WHITEPAPER

Wi-Fi 6: Leveling Up Business Technology

Check out the benefits and capabilities of Wi-Fi 6 (802.11ax). It's all here, in this whitepaper.

Introduction

The IEEE 802.11 working group, established in 1990, published its first Wi-Fi standard in 1997. Since that time, the rapid adoption of Wi-Fi-enabled devices, streaming services, and applications has provided users with innovative solutions to participate in nearly all facets of daily living—from anywhere and at any time.

This convenience, however, does not come without challenges. The need for constant connectivity brings increasing performance demands on the Wi-Fi network, requiring greater capacity, faster speeds, and higher quality of experience, as well as the need for Wi-Fi networks to operate reliably in crowded and congested environments.

For enterprise customers and organizations of all shapes and sizes, Wi-Fi has become a fundamental technology in support of hybrid work environments and will remain essential to enabling a future with increasingly diverse and distributed workforces.

Wi-Fi is no longer an emerging technology. It has become a global necessity for both business and personal use.

Redway Networks is an IT reseller and Cisco Meraki Partner

Wi-Fi 6: the new business generation

Wireless faces an increasing use of high-throughput applications, increased density of wireless devices, and a change in the needs of networks.

Since the initial Wi-Fi standard was published more than 20 years ago, faster modulation and coding schemes (MCSs), wider channels, additional frequency bands, and technologies such as multiple-input, multiple-output (MIMO) and orthogonal frequency-division multiple access (OFDMA)—to name a few—have addressed the challenges facing Wi-Fi networks: increasing both performance and throughput to support users' growing demands of Wi-Fi networks and devices.

Like other broadband technologies, each generation of Wi-Fi (Table 1) has adapted and evolved to meet emerging new connectivity challenges as the number of devices, applications, and their requirements continues to change and grow.

TABLE 1: WI-FI GENERATIONS

Generation	IEEE standard	Max. throughput	Year adopted	Radio frequency (GHz)
Wi-Fi "0"*	802.11	2 Mbps	1997	2.4
Wi-Fi "1"*	802.11b	11 Mbps	1999	2.4
Wi-Fi "2"*	802.11a	54 Mbps	1999	5
Wi-Fi "3"*	802.11g	54 Mbps	2003	2.4
Wi-Fi 4	802.11n	600 Mbps	2008	2.4/5
Wi-Fi 5	802.11ac	6.8 Gbps	2014	5
Wi-Fi 6	802.11ax	10 Gbps	2019	2.4/5
Wi-Fi 6E	802.11ax	10 Gbps	2020	6
Wi-Fi 7 (future)	802.11be	46 Gbps	2024	1–7.25 (2.4/5/6)

* non-official designation

Historically, the focus of each generation of Wi-Fi has been on faster speeds and higher data rates to meet the high-density demands in enterprise WLANs. With 802.11ax (Wi-Fi 6), the focus shifted toward addressing the challenges facing Wi-Fi networks—such as increased interference and decreased performance. In addition, it considered the need to get legacy, IoT, and high-throughput devices to work together efficiently. Finally, it was agreed that this new generation of Wi-Fi would be intelligent enough to enable and support dense and pervasive wireless environments with high throughput and lower latency. In short, Wi-Fi 6 introduced new capabilities to effectively handle the traffic demands of an always-connected society with increased capacity, coverage, and network intelligence.

Capabilities and benefits of Wi-Fi 6:

Wi-Fi 6 was designed with performance that exceeds the previous generation (802.11ac wave 2) by more than 3 to 4 times, with support for higher density with more efficient airtime, support for a higher density of client devices, and significant battery savings. As the number of clients increases, Wi-Fi 6 can sustain far more consistent data throughput than prior generations due to the longer frames and wider guard intervals of 802.11ax, which help provide resiliency and enable a range of use cases.

