delay bound, and other optional information for the duration of the traffic flow. This helps the AP schedule triggered uplink access more efficiently and improves spectrum efficiency by eliminating channel access overhead from multiple STA devices. Additionally, it reduces the overhead from the necessary buffer status polling and reports by taking advantage of the periodic traffic pattern of the flows.

Emergency Preparedness Communication Service

EPCS features are specified in Wi-Fi 7 to support priority access to the wireless medium for authorized stations supporting the NSEP Communications. The Wi-Fi CERTIFIED 7 APs with EPCS capability advertise the priority access capabilities via Beacon and Probe Response messages. The Wi-Fi CERTIFIED 7 STAs with EPCS capability associate with the Wi-Fi 7 APs to obtain priority channel access. Both APs and STAs can enable and disable the priority access securely via the following process:

- EPCS Priority Access Invocation: Using a request message, both AP and STA can invoke the priority access features. When a STA invokes the priority access features, the AP verifies the authorization information before granting the priority access via a response message. The authorization can be performed through the use of a remote entity server connected to the AP via an external interface (e.g., using a Subscription Service Provider Network interface to an Authentication Authorization and Accounting server). This will ensure that priority functionality is restricted to those with a critical need
- EPCS Priority Access Revocation: When the priority treatment is no longer needed (e.g., when the congestion eases), the STA or the AP can disable EPCS priority access by sending a teardown message

The EPCS features that give users priority channel access are built upon the Wi-Fi CERTIFIED Wi-Fi Multimedia™ (WMM®) concepts used to apply suitable relative priority to various types of media (e.g., voice, video, and best-effort data). WMM defines a set of channel access parameters for each media type or access category. The EPCS priority access mechanism allows the AP to assign different sets of parameters to devices that are authorized to use the EPCS priority access feature. The mechanism ensures that those parameters increase NSEP users' EPCS-capable devices' likelihood of gaining access to the wireless medium compared to other devices. In this way, the EPCS priority access retains the advantages of WMM in enabling multimedia services while at the same time providing an advantage for users with NSEP responsibilities when networks are congested.

