# Wi-Fi 6:
# High performance, next generation Wi-Fi®


## October 2018

## Executive summary

The ubiquity of rich digital media content and user desire for constant connectivity bring increasing performance demands to every Wi-Fi® device. This in turn calls for a great increase in overall network capacity, as well as new modes of operation to mitigate inefficiencies that could manifest in large-scale deployments. As Wi-Fi network deployments continue to grow, Wi-Fi devices must continue to operate reliably in crowded, congested environments. Users increasingly expect solid Wi-Fi connections in dense network environments that frequently include multiple interfering sources, moderate-to-heavy user loaded access points (APs), and a wide variety of client devices.

The next generation of Wi-Fi, based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11ax standard, is Wi-Fi 6. This new generation of Wi-Fi delivers features to effectively meet the increasing, evolving use of Wi-Fi technology. Wi-Fi Alliance® has announced an upcoming certification program, Wi-Fi CERTIFIED 6™, to ensure Wi-Fi 6 devices meet expectations for quality and interoperability. Expected in 2019, the Wi-Fi CERTIFIED 6 program continues the 20-year tradition of Wi-Fi Alliance standards-based testing.

Market needs have evolved, and new techniques are required to manage them. Wi-Fi 6 addresses challenges revealed by the continued, expanding success of Wi-Fi in the 2.4 GHz and 5 GHz bands and plays a crucial part in the quest for the increased capacity and performance required by next generation connectivity.

**Wi-Fi 6 key benefits**

- **Higher data rates**
- **Increase in overall network capacity**
- **Improved performance in dense and congested environments**
- **Improved power efficiency**

**Wi-Fi 6 capabilities**

- **Simultaneous multiple user operation in same channel**
- **Increased simultaneous upload capability**
- **Better spectrum usage**
- **New modulation modes**
- **Improved MAC control signaling**

# The next generation of Wi-Fi is here

Over the past 20 years, Wi-Fi has grown from a nascent technology to global, vital necessity for business and personal applications. Wi-Fi innovation has given individuals more flexibility to work, be entertained, and connect to friends and family in a growing variety of places. The ability to increase productivity without a wired connection changed the way we work and live. Global businesses have been built on Wi-Fi, cellular operators depend on Wi-Fi to enhance and expand their networks, and Wi-Fi is being utilized to bridge the economic digital divide. Now every person expects to be able to connect with Wi-Fi, any time and everywhere. Nearly every smartphone, tablet, and computer ships with Wi-Fi, and new Wi-Fi capable device types with a variety of form factors, from fitness trackers to refrigerators, enter the market every year.

Each generation of Wi-Fi offers users faster speeds, higher density, additional frequency bands, and faster throughput to enable users to integrate Wi-Fi into everything they do at home, at work, and on the go. As the world enters the next generation of mobile connectivity, Wi-Fi 6 introduces new capabilities to effectively handle the traffic demands of today's society, increasing capacity, coverage, and network intelligence.

## Enhancing Wi-Fi capabilities and efficiency

Built upon key elements defined in IEEE standard 802.11ax, Wi-Fi 6 offers highly efficient operation in dense environments while maintaining backward compatibility and coexistence with legacy IEEE 802.11 devices operating in the 2.4 GHz and 5 GHz bands. The 802.11ax standard includes a broad range of physical (PHY) layer and medium access control (MAC) layer features for efficiently handling demanding applications in dense network environments, even on the network's edge.

## Meeting the needs of demanding wireless networks

Today's networks require enhanced Wi-Fi capabilities that improve performance, spectrum efficiency and throughput while in the presence of interfering sources in dense networks, with heavily loaded APs, and indoor and outdoor deployments. Users demand constant connectivity and effective Wi-Fi performance at home and work, as well as in transportation hubs, stadiums, and malls— even while utilizing public transportation.

Wi-Fi 6 includes a broad range of features to deliver significantly increased capacity and lower latency in increasingly dense deployment scenarios, while maintaining or improving power efficiency. Key features of Wi-Fi 6 include:

- Uplink and downlink orthogonal frequency division multiple access (OFDMA) increases efficiency and lowers latency for high demand environments
- Downlink multiple user multiple input, multiple output, also known as multi-user MIMO, provides performance improvements for networks with many users
- New modulation mode enables peak gigabit speeds for emerging, bandwidth-intensive use cases
- Increased symbol durations make outdoor network operations more robust
- Improved medium access control (MAC) control signaling increases throughput and capacity while reducing latency

# Technology overview

Key features that enable Wi-Fi 6 to offer an enhanced user experience are summarized below.