WI-FI 6 KEY BENEFITS:

- Consistent data throughput in dense environments
- Wider coverage range
- Increased reliability and reduced disconnections
- Power savings for wireless devices
- Improved outdoor performance
- Better spectrum usage
- New modulation modes
- Utilization of wider channels
- Simultaneous multiple user operation in the same channel

ENHANCED MOBILE BROADBAND

- Higher performance to mobile devices
- 50 Mbps or higher to every user in dense environments
- Enhanced video (4K, 8K), AR/VR, immersion experiences

MASSIVE SCALE IOT

- Support a high density of IoT devices
- Asset tracking, context-based services, electronic payments
- IT & IoT integration, automation

MISSION CRITICAL SERVICES

- Ultra reliable and low latency applications
- Process automation, automatic guided vehicles, real-time analytics

Wi-Fi 6 introduces several new technologies and enhancements over 802.11ac (Wi-Fi 5), including power-saving features such as target wake time (TWT) and OFDMA (in both the uplink and downlink), which subdivides the Wi-Fi channels into smaller frequency allocations called resource units. OFDMA combined with MU-MIMO (in both the uplink and downlink) allows more data to be transferred at one time, enabling access points (AP) to concurrently handle more devices.

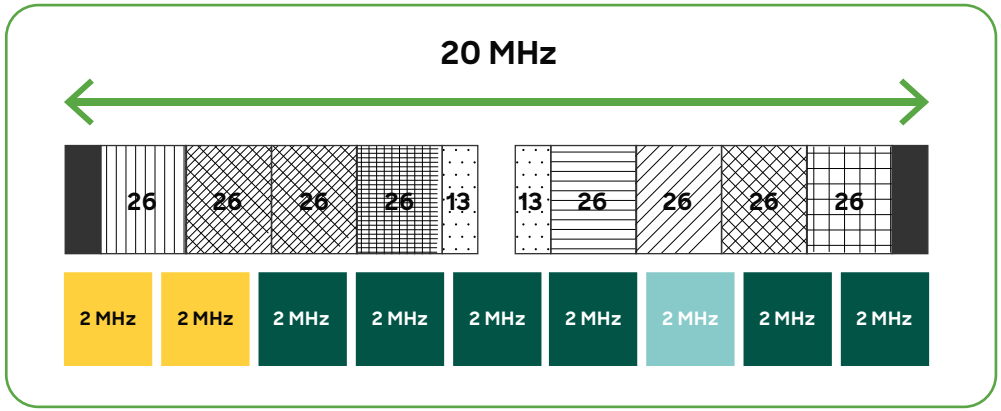
The following table compares 802.11ax to the previous two standards.

Capabilities	802.11n	802.11ac	802.11ax
Physical layer (PHY)	High throughput (HT)	Very high throughput (VHT)	High-efficiency wireless (HEW)
Operating bands	2.4 and 5 GHz	5 GHz only	2.4 and 5 GHz
MU-MIMO	N/A	DL MU-MIMO only	DL and UL MU-MIMO
Channel width	20, 40, 80 MHz	20, 40, 80, 80+80, 160 MHz	20, 40, 80, 80+80, 160 MHz
Guard interval	800/400 ns	800/400 ns	800/1600/3200 ns
Spread spectrum technology	OFDM	OFDM	OFDM, OFDMA
Frequency modulation	64 QAM	256 QAM	1024 QAM with MCS 10, 11
Power save	STBC, U-APSD	STBC, U-APSD	STBC, U-APSD, TWT
Spectral efficiency	N/A	N/A	BSS coloring

Operation in both 2.4 and 5 GHz spectrum provides better propagation and efficiency and improvements makes 802.11ax highly suitable to support IoT at scale.

Uplink/downlink OFDMA

Unlike 802.11ac (Wi-Fi 5), which only focused on the 5 GHz band, 802.11ax (Wi-Fi 6) operates in both the 2.4 and 5 GHz bands. Additionally, 802.11ax operates in 20, 40, and 80 MHz. The added 2.4 GHz spectrum provides several benefits for longer-range outdoor use cases and improved coverage for IoT devices. With 2 MHz channels, coexistence with other 2.4 GHz IoT technologies is much more effective, despite a noisy and congested 2.4 GHz spectrum. The better propagation abilities of 2.4 GHz combined with efficiency improvements of 802.11ax help maximize the potential of the 2.4 GHz band.