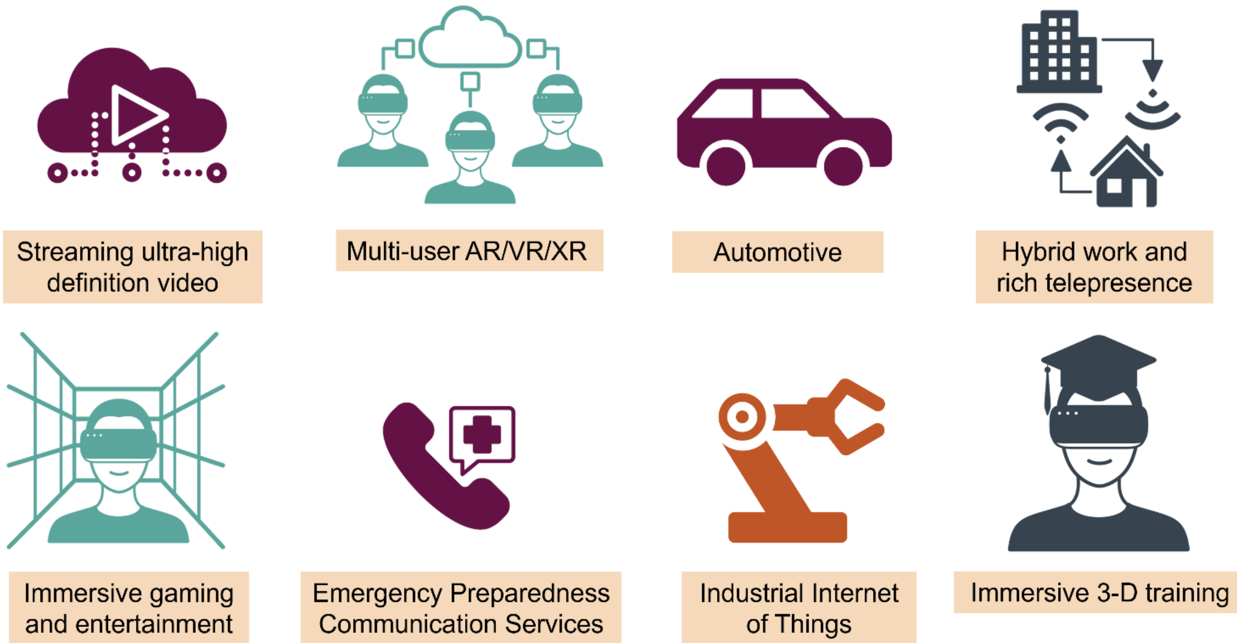
Security

Wi-Fi 7 requires Wi-Fi CERTIFIED WPA3™ to protect communications between Wi-Fi 7 devices. WPA3 security for Wi-Fi 7 devices has been extended to make use of stronger key management. In addition to mandating Protected Management Frames, Wi-Fi 7 devices are mandated to support beacon protection, a mechanism that allows a device to cryptographically verify the contents of beacon frames transmitted by an AP.

Wi-Fi 7 requires support for Wi Fi CERTIFIED Enhanced Open™ between Wi-Fi 7 devices in open networks. Wi-Fi Enhanced Open networks provide unauthenticated data encryption to users, an improvement over traditional open networks with no protections at all. These protections are transparent to the user.

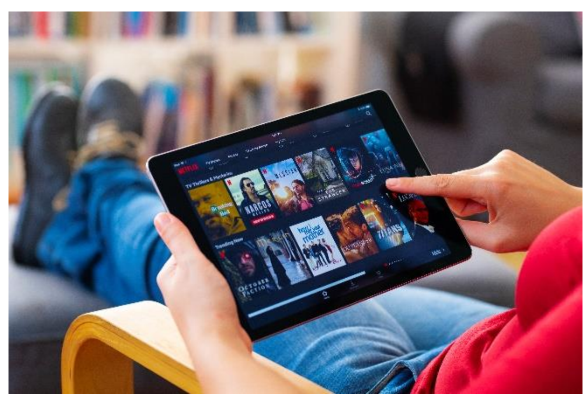
Use Cases

Wi-Fi 7's cutting edge capabilities enable a wide swath of new use cases that all rely on higher throughput, more bandwidth, and lower latency. Video is a particularly demanding medium and plays a large role in many of these use cases, as does processing large data loads. Wi-Fi 7 provides the needed capacity to handle these intensive scenarios and enable the rich experiences sought across the home and enterprise environments.



Streaming ultra-high definition video

Video dominates today's Internet, and this trend is expected to continue into the foreseeable future. As internet video traffic soars both in use and in higher resolution, so do user expectations regarding video quality.



Internet video service providers like Netflix, Prime, and Disney are challenged with providing a high standard of video quality balanced with a massive amount of data throughput required to deliver high definition (HD) and ultra-high definition (UHD) streams to consumers. The success of this video streaming balance lies in 1) powerful compression methods, 2) fast, reliable end-to-end internet access, and 3) adapting to lower video quality if the available link throughput plunges or does not stream content with a resolution supported by a screen's capability.

Consumers want reliable, high-quality video. However streaming HD and UHD video over Wi-Fi is a formidable challenge for both internet content providers and internet service providers. While content can be compressed to reduce the delivery rate, the inherent variability in the throughput of the Wi-Fi environment has the most impact on video quality. A poor connectivity environment can result in:

- Skipping video or long buffering times
- Poor video quality
- High latency

Internet video service providers employ hypertext transfer protocol (HTTP) adaptive streaming or Adaptive Bit Rate (ABR) streaming concepts at the heart of their services to provide uninterrupted high video quality that can adapt to network performance adversities in the network.

In ABR streaming, algorithms determine what profile is used to initiate video playback, and based on the network performance parameters, video playback quality may adapt up or down over the duration of playback. Network performance parameters are typically judged by their performance in a wireless environment, such as over Wi-Fi. The goal of ABR streaming algorithms over the last decade has been to maximize achievable video quality based on the variance in the underlying network throughput. These algorithms operate by estimating network conditions and adapting video quality profiles based on available network resources.