## Orthogonal frequency division multiple access (OFDMA)

OFDMA brings an improvement over prior versions of Wi-Fi that use orthogonal frequency division multiplexing (OFDM). It subdivides the Wi-Fi channel into smaller frequency allocations called resource units. By partitioning the channel, parallel transmissions of smaller frames to multiple users occur simultaneously (Figure 1). For example, a traditional 20 MHz channel might be partitioned into as many as nine smaller channels. Using OFDMA, a Wi-Fi 6 AP could simultaneously transmit smaller frames to nine Wi-Fi 6 clients.

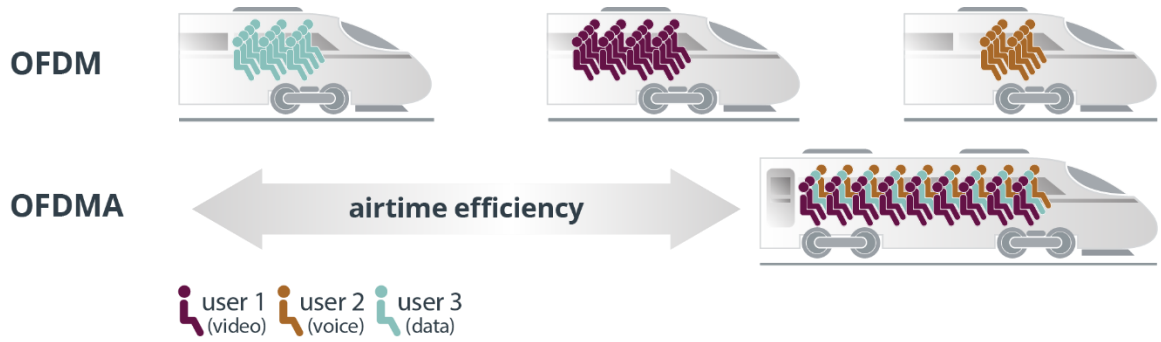


*Figure 1. OFDMA in Wi-Fi 6 allows multiple users with different traffic profiles to transmit simultaneously over the same channel*

### Uplink OFDMA

Uplink OFDMA is one of the key features introduced by Wi-Fi 6 and is among the most significant differences relative to 802.11ac. Uplink OFDMA allows data frames to be transmitted simultaneously by multiple stations. This amortizes preamble overhead and medium contention overhead, which leads to high aggregated network throughput. Uplink OFDMA can provide additional gains by permitting greater transmit power level per device, subject to regulatory requirements, and thus signal coverage on the uplink, since the transmit power of each client device can be concentrated on smaller allocated resource units.

### Downlink OFDMA

Downlink OFDMA allows multiple data frames to be transmitted in a single data unit to multiple stations, thus amortizing preamble overhead and medium contention overhead, leading to higher aggregated network throughput. Downlink OFDMA can further optimize aggregate throughput by balancing the allocation of power between users at high versus low signal-to-noise ratios, subject to total power constraints and regulatory requirements.

## Downlink multi-user multiple input, multiple output (multi-user MIMO)

Downlink multi-user MIMO allows higher throughput in environments with devices containing a limited number of antennas by multiplexing their transmissions in the spatial domain. Introduced in 802.11ac to support up to four users simultaneously, Wi-Fi 6 extends multi-user MIMO and doubles the number of devices that can be supported efficiently to eight users. Together with downlink OFDMA, which operates in the frequency domain, this feature permits a Wi-Fi 6 AP to schedule downlink multi-user transmissions across spatial streams or frequencies (Figure 2).

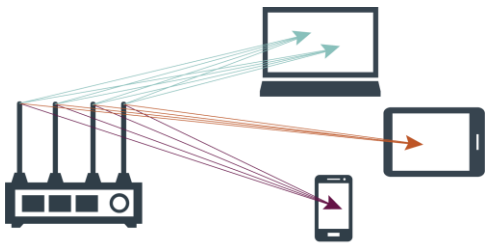

*Figure 2. Multi-user multiple input, multiple output*

## Transmit beamforming

Transmit beamforming enables significantly higher rates at a given range which results in overall higher network throughput. Wi-Fi 6 adds significant improvement by supporting up to eight spatial streams.