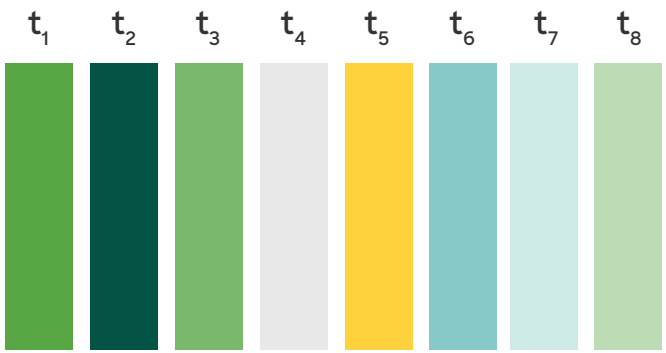


Uplink and downlink orthogonal frequency-division multiple access (OFDMA) increases network efficiency and lowers latency for high-demand environments.

One of the biggest benefits of 802.11ax is the transition from orthogonal frequency division multiplexing (OFDM) toward orthogonal frequency division multiple access (OFDMA). OFDM offers the ability to divide bandwidth into multiple frequency subchannels, while OFDMA divides the same 20 MHz spectrum into smaller subcarriers that can carry small packets faster. Using resource units (RU) allows each subcarrier to handle multiple users. This is particularly important as the number of connected devices—especially IoT devices—continues to increase, placing a strain on APs when trying to connect along with a host of other devices.

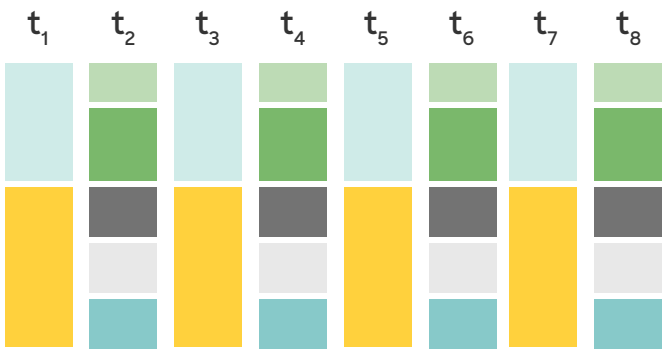
In previous generations of Wi-Fi, a small transmission from a single client would be able to monopolize an entire channel. An 802.11ax AP can use the entire 20 MHz channel to send data to a single client or split the channel to send data to nine clients using nine RUs. Additionally, the data can also be modulated using MCS 10 or MCS 11 to increase throughput.

OFDM



- Each user gets 1 time slot - whole channel bandwith
- Each user must wait t_8 before next TX_op
- As more clients join the cell, latency - jitter increases
- QOS only manages TXop - someone has to wait

OFDMA



- Multi uber packet makes flight more efficient
- Also provides much more regular and consistent TX_op
- Deterministic nature - miss this truck - no worries here comes another, meaning “the truck” is always leaving “full”... net result is lower latency

User 1 Telemetry | User 2 VoIP | User 3 Video | User 4 VoIP | User 5 Data | User 6 IoT | User 7 Data | User 8 VoIP

Uplink OFDMA is one of the key features introduced in 802.11ax, allowing data frames to be transmitted simultaneously by multiple stations. 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 allows multiple data frames to be transmitted in a single data unit to multiple stations. It 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.

Since most traffic consists of downloads (from AP to clients), downlink OFDMA is of particular interest for most deployments because it allows more efficient aggregation of data to multiple stations. These capabilities will be beneficial to allow a diversity of applications and devices with different needs to work efficiently together.

MIMO technology, introduced in 802.11n, uses multiple antennas to take advantage of multipath—the way a signal takes different paths to reach the antenna. MIMO allows devices to identify the different paths the signals take to the receiver and sends unique streams of data—known as spatial streams—along different paths.