Using “Top Gun: Maverick” 4K UHD at 60 fps at 3840 x 2160 for example:

- The native baseband or uncompressed production bitrate is 12 Gbps
- Once encoded for distribution on physical media such as Blue-Ray, the bitrate is 90 Mbps
- Internet content providers will do further compression for ABR streaming for best effort HD and UHD video quality. Streaming service bitrate ranges between 375 Kbps and 40 Mbps depending on network quality

Wi-Fi 7 materially elevates the internet streaming experience because the inherent improvements in near zero latency, MLO modes, and removed congestion eliminate almost all network performance adversities often found in the Wi-Fi link impeding best bitrate profile playback offered by internet video providers. Even with rigid algorithmic ABR streaming parameters, Wi-Fi 7 removes Wi-Fi as a third-party barrier to high performance internet streaming. While this document explains how ABR streaming works, innovators in Wi-Fi internet playback devices should understand Wi-Fi 7 is a requirement to achieve best in class video playback and consumer experience.

Multi-user AR/VR/XR

Enterprise networks are expected to use AR/VR/XR — computer generated environments that make the user feel immersed in their surroundings — for collaboration, education and training, remote support, and general productivity. Education in particular may benefit from a multi-user VR classroom experience (up to 20 head-mounted displays (HMDs) per single-AP room) using either standalone architectures (HMD contains image rendering) or edge/tethered compute architectures (rendering is performed in the network or personal compute device and transmitted to the HMD over Wi-Fi). This latter deployment might require up to 100 Mbps to 200 Mbps throughput per HMD and less than 10ms of one-way latency enabled by Wi-Fi 7 to deliver a high-quality immersive experience. Low quality connectivity in multi-user AR/VR/XR scenarios risks:

- Disruptions to classroom proceedings
- Potential motion sickness
- Video/audio lagging

Automotive

Wi-Fi 7 opens up significant opportunities for automotive use cases, such as connected vehicles, autonomous driving, intra-vehicle communication, and fleet management. In each automotive use case, the vehicle can function as an AP, a STA, or a means casting devices brought onboard the vehicle. This creates a range of connectivity scenarios that pose challenges such as link robustness, range of coverage, and predictable and persistent QoS.

Wi-Fi 7 features offer a range of benefits to automotive use cases. These include reducing the likelihood of disruption in data exchanges, increasing the range and robustness of an uplink, and improving QoS predictability and consistency of experience for QoS-sensitive applications.

Some of the challenges that need to be addressed to fully realize the potential of wireless technologies in the automotive industry include:

- Wireless technologies must be highly reliable and secure to ensure the safety of drivers and passengers. Any failure or disruption in communication could have serious consequences in a vehicle. In particular for audio/visual (AV) applications, users expect wireline QoE for multimedia
- Automotive environments are noisy and congested, with many devices competing for limited bandwidth. Interference and congestion can impact the reliability and speed of wireless communications
- Automotive applications, such as autonomous driving, require low latency communications. Any delay in communication can affect the ability of the vehicle to make real-time decisions. This is especially true for actuators, which need wire-like responses, and for AV applications AVB/TSN/AVnu (802.1BA and 802.1AS), which require very low latency
- Security is emerging as a key requirement in the automotive space. In the case of AV applications (intra-vehicle), encryption for content protection is highly likely to be required. The security requirements for actuators and sensors are also very high
- Many automotive devices are battery-powered, and power consumption is a critical factor in their design. Wireless technologies that consume a lot of power can reduce battery life and increase maintenance costs

To address these challenges, wireless technologies in the automotive industry are being developed and optimized to meet the unique demands of this environment. Wi-Fi 7 technologies offer faster speeds, greater bandwidth, and lower latency, making them well-suited for automotive applications.

Hybrid work and rich telepresence

In a post-pandemic world, many companies allow employees to work from anywhere or they require in-office work only two or three days per week. Video has become the preferred method of telecommunication in business and can add efficiency to enterprises by enhancing collaboration and strengthening working relationships. In these scenarios, companies benefit from increased productivity and employees are happy with less commuting and more time with family. The popular use cases for video calling and conferencing include collaboration, project management, training, recruiting, sales presentations, business negotiations, and social communication.