## Per link enhancement

### 1024 Quadrature Amplitude Modulation (1024-QAM)

Wi-Fi 6 uses a maximum symbol constellation size of 1024-QAM compared to Wi-Fi 5, which is based on IEEE standard 802.11ac. Wi-Fi 5 uses a maximum symbol constellation size of 256-QAM. At short range, 1024-QAM increases throughput by 25% in Wi-Fi 6 over Wi-Fi 5.

### Increased symbol time, various symbol size, guard interval combinations

The increased OFDM symbol time, combined with the different combinations of guard interval, enable both higher efficiency and tolerance of long delay spread channels by providing combinations tailored to each.

### Multi-Traffic Identifier Aggregated MAC Protocol Data Unit (multi-TID AMPDU)

Multi-TID AMPDU allows the aggregation of frames from multiple different traffic identifiers from the same or different quality of service (QoS) requirements within a single transmission. This new feature, not available in earlier generations of Wi-Fi, gives devices extra flexibility to aggregate more efficiently, reducing overhead and thus increasing throughput and overall network efficiency.

## Target wake time

Individual target wake time (TWT) is a mechanism that allows scheduling of traffic exchanges between an AP and a client device. Scheduled behavior reduces the overhead and inefficiency of the channel access method for obtaining transmit opportunities and allows power saving client devices to reduce power consumption by explicitly identifying the times when they should be awake.

## Operation mode indication (OMI)

OMI provides an efficient way for client devices to signal the maximum number of space-time streams and maximum bandwidth they will use to transmit and receive. This feature increases overall device power efficiency, as well as permits more frequent changes to transmit and receive operating mode.

## Spatial reuse

Wi-Fi 6 introduces many techniques which allow a device under certain circumstances to be more aggressive in accessing the medium during the time that devices in other networks are transmitting. This is known as spatial reuse. One such technique is the coloring mechanism, which enables a device to quickly determine whether an ongoing transmission belongs to its network.

# Use cases

Wi-Fi 6 devices deliver improved performance and substantially enhance the end user experience in both consumer and enterprise applications, especially in congested radio frequency environments with a high density of devices engaging in bandwidth intensive and latency sensitive applications.

## Home Wi-Fi

Modern home Wi-Fi use includes high definition and 4K video streaming, online and virtual reality gaming, wireless display, surveillance video, and smart home systems. This environment is characterized by a large number of devices, high diversity in device types from multiple Wi-Fi generations, and a variety of wireless applications running in the coverage area. Individuals and families want to successfully track fitness, stream movies, control thermostats and more, all while maintaining good connectivity.

Multi-family housing environments have the added potential to bring stronger interference from a greater variety of sources, including unmanaged, overlapping networks in neighboring apartments.

The increased Wi-Fi network capabilities in Wi-Fi 6 include mechanisms to effectively handle different types of traffic from multiple users simultaneously, provide users with higher throughput, and extend device battery power and overall coverage for dense environments with overlapping networks.

## Smart cars and infotainment systems

Many automobiles include premium infotainment systems that include Wi-Fi for internet access, in-vehicle infotainment display, wireless rear and front cameras, and rear seat infotainment systems. These systems support audio/video (A/V) content delivered to factory installed displays, audio speakers, and headphones, aftermarket A/V systems, and user devices such as tablets, notebooks, smartphones, and gaming devices used in transit.

Wi-Fi 6 enhances each connection, by reducing latency through use of OFDMA, while providing better performance in infotainment environments.

## Business

Today Wi-Fi enables businesses to effectively handle high numbers of users in large-scale deployments, transfer large amounts of video and data, and enable mobile workers. Wi-Fi 6 provides a more consistent, high performance experience to enterprise users for mission-critical applications requiring low latency as well as automated control and manufacturing systems.

Improved MAC signaling and scheduling in such managed environments offered by Wi-Fi 6 allow the full potential of OFDMA and multi-user MIMO to be attained. This leads to an increased aggregate network throughput and reduced latency in demanding applications.

## e-Learning

Today's classrooms rely heavily on technology not only to deliver information but to engage students through interactive HD and 4K video. The near future will add augmented and virtual reality (AR/VR) to enhance the learning experience.