802.11ac expanded MIMO to allow the AP to use different spatial streams to transmit to multiple clients (up to four) simultaneously. This is known as downlink multiuser MIMO (DL-MU-MIMO). 802.11ax increased this to eight clients across eight spatial streams and also allows for clients to transmit to the AP at the same time across different spatial streams (uplink, UL-MU-MIMO).

MU-MIMO is technology that allows an AP to service multiple clients simultaneously across a supported number of wireless streams or channels. MU-MIMO allows more data to be transferred at one time, enabling APs to concurrently handle more devices. MU-MIMO will work together with OFDMA to allow multiple clients to communicate at the same time across multiple frequency ranges as well as multiple spatial streams.

Multi-user multiple-input, multiple-output (MU-MIMO) allows more data to be transferred at once and enables an access point to transmit to a larger number of concurrent clients at once.

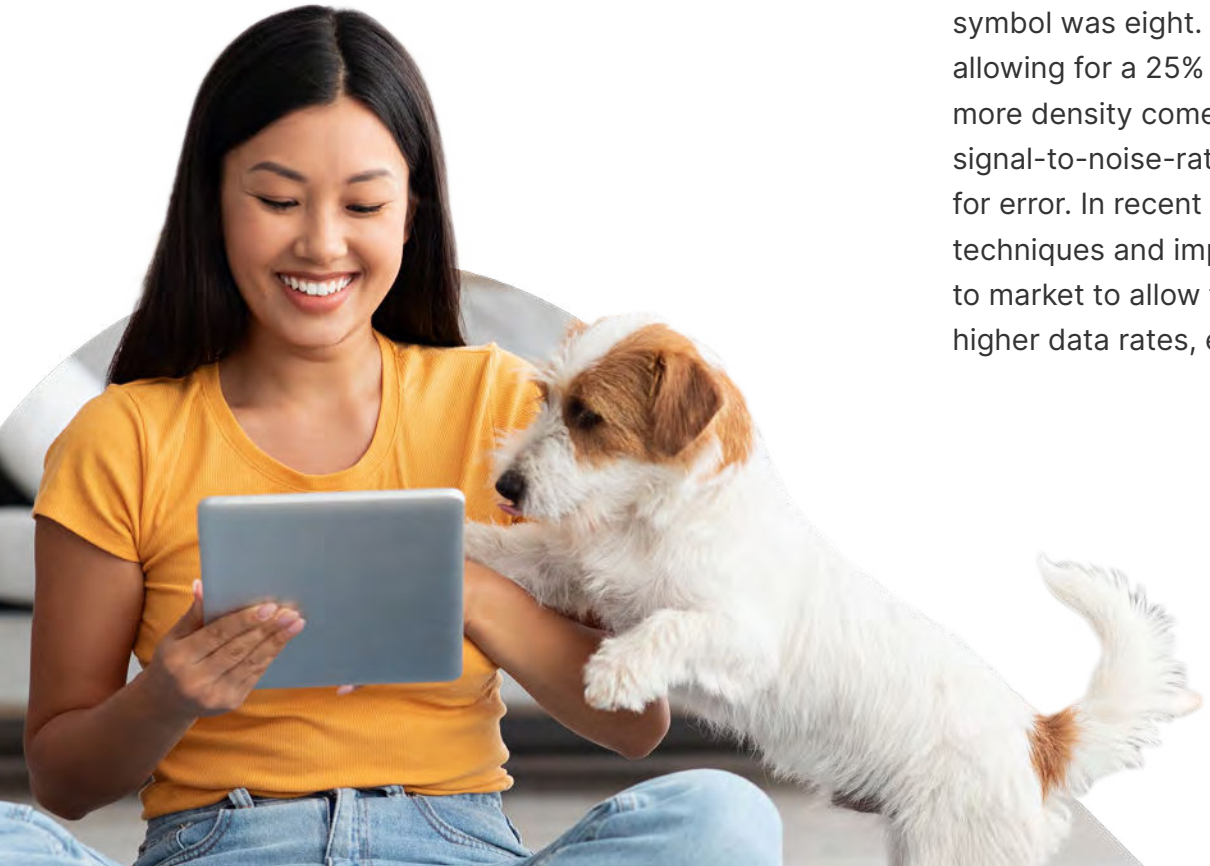
KEY FACT

Both MU-OFDMA and MU-MIMO allow APs to communicate with multiple clients simultaneously. The difference is that MU-OFDMA uses different frequencies for each client and MU-MIMO reuses the same frequency in different spatial streams