In the office, the environment is characterized as high density, with many users, high peak upload and download traffic, and in many cases, interference from overlapping basic service sets (OBSSs). Coverage, capacity, and reliability are key metrics. In the home, the environment is characterized by strong interference from unmanaged overlapping wireless networks from other unlicensed technologies in the 2.4 GHz, 5 GHz, and 6 GHz bands, and in the case of multiple dwelling units, from OBSS interference. Reliable low latency Wi-Fi connectivity is a must for productive remote work. Distortion in a remote meeting — even if it is for a single participant of a large meeting — may cause:

- Loss of work time as everyone waits while the topic is explained and reexplained
- Feeling of not being part of the meeting
- Overlapping audio resulting in people talking over each other

Video conferencing applications must have a reliable, low latency connection with sustained high throughout to the network in order for the video codec to maintain its best resolution and frame rate, providing a consistent user experience throughout the session. Any sustained deviation will cause "video down-speeding" which leads to a poor user experience.

Remote work would not be possible without rapid development of Wi-Fi technology. The latest Wi-Fi 7 technology has MLO and triggered uplink access optimization using SCS and QoS Characteristics features to minimize distortions and provide sustained high throughput and low latency in the presence of strong interference in the 2.4 GHz, 5 GHz, and 6 GHz bands. MLO enables Wi-Fi 7 to tolerate even long times when a link is busy. In these cases, the transmissions may be done at a different band or channel. The triggered uplink optimization makes sure that uplink transmissions are done continuously at the correct time.

As a result, remote meetings become distortion-free and participants sense that they are present together within the meeting.

Hybrid work requires that information be easily available, and that employees be contacted within seconds. Today, information and messages are available on multiple devices, laptops, phones, watches, etc.

- Getting a copy of a message to all devices ensures that urgent messages are responded to promptly. A quick response shows that the received message and the sender are important
- Employers can cooperate to create the same document in real time
- Information is easily available. Huge files can be downloaded within seconds

In the home, video conferencing has also proven to be the preferred mode of remote communication when individuals connect with family and friends, and the same Wi-Fi 7 network can be used for videos, gaming, schoolwork, and connecting Internet of Things (IoT) devices to the Internet. Even if the traffic load of all simultaneous transmissions is high, the reliability, ease, and speed of remote work is not compromised. This is achieved by triggering optimizations and the MLO framework of the Wi-Fi 7 network. Video applications are expected to continue to grow rapidly, and Wi-Fi 7 will ensure that Wi-Fi can handle the expected growth in video traffic, including video calling and conferencing applications.

Immersive gaming and entertainment

AR, VR, and XR are redefining the limits of immersion for gaming and entertainment by simulating real-life experiences and converging the physical and digital worlds. Players can enjoy truly immersive in-game experiences with a rich first-person perspective and explore an endless variety of digital environments through their HMDs and other XR devices and interact with them in real-time via controllers and other accessories. Cloud gaming further expands the possibilities and potential of mobile gaming by shifting most computing to remote servers. This enables XR and mobile devices to deliver the same immersive gaming experience and high-fidelity graphics with low power consumption and reduced on-device compute, reducing the overall cost of gaming platforms. Delivering these rich experiences, however, demands wireless connectivity with very high throughput and low latency and jitter sustained throughout gaming sessions to ensure high responsiveness and high-resolution graphics.

Massively multiplayer online games are another rapidly growing component of the gaming market, with multiplayer online battle arenas and e-sports gaming competitions becoming ever more popular. In an e-sports arena, as shown in the image to the right, the wireless network infrastructure that connects players to gameplay via gaming servers is essential to guaranteeing reliability and low latency because large groups of professional players are performing dazzling moves and expect responses on their devices in milliseconds. Additionally, tournaments are broadcasted live via streaming platforms where the graphics are displayed in high definition, with rich details, which imposes a high requirement on network capacity and link throughput.