Relying on OFDMA, Wi-Fi 6 delivers the high throughput, low latency, and network efficiency in dense environments that is needed to support many students per room and virtual online classrooms.

## Internet of Things (IoT)

IoT devices require low latency, low speed, and/or low power consumption. Information technology (IT) and operational technology (OT) are converging on Wi-Fi as a common radio access technology to support IoT applications such as in-building asset tracking for retail, enterprise resource planning and sensors for climate control systems and manufacturing operations.

Wi-Fi 6 includes low power improvements, such as target wait time (TWT), that are well-suited for IoT devices. There are also improvements in overhead reduction and robust outdoor operation.

## Stadiums and venues

Wi-Fi 6 can provide a superior user experience for stadiums and other highly congested venues. Users want to have access to video from different camera angles as well as ability to provide real-time social media commentary in every seat. Attendees frequently upload pictures and videos as well as download data to share their experience during the events.

With OFDMA and its improved client transmission control mechanisms, Wi-Fi 6 helps network planners and venue owners manage Wi-Fi coverage for these dense scenarios, improving coexistence with overlapping networks to provide a high quality user experience.

## Transportation hubs and shopping malls

Transportation hubs and malls are challenging environments that experience very high interference levels between APs in the same network, or between APs belonging to different networks. Unmanaged networks and other technologies in the same spectrum, present additional interference challenges. These venues tend to incur significant levels of mobility between APs but must also manage changing needs for hotspot capacity based on events, time of day, and other factors. Since mobile devices tend to have limited spatial streams, it is key that Wi-Fi networks in transportation hubs and malls have high capacity to handle a lot of users at once, and that the network edge and roaming capabilities are reliable to avoid client disconnects.

Wi-Fi 6 uses transmit beamforming and enhances each connection to a hotspot, enabling more users to connect to APs while still providing high throughput. This expands and improves the ability of networks to deliver better performance for each user application despite high traffic and interference levels.

## Wi-Fi CERTIFIED 6 certification program

The upcoming Wi-Fi CERTIFIED 6 certification program will test and certify critical features of the IEEE 802.11ax standard, interoperability with equipment from multiple vendors, and performance thresholds.

Wi-Fi CERTIFIED 6 will deliver benefits common to all Wi-Fi CERTIFIED™ programs:

- Interoperability with 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 WPA2™ and WPA3™

To fully benefit from the features of Wi-Fi 6, both the AP and the client device, or the two peer-to-peer connected client devices, should to be certified for Wi-Fi CERTIFIED 6.

## Summary

Wi-Fi has become a fundamental requirement for nearly all connected devices. Wi-Fi proliferation has drastically increased demand for advanced user experience, creating bandwidth, latency, and power efficiency challenges. The growing penetration of connected Wi-Fi devices and users require high speed connectivity for a variety of uses such as media streaming and sharing—no matter the location.

The table below summarizes the key features and benefits of Wi-Fi 6.

| Feature | Benefit | | | | | |
|---|---|---|---|---|---|---|
| | Overhead Reduction | Dense Network Efficiency | Increased Throughput, Reduced Latency | Performance at Network Edge | Robust Outdoor Experience | Client Power Efficiency |
| Uplink OFDMA | √ | √ | √ | √ | √ | |
| Downlink OFDMA | √ | √ | | | √ | |
| Downlink multi-user MIMO | √ | √ | √ | | √ | |
| Transmit beamforming | | √ | √ | √ | √ | |
| Per-link enhancement (benefits via one or more of):<br>• 1024-QAM<br>• Incr. symbol time, varied guard interval combinations<br>• Multi-TID AMPDU | √ | √ | √ | √ | √ | |
| Target wake time | √ | | | | | √ |
| Operation mode indication | | | | | | √ |

Wi-Fi 6 powers the next generation of Wi-Fi to address high bandwidth, low latency applications and highly congested wireless environments. Wi-Fi 6 leverages technological advances such as uplink and downlink OFDMA, new symbol durations, and lower power features to provide an improved user experience while maintaining support for legacy Wi-Fi devices.

More information on Wi-Fi Alliance certification programs and for information and white papers on Wi-Fi–related topics is available at www.wi-fi.org.

## 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 40,000 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.