256 QAM to 1024 QAM increases throughput in Wi-Fi devices by encoding more data in the same amount of spectrum.

Quadrature amplitude modulation, or QAM, enables packets to be sent more efficiently by modulating the amplitude and phase of a signal. 802.11ac enabled 256 QAM, while 802.11ax will move to a higher constellation density of 1024 QAM. When coupled with OFDMA, 1024 QAM significantly improves the noise threshold, offering high performance at a bandwidth of 20 MHz or less.

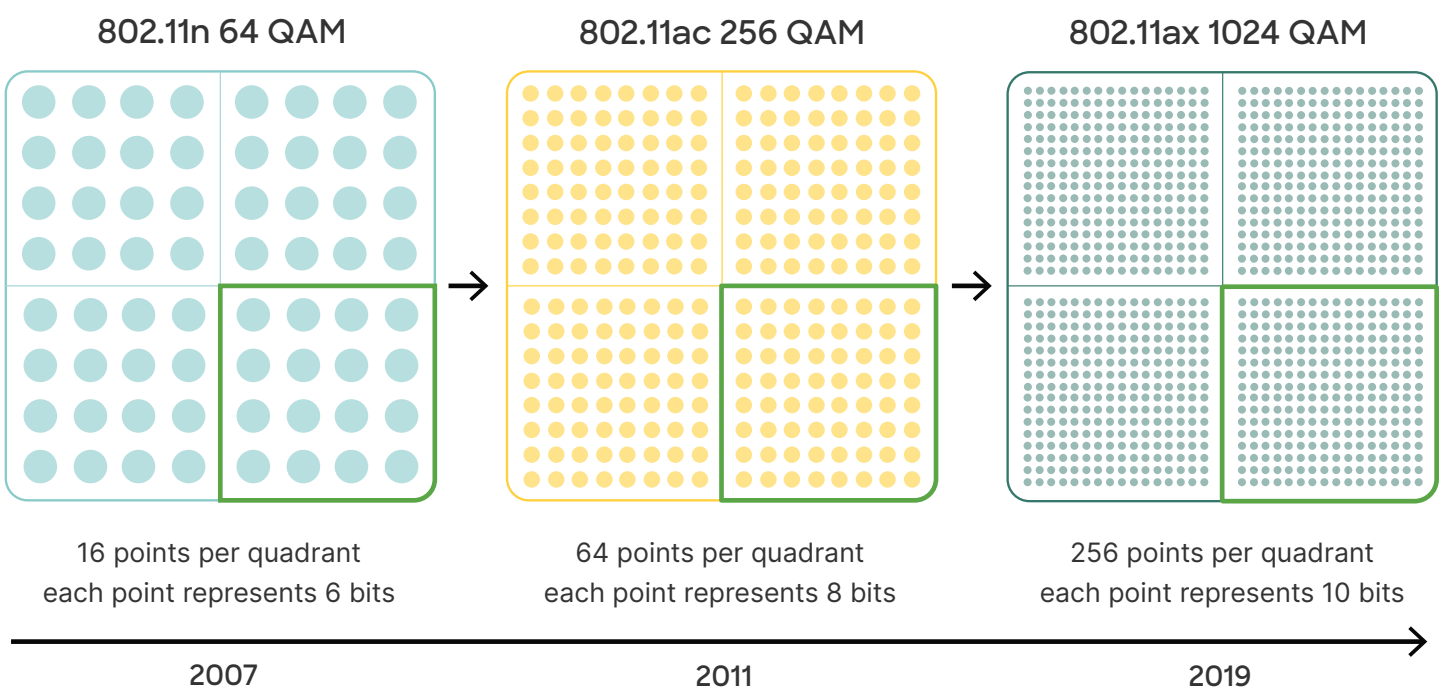
With 256 QAM, the number of bits transmitted per OFDM symbol was eight. 1024 QAM increases that to ten bits, allowing for a 25% increase in spectral efficiency. With more density comes increased importance for high signal-to-noise-ratio, as 1024 QAM has very little margin for error. In recent years, more accurate DSP filtering techniques and improved radio technologies have come to market to allow this increased density to result in higher data rates, even in non-ideal scenarios