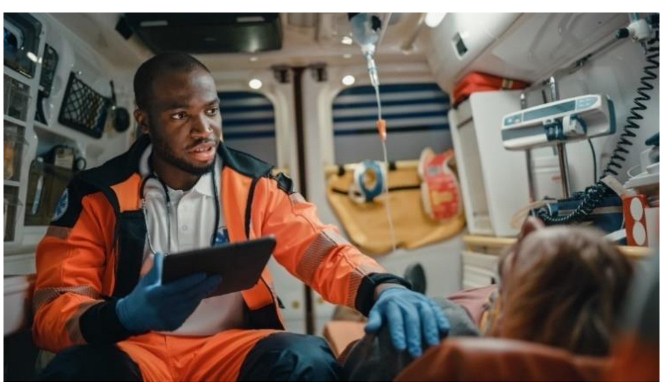
Wi-Fi 7 is ideally suited for delivering the full potential of XR and mobile gaming, e-sports, and related entertainment use cases. In particular, Wi-Fi 7 features as summarized in Table 1 overcome the following key challenges for immersive gaming and entertainment:

- High throughput: Multi-gigabit speeds are required to deliver 4K and 8K video streams and graphics wirelessly for immersive gaming. Multi-user games and e-sports use cases require multiple such connections simultaneously. Wi-Fi 7 features such as MLO, 320 MHz channels, and 4K QAM significantly increase per-device and network-wide throughput to enable gaming use cases with the highest throughput demands
- Low latency: Extremely low latency and jitter is required for immersive and lag-free gaming experience. Wi-Fi 7 features such as Triggered Uplink Access enable prioritized delivery of latency sensitive traffic with predictable latency

Emergency Preparedness Communication Services

NSEP communications are a part of Priority Telecommunications Services that provide priority access on commercial wireline and cellular networks to authorized NSEP users to ensure that they can communicate. Communication can be challenging when:

- Networks are overloaded (e.g., first responders and citizens are sharing the same network)
- Equipment failures reduce network capacity (e.g., during power outages or cyberattacks)
- Network infrastructure is damaged (e.g., during natural disasters or terrorist attacks)
- An alternative network is not available (e.g., limited coverage)



Several countries have deployed this type of service in wireline and cellular networks based on International Telecommunication Union standards on Emergency Telecommunication Service and Third Generation Partnership Project Multimedia Priority Service Standards, respectively.

While NSEP priority communications services are deployed over wireline and cellular networks, it is becoming essential to deploy this type of service over Wi-Fi networks. In many scenarios, the Wi-Fi access networks may be the best or the only means for NSEP personnel to communicate. Imagine that NSEP personnel from multiple organizations are dealing with an emergency situation, such as a terrorist attack or a natural disaster. Personnel at the site of the disaster need to communicate with the command center to coordinate with those overseeing the response. Various devices in the field, including personal computers, cellular telephones, tablets, and IoT appliances, such as cameras, are supplying critical situational awareness information over both public access and commercial networks, many of which employ Wi-Fi access technology. Public users may be communicating over those same networks. The onslaught in traffic from the public users, as they attempt to contact loved ones or alert colleagues, congests the Wi-Fi access network.

If the public users' traffic congests the Wi-Fi access network, authorized emergency responders (i.e., NSEP users) may find their communications to be impaired, potentially preventing them from responding effectively. A Wi-Fi network that offered priority access to such authorized users would help ensure that they could perform their mission-critical activities despite the network congestion.

With Wi-Fi 7's capability of supporting priority access to authorized devices, service providers can offer NSEP priority services to emergency personnel similar to those offered in cellular networks to allow them to effectively communicate even when the network is congested. This will ensure that NSEP authorized users can stay connected and perform their missions that will result in saving human lives.

Industrial Internet of Things

Industrial Internet of Things (IIoT) refers to the application of IoT technologies and concepts to industrial settings such as manufacturing, logistics, energy, and transportation. In IIoT, an ecosystem of devices, sensors, actuators, applications, and associated networking equipment or devices are connected to each other and to the Internet, working together to collect, monitor, and analyze data from industrial operations. This allows real-time monitoring and control of industrial processes. The data collected from these devices can be analyzed to identify patterns, optimize processes, and improve efficiency.

IIoT enables new business models, such as predictive maintenance, where machines are serviced before they fail, rather than after. It can also facilitate the integration of different systems and processes, such as supply chain management and production planning, leading to greater visibility and efficiency across the organization.