MCS rates 10 and 11

MCSs define the possible data rates based on a variety of factors. With two additional modulation and coding sets (MCS)—MCS 10 and MCS 11—802.11ax is able to deliver throughput improvements over previous generations of Wi-Fi. For example, 802.11ac using a 20 MHz channel and MCS 8 could reach peak throughput of 86.7 Mbps. 802.11ax is able to use MCS 11 in a 20 MHz channel and deliver 143.4 Mbps, a 65% increase.

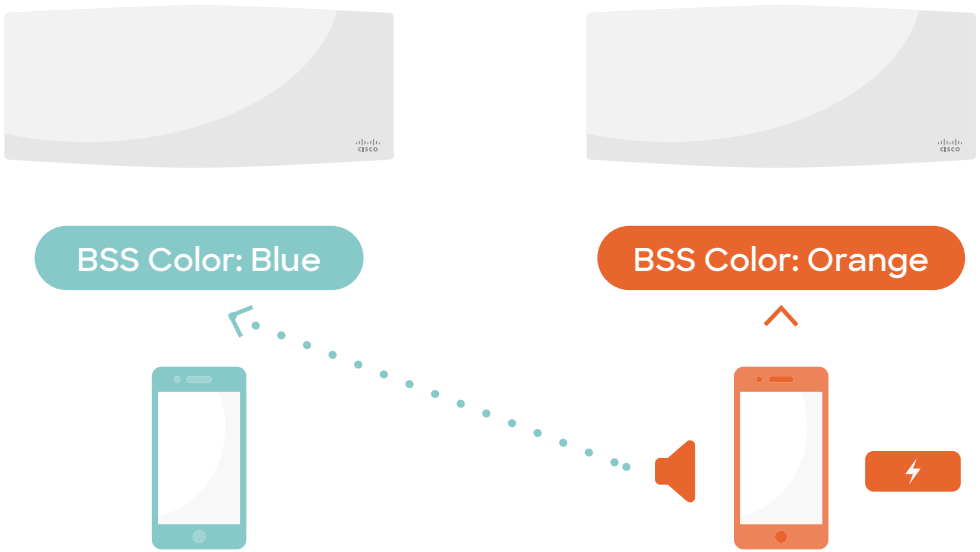
1024 QAM is used in MCS 10 and MCS 11.



BSS coloring allows spatial reuse and addresses interference.

BSS coloring is a method for identifying overlapping basic service sets (OBSSs). As wireless adoption grows, so does interference in the networks. Wi-Fi has a collision-avoidance technology called carrier-sense multiple access with collision avoidance (CSMA/CA), which allows only one device to transmit on a given frequency at a time. Before transmitting, devices check if there are any other transmissions on the channel. This check is known as a clear channel assessment (CCA). If any signal is heard, the STA backs off and tries again later.