There are several challenges that wireless technologies face in the context of IIoT:

- Industrial systems require high levels of reliability and security, and wireless technologies may not always provide the necessary levels of protection against interference, signal loss, or cyber-attacks
- Wireless signals can be affected by interference from other wireless devices or sources of electromagnetic radiation, such as machinery or power lines, which can cause signal degradation and connectivity issues. Wi-Fi 7 helps with interference by making use of the 6 GHz band
- Industrial environments can be large and complex, with a lot of physical obstacles that can block or weaken wireless signals, making it difficult to provide reliable coverage throughout the facility
- Industrial applications often require low latency, which is the time it takes for a signal to travel from one point to another. Wireless technologies may introduce latency due to the need for signal processing, transmission, and reception
- Many industrial IoT devices are battery-powered and need to operate for long periods without recharging. Wireless technologies can consume a lot of power, which can reduce battery life and increase maintenance costs

To overcome these challenges, wireless technologies must be designed keeping IIoT applications in mind. As can be seen from Table 1 and Table 2, Wi-Fi 7 is particularly suited to address the needs of IIoT.

Immersive 3-D training

XR technology is already being utilized in an expanding number of applications beyond gaming. Mass General Brigham Sports Medicine employs virtual reality to train medical students on orthopedic surgical procedures, allowing for in-depth practice in an immersive setting. The United States Air Force utilizes virtual reality for aircraft simulations, allowing students to complete the training up to 46% faster. In the field of mental health, XR technology is used to aid in the treatment of patients with PTSD by recreating stressful scenarios in a controlled environment. Automobile companies such as BMW, Audi, and Volkswagen are also using the technology to train employees to design new products and assemble parts. Wi-Fi 7 will enhance immersive 3-D training use cases.

Certification program testing

Wi-Fi CERTIFIED 7 tests and certifies critical features of the IEEE 802.11be standard, interoperability with equipment from multiple vendors, and performance thresholds. Wi-Fi CERTIFIED 7 delivers benefits common to all Wi-Fi CERTIFIED programs:

- Interoperability with other generations of Wi-Fi CERTIFIED equipment from any vendor
- Backward compatibility with previously certified equipment operating in the same frequency bands
- Proven Wi-Fi security provided by WPA3

To fully benefit from the features of Wi-Fi CERTIFIED 7, both the AP and the STA (or the two peer-to-peer connected STAs), should be certified for Wi-Fi 7.

Summary

Wi-Fi CERTIFIED 7 delivers an unprecedented level of connectivity through an impressive list of new features to support a wide variety of cutting-edge use cases. Among these key features is 320 MHz channel widths, which increases capacity by enabling a higher number of simultaneous transmissions at the fastest possible speeds, and MLO, which increases throughput and lowers latency by enabling devices to combine different channels across frequency bands together. In countries with 6 GHz access, native 6 GHz support allows Wi-Fi 7 to take full advantage of the 1200 MHz of unlicensed spectrum being made globally available.

Both home and industrial settings will be able to use Wi-Fi 7 to maximize user experiences and productivity by leveraging Wi-Fi 7's high throughput, high bandwidth, and low latency features. Video use cases, in particular, require high performance connectivity, which Wi-Fi 7 provides in abundance to allow for ultra-high definition streaming, video conferencing, and AR/VR/XR connections.

The future of Wi-Fi through Wi-Fi CERTIFIED 7 is extremely promising and time will show the various ways its high-speed potential will be leveraged to better interconnect our world.

About Wi-Fi Alliance®

www.wi-fi.org

Wi-Fi Alliance® is the worldwide network of companies that brings you Wi-Fi®. Members of our collaboration forum come together from across the Wi-Fi ecosystem with the shared vision to connect everyone and everything, everywhere, while providing the best possible user experience. Since 2000, Wi-Fi Alliance has completed more than 80,000 Wi-Fi certifications. The Wi-Fi CERTIFIED® seal of approval designates products with proven interoperability, backward compatibility, and the highest industry-standard security protections in place. Today, Wi-Fi carries more than half of the Internet's traffic in an ever-expanding variety of applications. Wi-Fi Alliance continues to drive the adoption and evolution of Wi-Fi, which billions of people rely on every day.

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