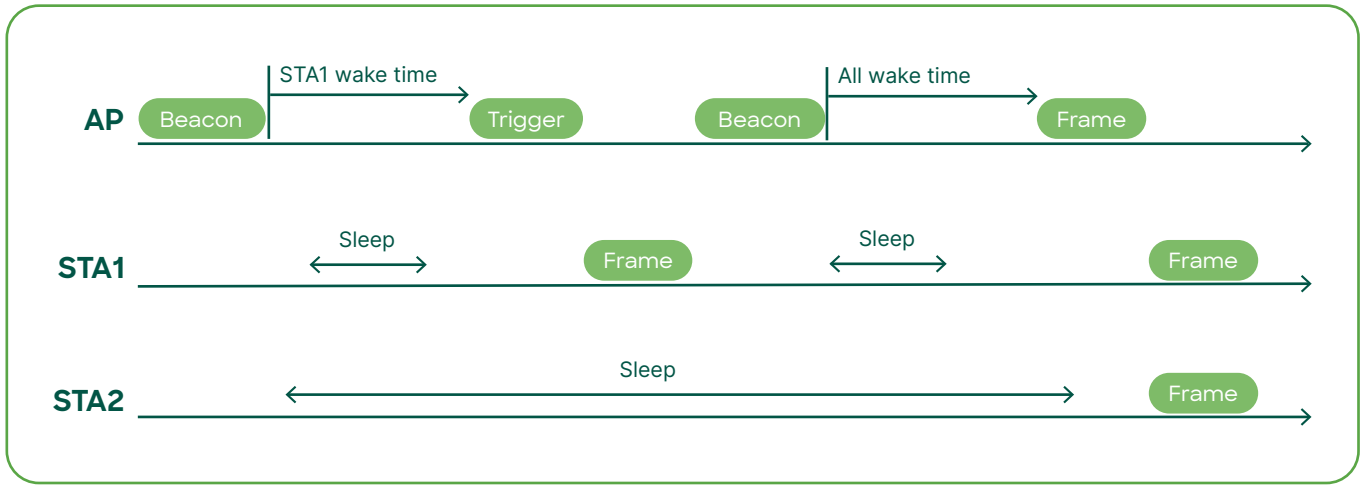
To help mitigate the effects of co-channel interference, 802.11ax allows for a 6-bit BSS color field in the SIG-A field at the physical layer, as well as within management frames. This allows for up to 63 different BSS color values. With devices of each BSS transmitting a locally unique color, they can quickly and easily distinguish transmissions coming from its own BSS versus from those of a neighboring BSS. If a device hears traffic being transmitted, it checks the BSS color value. If the color value matches its own, this is considered an intra-BSS transmission, as the transmitting device belongs to the same BSS as the receiver. In this case, the STA backs off to let the transmission complete. If the color value is different, it is considered an inter-BSS transmission. In this case, in order to avoid co-channel interference, the device can transmit with a received signal strength indicator (RSSI) that is below the overlapping BSS packet detect (OBSS-PD) threshold rather than deferring



Target wake time (TWT) significantly improves battery life in Wi-Fi devices, such as Internet of Things (IoT) devices.

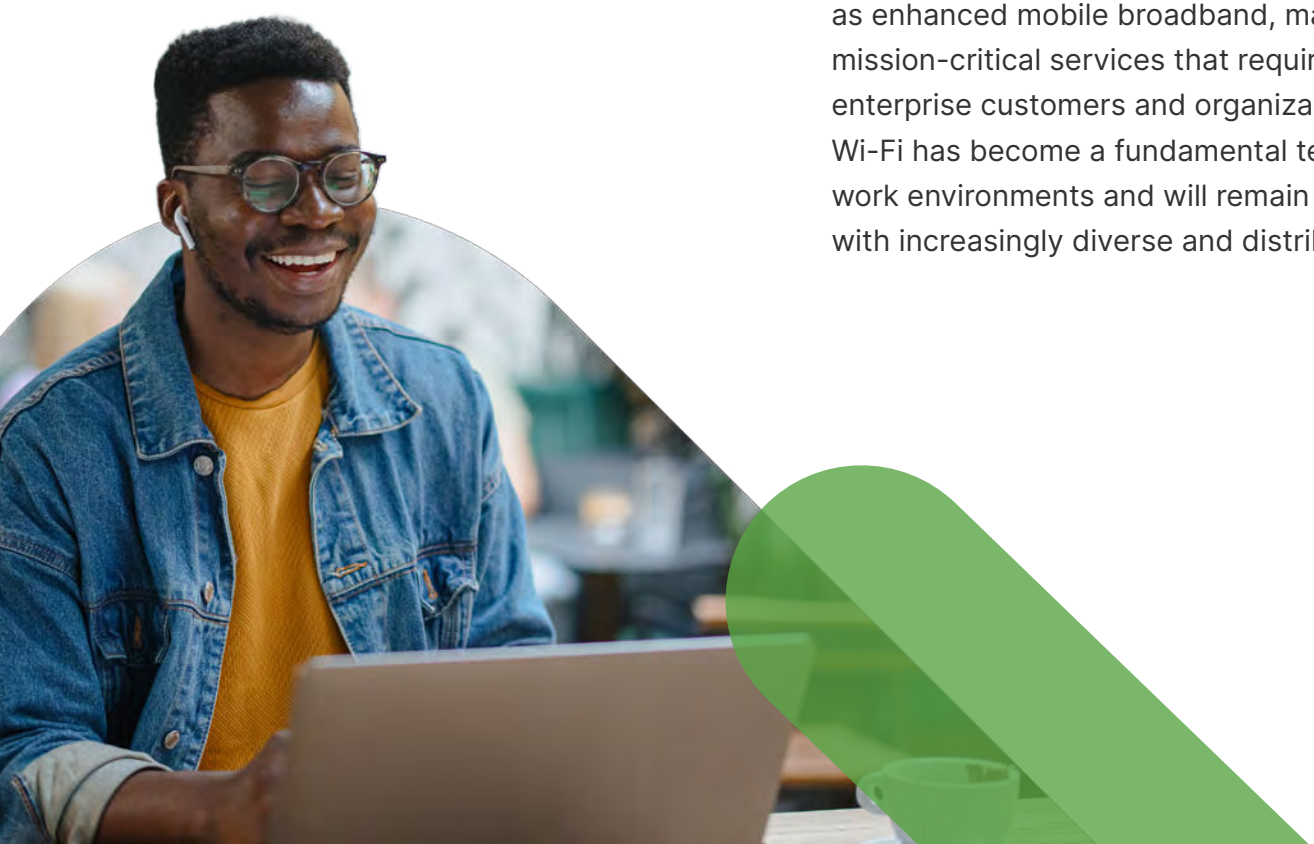
TWT is a power-saving technology that allows an AP and client to negotiate when and how long a client can put its wireless radio into power-save mode. The goal is to minimize wireless medium contention and maximize the amount of time client wireless radios spend in power-save (PS) mode based on the client's traffic needs. This allows the AP to manage wireless contention and potentially coordinate simultaneous transmissions with multiuser technologies, as discussed in earlier sections of this document

To enable this capability, the access point defines a set of target wake times (TWT) and sleep times for the wireless clients within the BSS. This enables clients to determine their unique wake-up pattern and duration for wireless access, thereby scheduling stations to operate at different times and lower contention. This has the effect of lowering power consumption and improves battery life by as much as 67%. TWT achieves these capabilities by sending a series of beacons from the AP to notify a “sleeping” device that it has data to send.



Summary

802.11ax (Wi-Fi 6) has proven to provide wireless networks with significantly higher throughput and performance over 802.11ac, particularly in high-density situations. With a number of key feature innovations, 802.11ax offers greater reliability and efficiency than previous generations, enabling a range of new use cases such as enhanced mobile broadband, massive IoT deployments, and mission-critical services that require reliable connectivity. For enterprise customers and organizations of all shapes and sizes, Wi-Fi has become a fundamental technology in support of hybrid work environments and will remain essential to enabling a future with increasingly diverse and distributed workforces.



Key features of Wi-Fi 6 over Wi-Fi 5

Key features	Benefits
Operation in both 2.4 and 5 GHz spectrum	Better propagation and efficiency improvements makes 802.11ax highly suitable to support IoT at scale.
Uplink and downlink orthogonal frequency division multiple access (OFDMA)	Increases network efficiency and lowers latency for high-demand environments.
Multi-user multiple-input, multiple-output (MU-MIMO)	Allows more data to be transferred and enables an access point to transmit to a larger number of concurrent clients at once.
256 QAM to 1024 QAM	Increases throughput in Wi-Fi devices by encoding more data in the same amount of spectrum.
BSS coloring	Allows spatial reuse and reduces co-channel interference.
Target wake time (TWT)	Significantly improves battery life in Wi-Fi devices, such as Internet of Things (IoT) devices.

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